# ‘Science for all’ – a mission impossible?

A multimodal discourse analysis of practical work and inquiry in Norwegian upper secondary school

Philosophiae Doctor (PhD) Thesis

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The purpose of a Ph.D.-journey is to have experiences and perhaps to become a little wiser… and to become a more experienced traveller. I’m sure not the same person who set out on this quest. In spite of all the help and support there will be errors in the text, for which I only blame myself. Feedback on shortcomings might help my further journeys.

Halden, March 2013
Gerd Johansen

# Sammendrag

Målet for denne avhandlingen er å undersøke hvordan den retoriske innrammingen av praktisk og utforskende arbeid realiserer naturvitenskapelig kunnskap samt læring *om* naturvitenskap. Avhandlingen har et allmenndannende perspektiv[1], der formålet i Læreplanen for kunnskapsløftet om at faget skal "*gi den enkelte et grunnlag for deltakelse i demokratiske prosesser i samfunnet*" brukes som utgangspunkt for å vurdere klasseromspraksisen.

Tilnærmingen til kommunikasjonen i klasserommet er sosialsemiotisk, og kommunikasjonen er sett som retorisk innrammet. Det betyr at kommunikasjonen gir deltakerne en fortolkningsramme samtidig som den former hva de anser for å være høvelige måter å uttrykke naturfaglige termer, fenomen og metoder på. Gjennom semiotiske handlinger uttrykker lærer og elever faglig innhold og relasjoner seg imellom. De semiotiske handlingene kan være i form av tale- og skriftspråk, så vel som gester og fysiske handlinger med artefakter. Avhandlingen har med andre ord et multimodalt perspektiv på kommunikasjon.

Den fortolkede læreplanen, ressurser (artefakter og verbale), tid og rommets utførelse influerer sammen med normene på den retoriske innrammingen. Med normer menes det som anses for å være høvelige og gode måter å uttrykke faglig innhold og relasjoner mellom deltakerne. Normene uttrykker således 'naturfag slik vi mener det bør gjøres'. Videre er normene ikke eksplisitt uttrykt. Forskningsmessig betyr det at normer må tolkes ut fra det som sies og gjøres *og* det som ikke sies og gjøres. Det som ikke uttrykkes vil være det som ikke vektlegges, eller det som anses for å være lite formålstjenlig.

I denne retoriske tilnærming til kommunikasjon er makt, motstand og solidaritet sentrale faktorer. Læreren har det overordnete ansvar for det som foregår i klasserommet og er dermed ansett for å være hovedretor. Men i kommunikasjonen vil lærer ta hensyn til elevenes ståsted i tillegg til læreplanen og de muligheter fysiske ressurser gir. Dessuten er elevene med på å forme (over tid) de retoriske valg lærer foretar i klasserommet. Videre er den retoriske innrammingen sett som delvis stabil, fordi deltakernes forventninger og interesser former normene for hva som anses for å være gangbar praksis i praktisk og utforskende arbeid.

*Forskningsspørsmål:*
Hvordan reflekterer retorisk innramming av praktisk og utforskende arbeid naturfaglig allmenndannelse?
For å svare på dette spørsmålet stilles to underspørsmål:

I. Hvilke normer er innbakt i lærers retoriske innramming av praktisk og utforskende arbeid?
II. Hvordan tilpasser og transformerer elevene disse normene i sitt praktiske og utforskende arbeid?

[1] I den engelske teksten er 'science for all' den brukte termen, den har en litt annen konnotasjon enn 'allmenndannelse'.

I denne avhandlingen skilles det mellom (tradisjonelt) praktisk arbeid og utforskende arbeid i naturfag. Praktisk arbeid er typiske kokebokøvelser, der elevene følger en oppskrift gitt av lærer for å komme fram til et resultat. I utforskende arbeid har elevene i større grad kontroll over prosessen, både hva som skal undersøkes, hvordan det skal undersøkes og hvordan undersøkelsen skal presenteres.

Forskningen ble gjennomført ved en videregående skole, studieforberedende linje. Elevene som alle var omtrent 16 år har fellesfaget naturfag. Dette er deres siste år med obligatorisk naturfagundervisning. Elevene er i utgangspunktet ikke spesielt interessert i naturfag og de har lave til middels karakterer. Lærer, Ellen, har lang erfaring som lærer for denne typen elever, og hun har en solid naturvitenskapelig bakgrunn. Forsker og lærer jobbet sammen i to år. Det året det empiriske materialet ble samlet var naturfagundervisningen lagt til en dag per uke. Det medførte at det var mulig å ha introduksjon til praktisk og utforskende arbeid, gjennomføring så vel som etterarbeid på en og samme dag.

Forsker hadde en etnografisk tilnærming i feltarbeidet og var tilstede i naturfagundervisningen gjennom hele skoleåret. Dette resulterte i et materiale bestående av feltnotater, video- og lydopptak av undervisning (inkludert en elevgruppes praktiske arbeider), samt lydopptak av lærer og forsker som sammen planla undervisning. Det ble også utført intervju av lærer og elever (lydopptak). I tillegg ble ulike elevarbeider samlet inn. Dette rike materialet muliggjør beskrivelser av kommunikasjonen i klasserommet. Fra dette materialet ble det valgt tre case. To av disse er tradisjonelle praktiske arbeider og det siste er et utforskende arbeid elevene gjennomførte. Hvert case er analysert ved multimodal diskursanalyse som gir mulighet til å fortolke normer og retorisk innramming.

Multimodal diskursanalyse er en kombinasjon av multimodal sosialsemiotisk- og kritisk diskursanalyse. Multimodal sosialsemiotisk analyse er et verktøy som muliggjør det å se ulike moder i sammenheng, som for eksempel handlinger i kombinasjon med tale. Kritisk diskursanalyse har sin styrke i å undersøke hvordan makt og ideologi uttrykkes gjennom verbalspråket. Multimodal diskursanalyse muliggjør således en fortolkning av hvilke normer som uttrykkes gjennom handling og verbalspråk. Ved å ta utgangspunkt i Hallidays språklige metafunksjoner er det mulig å identifisere mønstre i deltakernes semiotiske handlinger. Disse mønstre er det første steget for å identifisere hva deltakerne anser for å være verdifulle måter å uttrykke relasjonen seg i mellom og til det faglige innhold (dvs. normene). Den retoriske innrammingen er så fortolket ut fra hvordan normene spiller sammen med fysiske omgivelser, læreplanen, tid og ressurser. Etter analysen av hvert case er det gjort en sammenlikning mellom casene for å identifisere stabile normer i klasseromkommunikasjonen.

Hovedfunn er at makt i hovedsak uttrykkes gjennom det faglige innhold og ikke gjennom sosiale relasjoner mellom lærer og elever. Elevene uttrykker motstand mot undervisning ved uoppmerksomhet. Klasseromspraksisen søker å holde motstanden fra elevene så lav som mulig. Dette gir en retorisk innramming som er preget av:

- Overforenkling av fagstoff. Naturfaget er presentert som sikker og uproblematisk kunnskap. Det er svært få situasjoner der naturvitenskapelig kunnskap, metoder og resultater er vurdert eller stilt spørsmål ved. Det er i svært liten grad ansett som nødvendig å koble naturvitenskapelig teori sammen med det praktiske arbeidet.

- Kommunikasjonen i klasserommet utfordrer ikke faglig innhold. Forskjeller i metodiske tilnærminger og resultater utforskes ikke. Hverdagsspråket gis forrang. Lærers forelesninger er i større grad i et naturvitenskapelig språk, men i introduksjon til praktisk arbeid vektlegges hverdagslige måter å uttrykke seg på. Elevene stiller spørsmål, men svært sjelden til det faglige innholdet.
- Prosedyrer og metoder er presentert som stegvise oppskrifter som ikke krever begrunnelse eller gir mulighet for valg. Både elever og lærer legger vekt på å *gjøre* det praktiske arbeidet, ikke på å observere, tenke eller verbalisere metoder og resultater. Elevene har svært liten innflytelse over den faglige dimensjonen av praktisk og utforskende arbeid. Derimot har elevene en stor grad av autonomi for hvordan de sosialt ønsker å organisere arbeidet. Elevene fordeler arbeidet seg i mellom på en tidseffektiv måte, men er mindre opptatt av å konstruere mening sammen.

Det er altså en hovedvekt på å utføre praktisk og utforskende arbeid. Det å verbalisere refleksjon rundt metoder er fraværende, og resultater av det praktiske arbeidet vurderes sjelden. Det er dermed lite vekt på sosiale og epistemologiske dimensjoner ved naturvitenskapelig tenke- og arbeidsmåte. Dette er funn som i stor grad samsvarer med forskning på praktisk og utforskende arbeid.

Denne praksisen fungerer godt innenfor en skolekontekst der hovedmålet ser ut til å være å fullføre og bestå. Kompetansemålene i læreplanen for dette trinnet dreier seg i hovedsak om beskrivelser og etablerte forklaringer, og det er mange mål elevene forventes å mestre. Elevene ser i liten grad at faget er relevant, og de velger i stor grad å gjøre det de absolutt må uten å stille kritiske spørsmål.

For å kunne håndtere naturvitenskapsrelaterte spørsmål i samfunnet for å kunne ta del i demokratiske prosesser kreves det at elever kan stille spørsmål, stille seg kritisk til naturvitenskaplig kunnskap, metoder og resultat, og at de har en viss innsikt i hvordan naturvitenskap produseres og kommuniseres. I hvor stor grad elevene kan bruke skolens naturfag for å kunne ta stilling og muligens handle i  naturvitenskapsrelaterte spørsmål i samfunnet er mer tvilsomt.

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# 1. INTRODUCTION

This chapter sets the scene by opening up the problem field and chosen perspectives. As this is a thick book without pictures, I will provide a short summary and a reader's guide. At the end of this chapter, I have chosen to present some of my own views on science education. Since my views would 'lurk' in the background and govern what I mean to be relevant, I believe it tidier to explicate my views in the start of the thesis.

## 1.1. Points of departure

The starting point for this thesis is the research project "Elever som forskere i naturfag", in English: "Students in school science as researchers" or StudentResearch for short. StudentResearch lasted from 2007-2011. This project was funded by the Norwegian Research Council as a part of the research program PRAKSISFOU (2005-2010). StudentResearch has been led by Professor Erik Knain. The project's objective was to enhance students' inquiry practises by emphasizing argumentation, text production in various formats, as well as critical reading. On the StudentResearch wiki it is stated:

> Our goal is that the students will become knowledge builders in practices that will have some common traits with scientific research. This means that the students will get to know the creative, reflecting and communicative parts of science, and that they will develop knowledge about the characteristics of science in order to carry through experiments. (StudentResearch, 2012)

StudentResearch was a collaboration project between the Norwegian University of Life sciences (Erik Knain), University of Bergen (Professor Stein Dankert Kolstø) and University of Oslo (Professor Ola Erstad). There have been four Ph.D. students in the project as well as several master students. StudentResearch has been an action research project aiming at changing the practice of school science through the collaboration between teachers and researchers. Teachers at six different schools at secondary and upper secondary levels have been involved in the project. The schools have been located in the Bergen area and in the area around Oslo. In the duration of StudentResearch, there have been several meetings, some with teachers, school managers and researchers and some with researchers only. The spring 2008, I received a research fellowship (stipend) for four years which included 25% teaching at Østfold University College. I considered myself very fortunate to work in this project, as perspectives of communicating science have always intrigued me and practical work is an essential part of school science. In addition, I bring forth the perspective of 'science for all'. These three perspectives are at the centre of this thesis.

Science is an important part of modern society and there is no debate about whether or not science should be a subject for all students. Science is a mandatory part of formal education in Norway and all students have the same curriculum in science, even in the first year of upper secondary school. 'Science for all' might thus seem as an unnecessary slogan, but 'science for all' alludes to something more than a mandatory subject. It means science for all citizens opposed to a science subject facilitated for future scientists (Fensham, 2002; Jenkins, 1999; Smith & Gunstone, 2009). I will claim that the current science curriculum is (at least partly) preparing for further studies in science. This is a curriculum emphasis that is not seen as relevant by many students (Aikenhead, 2000; Jenkins, 2000, 2009; Schreiner & Sjøberg, 2005). The students in this class were not very interested in science. In this thesis, I seek to describe the science the students encountered in communication about practical work and discuss what possibilities there are to enhance subject matter relevance. This leads to the question of what subject matter students need to be able to deal with science-related issues in society. Moreover, to me, these students gave a salient research perspective of two reasons. First, it is difficult to teach science or any other subject to students who are not very interested. This implies that the problems with the subject matter become simpler to notice, as students might detach themselves more readily from it. The other reason is that this is a group of students not described much in research literature, with some excellent exceptions.

When I started more than four years ago, I knew I wanted to do something about 'language' and school science. I have to admit I was somewhat hazy about what I meant by 'language', but it was important for me to include expressions of science understanding that were not neatly verbalized. This had two reasons. First, when I started teaching in the mid 1990s, I experienced that I was practically unable to communicate science orally. As a student in physics, I did not speak about what I did – I wrote – and much of what I wrote was mathematics. My years as a teacher in upper secondary school and later in teacher education have been a constant struggle to formulate science such that it becomes 'understandable' for students. The second reason for emphasizing 'language' was what I saw during a short observation study in 2006. In this study, there were students (11 years old) that did not use standard ways of expressing science, but I could identify their attempts toward making meaning. I also saw that the teacher did not acknowledge these 11 year olds' attempt to make meaning, as they did not use standard textbook formulations. The students' expressions were provisional from a science point of view. These experiences led me to a social semiotic view of language. Intuitively, I found social semiotic a fruitful approach as it allows for seeing the students' contributions as apt representations of science, from their point of view. Social semiotic also opens up for multimodality. Multimodality is essential in communicating science (Lemke, 1998a; Ogborn, Kress, Martins, & McGillicuddy, 1996). There are several ways of expressing science subject matter, and words are just one way. Ellen, the teacher I collaborated with, used a wide range of modes and resources in her teaching. This was very interesting from my perspective. Later in this thesis I will present an analytical framework that that is based upon multimodal social semiotic. The framework makes it possible to carry out a close up analysis of communication of practical work in school science.

The last perspective is practical work and inquiry. Practical work and inquiry in science has for a long period of time had a particular research interest in the community of researchers in science education (Duschl & Grandy, 2008; Hofstein & Kind, 2011). But the research literature reveals problems regarding practical work (Hofstein & Kind, 2011) and inquiry (Grandy & Duschl, 2008). These problems seem to run along different axes – students' meaning-making, argumentation and meta-cognitive skills (Hofstein & Kind, 2011) and students' and teachers' rather simple understanding of Nature of Science (Bryan, 2011; Deng, Chen, Tsai, & Chai, 2011). There appears to be a preference for 'cookbook' procedures in practical work (Abrahams & Millar, 2008), that provide few possibilities to deliberate over, e.g., questions, methods and results. However, these are important deliberations for citizens dealing with science-related issues (Kolstø, 2001; Ryder, 2001). Moreover, the 'language of science' seems often to be loosely coupled to 'doing science' (Millar, 2010; Mortimer & Scott, 2003; Tiberghien, Veillard, Le Maréchal, Buty, & Millar, 2001). Connecting language and practical work is seen as important for students' meaning-making. Hodson states:

> Students will not just 'pick up' this complex language unaided. It has to be taught, practiced, deployed in authentic contexts and evaluated in action, such that students see themselves as members of the scientific community or the school version of it. (Hodson, 2009, p. 243)

However, all of these problems with practical work and inquiry in science are still prevalent after several decades of research. My contribution into the field is to describe how the classroom communication creates a rhetorical framing of practical work and inquiry as well as to discuss how this framing reflects particular view(s) of science (subject).

There are many possible ways to deal with a substantial field such as this. I could have tried to focus narrowly on resources to aid students' meaning-making or students' interest or… Instead, I have chosen a rather broad approach where several perspectives are incorporated. This might of course lead to a rather complex presentation of results and arguments concerning the complex school science practice. Thus, to aid the reader before the 'proper' presentation of methodological and analytical approaches, results and arguments, there is a short overview of this thesis.

## 1.2. Short summary of the thesis

The aim of this thesis is to explore and explain how rhetorical framing of practical work and inquiry realize learning science, doing science and learning *about* science in a 'science for all' perspective. The Norwegian curriculum in mandatory science has an objective that the science subject is to "*give one the basis for participation in democratic processes in society*". 'Science for all' in this thesis is seen as the science students need to partake in science-related issues in society. The thesis attempts to investigate if it is possible to achieve this curriculum objective.

Communication is approached from a multimodal social semiotic perspective and is seen as rhetorically framed. Rhetorical framing means that the communication shapes the participants' interpretation and what the participants regard as appropriate to express through their semiotic actions. Through semiotic actions (expressions), the teacher and students relate to the subject matter as well as each other. The semiotic actions may take the form of speech, writing and/or physical action with artefacts. The thesis has thus a multimodal perspective on classroom communication.

The interpreted curriculum, physical space, time, resources, and norms are all factors that influence the rhetorical framing. Norms are what is seen as appropriate semiotic actions of social as well as subject matter. The norms thus provide a stance on 'school science as we believe it should be'. Moreover, the norms are not explicitly expressed. For the research, this means that the norms have to be inferred from what is said and done – and that which is *not* said and done. That which is not expressed, is perhaps not seen as appropriate or unnecessary.

In this rhetorical approach power, resistance and solidarity are central aspects. The teacher has the main responsibility for what happens in the classroom and is thus seen as main rhetor. However, communication is relational which means that students have an impact on the teacher's rhetorical choices. Moreover, the rhetorical framing is seen as an on-going process, but as norms will be relatively stable the rhetorical framing is regarded as semi-stable, as the participants' interests and expectations creates the norms for what is apt ways of expressing practical work and inquiry.

The research questions are:
*How does the rhetorical framing of practical work and inquiry reflect 'science for all'?*
To be able to answer this question, the two following subordinate research questions are asked:

I. What norms are embedded in the teacher's rhetorical framing of practical work and inquiry?
II. How do students adapt to and transform these norms in their practical work and inquiry?

In this thesis there is a distinction between (traditional) practical work and inquiry. Practical work is typically cookbook or lockstep, where students follow a recipe given by teacher to arrive at a (known) result. In inquiry students have more influence over the investigation process, to pose questions, decide methods and ways of representing the results.

The research was conducted in an upper secondary school that attracts students who are not very interested in science and are low to medium achievers. Students were 16 years old and this was their last year with compulsory science. The teacher, Ellen, has a long experience teaching at this school. Ellen has a master's degree in science. The teacher and researcher worked together for two years. The science course was organized in days and not as lessons spread out during the week. This provided the possibility to have introductions to practical work, carry it out and do post-practical activities in the same day.

A prolonged ethnographic fieldwork (one year) provided material in the form of field-notes, video material of the teacher presenting and one group of students doing practical work and inquiry, and audio of the teacher and researcher planning. The data material also contains interviews with a group of students and teacher (audio), as well as audio and video material of other parts of lessons and various students' products. From this material, three cases are chosen, two of which can be categorized as practical work (cookbook) and one practical inquiry. Each case is analysed with multimodal discourse analysis to enable inference of norms and rhetorical framing.

Multimodal discourse analysis is a fusion of multimodal analysis and critical discourse analysis. Multimodal analysis as a tool makes it possible to see how actions (e.g., how equipment is handled) and speech play together. Critical discourse analysis has its strengths in eliciting power transmitted through the use of verbalized language. By combining these two analytical approaches in Halliday's (see, e.g., 2004) metafunctions of language, it is possible to find patterns in semiotic actions (expressions). These patterns can be seen as a first step toward inferring norms. The rhetorical framing is then inferred from how norms play together with resources, time and subject matter (curriculum). After the analysis a cross case comparison is made where norms and rhetorical framings are described and discussed.

The main findings are that power is largely expressed through subject matter and not through social relations between the teacher and students. The students show resistance to teaching by inattention. The classroom practice aims tacitly at keeping the students' resistance low. This creates a rhetorical framing that is characterized by:

- Simplification of subject matter. Science is presented as certain and unproblematic. There are very few situations where methods and results are assessed or questioned. It is only to a very small extent seen as necessary to link theory to practical work.
- The classroom communication is not challenging subject matter. The teacher and students do not seek to explore subject matter differences and challenge methods and results. There is also given prevalence to everyday language. The teacher's lectures are to a greater extent in a 'science language'. However, in the introduction to practical work and inquiry everyday language is the common norm. Students ask questions in class, but very rarely to subject matter.
- Procedure and methods are presented as stepwise actions without any specific reasons and almost without any explicit choices. Both the teacher and students emphasize *doing*. There is thus little emphasis on observations, inferences or verbalizing methods and results. The students decide very little

> in the subject matter domain of practical work, they have somewhat more influence on their inquiry. However, how students organized their collaboration during the work is completely left to students to decide. Students divide work in a time efficient manner and are less concerned about joint meaning-making.

There is an emphasis on carrying out practical work an inquiry. Verbalizing reflections on methods are absent and results are to a little degree discussed and assessed. There is thus put little weight on epistemological and social dimensions of science. These findings are to a large extent in accordance with other research on practical work and inquiry.

This practice works well within a school context if the aim is that students are to pass and complete the course. The competence aims in the curriculum are overwhelmingly concerned with descriptions and established explanations – and there are many aims the students are supposed to master. The students express that school science is not very relevant. They do what they have to without asking critical questions.

However, to deal with science in society, students need to be able to assess and discuss methods and results, ask questions, and have a rudimentary understanding of the production and communication of science. Whether students can use the science learned in school as part of taking stance and action in regard to scientific issues in society is doubtful.

## 1.3. Reader's guide

I want to reflect some (but not all) of the messiness I experienced during the work with this thesis. This is one of two reasons why this thesis has a rather unconventional structure.

> If accounts of research omit descriptions of the messy areas experienced by so many researchers, descriptions of research in practice remain incomplete and offer no true and honest picture of the research process. (Cook, 2009, p. 279)

This citation has been taken seriously in this thesis, so I will reveal those messy areas that have had an impact on this research project and process. The major contribution to the messiness is that this project can be said to have two phases. The first phase was while collaborating with Ellen (the teacher) and we had a research focus and interest, see chapter 2. The second phase was after the fieldwork ended when a new research focus emerged, although the interest in 'science for all' and how school science could be part of students' shaping as citizens have been with me all the time. The transition between the two phases was largely driven by the entire field experience in addition to input from Gunther Kress. This generated questions that acted as a turning point. So, without this messiness *this* thesis would not have been written.

The other reason for the unconventional structure of the thesis is that this work is largely empirically driven, which does not mean that there are few perspectives from research literature. My Ph.D. process and as a consequence, the written thesis, revolve round the situated classroom practice. This is connected to a stance that practice needs to be thoroughly described before one tries to explain. Before one aims at changing a practice there is, I firmly believe, a need to understand how it works. By letting the empirical material be prominent in the first part of the thesis and not the research literature on science education, this is emphasized. In this thesis, the science education literature in front would have signalled a more 'normative' approach to this practice.

The chapters are divided into sections and subsections, but there are also some headings that are not sections. These subordinate headings are meant to help the reader in structuring the text, but I do not see these as important enough to give them the status of subsections. Moreover, I refer to what happened, i.e., the empirical descriptions in past tense. The main reason for this is that these descriptions belongs to a situated practice, which means that I cannot be sure that they are 'general' and the actions they refer to happened more than two year ago, so it feels strange to refer to them in the present tense. However, the inferences I make are in the present tense as this refers to what I do now – these inferences are of course also bound to a context.

To avoid repetition of excerpts, I sometimes use simplified versions of the participants' expressions. Simplified expressions are indicated by simple quotation marks, e.g., 'you shall', whereas direct citations are given as, e.g., "*you shall do this now".*

*The thesis chapter by chapter:*
Chapter 2 is about the initial research strategy (action research), and collaboration between the teacher and researcher in a close-to-practice research approach and the choices made during fieldwork. This chapter also deals with the ethnographic approach to gathering empirical material, overview of the material and ethical consideration during fieldwork. The purpose of this chapter is twofold. First, it is to show the initial research strategy that has affected greatly the perspectives of this thesis (e.g., the structure of presenting descriptions before educational literature) and then to describe the approach for gathering material upon which chapter 3 is based.

Chapter 3 provides background by introducing the teacher, class, school and curriculum. The overall purpose of this chapter is twofold. First, it is to introduce you to the classroom, to have a 'look' and to see some of the deliberations in the practice. So, this chapter serves as a 'welcome in'. The second purpose of this chapter is to establish a wider context around practical work for the final discussion (chapter 11). Practical work is but a part of what goes on in a science class, as practical work emerges out of a range of other activities in the classroom and thus cannot be totally separated. It starts with a presentation of the science curriculum:

the curriculum directs the subject matter. Next is a short literature review of being a young Norwegian. This section is given because I think it is important to have some backdrop for interpretation of students' actions. Students have more in their life than school and school science. The third section is a description of Hill upper secondary school. As the physical location and especially the science lab and the classroom are part of the rhetorical framing of practical work and inquiry, this description gives input (also) to the analysis of the cases (chapters 6-9). The rest of the chapter is about the (students in) class and Ellen (the teacher) and how they are dealing with school science and each other. Three 'snap-shots' will be given, that can act as illustrations of with how the science subject is dealt. These will be lightly discussed and a literature review on research on science education in Norway will be given. The purpose of this literature review is to make it plausible that what is going on in this classroom is quite normal for Norwegian schools. This is to 'normalize' the students and the practice in this class. In the last part of the chapter Ellen is presented, mostly through her own statements. The purpose of separating the presentation of teacher from that of the students' work with science is that the teacher is the one who sets the agenda in class and thus has a special responsibility for what is done and how it is done.  This chapter ends with some questions I asked after the fieldwork.

Chapter 4 builds upon the questions from chapter 3 – and the need these gave for a different approach to the empirical material. In this chapter, the redefined project, with aim and research questions, case study approach and multimodal discourse analysis, is established. Some central terms and criteria for selection of cases are given. This chapter also deals with quality in research (validity, etc.). Although I am somewhat partial, I try to give some critical comments to the research process and thus this thesis. The overall purpose of this chapter is to narrow down the empirical material and the ways of interpreting and explaining.

Chapter 5 is the analytical framework, based upon multimodal social semiotic and critical discourse analysis. It is perhaps a somewhat 'heavy' chapter, but as this is not an established analytical framework, there is a need to explicate it. This chapter provides a more thorough description of what the term rhetorical framing implies and how norms and rhetorical framing is inferred from empirical material.  This chapter also deals with practical analysis (making the analytical process as visible as possible) and some ethical reflections in analysis.

Chapters 6-8 are descriptions and interpretations of the three cases. The first case (chapter 6) is from March and practical work on heat pump. The second case (chapter 7) is from April and is concerning practical work on DNA-coding. The third case (chapter 8) is an inquiry 'Budding researcher' in May. Although the cases are different, they are presented with the same structure. First, there is a presentation of the subject matter and the empirical material upon which the case draws. Then there is a description of the close context, i.e., what happened the rest of this day – and how the practical work/inquiry was followed up later in class. The rest of the chapters are text descriptions and interpretations. The descriptions and interpretations are divided in two, the regulative domain of communication (i.e., structuring and organizing of task and dealing with behaviour) and the instructional domain of communication (i.e., dealing with subject matter including procedure and methods). At the end of each of the empirical chapters, there is an interpretation of the rhetorical framing.

Chapter 9 is inferring the rhetorical framing from all three cases. This chapter thus gives a cross-case description of rhetorical framing by identifying similarities and differences between the three cases. In this chapter, the two subordinate research questions will be answered by identifying the norms embedded in the teacher's rhetorical framing and how students respond to these norms. At the end there is a short summary of rhetorical framing.

Chapter 10 is perspectives from literature that will be used for discussing the empirical material. These perspectives are also chosen to give the empirical material resistance and counterweight. In this chapter, the arguments for science as a school subject are explored and there is an elaboration of the term 'science for all'. Further, this chapter add detail to what practical work is (in science for all). By using the curriculum as a starting point, I look into three interconnected domains; scientific knowledge, the language of science and procedures and methods. These three will be linked to perspectives from 'real' science, or what might be called the epistemology and ontology of science. The reason for this is that school science draws on 'real' science and students as citizens will encounter 'real' science – not school science when they leave school. However, it is important to emphasize that school science is not, nor can it be, real science. School science will differ from real science because of many constraining factors such as time, knowledge base, physical resources – and interest.

Chapter 11 is the final discussion where the main research question '*How does the rhetorical framing of practical work and inquiry reflect science for all?*' is explored. The input to the discussion is the empirical material primarily from chapters 3 and 9, as well as the literature presented in chapters 3 and 10. At the end of the chapter, some proposals for school science if the objective is 'science for all' are given.

## 1.4. My stance – a brief positioning

My stance or my position towards teaching and learning science in school will be implicitly visible through my choices regarding the perspectives on empirical material and literature. There is no neutral or objective position when dealing with education, though this does not imply that positions and arguments cannot be sustained or given explicit reasons. However, I will give a rough overview of what I consider important, in other words I am trying to make my 'interpretative horizon' explicit.

In my opinion, science is the best subject in school, or rather it has the potential of becoming so. It deals with some of the most important contemporary issues as well as some ideas that have a great impact on our view of ourselves as human beings on planet earth. This means that science is connected to other knowledge domains. To connect school science with other school subjects as well as the life outside school is a challenge and will create tensions. How 'pure' shall science education be? To deal with science-related issues students need some science, but they also need help to connect science to other knowledge domains. Perhaps too often the school just hopes that students are able to make the connections themselves. Further, school science has the possibility to integrate theoretical thinking with practical work, to inspire to awe, wonder and creativity, as well as critical and logical thinking. Science is, as I see it, one of the important subjects to foster citizenship.

Science is a way of understanding the natural and physical world and uses different resources for representing the knowledge. In science, there is some knowledge that is very well established, and not all ways of representing the established body of knowledge are equally good within the cultural and historical tradition of which we are part. However, there is a danger that when this body of knowledge is dealt with in school it becomes a 'fixed' way of representing truth. That this 'truth' once was contested (as all research) is omitted and I think this 'fixed and true' might result in students not wondering or asking questions. The established body of knowledge is what seems to be emphasized in school, there are many entities to *think about*, but seldom is the student given sufficient time to reach the level where they *think with* these entities. I mean that this leads to a missed opportunity for students to relate critically to science.

BUT I do understand that many students find it hard to see school science as meaningful. This might be because students have other motivations and interests. One of the most important reasons, I think, lies within the school system and its lack of engaging students in science. Perhaps students do not feel they master the subject matter sufficiently and it might be seen as boring if it is all about remembering 'details you never need'.

In my view, teaching and learning is basically communication. Communication is social. One tries to make oneself understood, and one tries to understand the other, but there is no direct access to thoughts and feelings. In an educational setting, it is important not to talk 'past each other', but this is hard to avoid as students' expressions are provisional in the sense that their ways of expressing subject matter is developing, i.e., learning. I think that teacher expressions are also somewhat provisional as the teacher has to interpret students and try to find the right 'level' and 'angle of incident'. Both the teacher and students express themselves as best as possible and make apt choices regarding what they mean is important and the needs of the other. In education, the teacher 'knows more' – and sometimes 'knows best'. This can result in two interlinked implications. First, the teacher will be the one in the classroom who support the students in their work with the subject matter through structuring and making choices regarding *what* and *how* to present. The other interlinked implication is that this will give an uneven distribution of power in the relation between students and teacher. This uneven distribution of power might be a constructive force, it just depends upon how it is wielded.

I see teaching and learning as difficult and complex, sometimes it is fun but at other times it is downright frustrating. The teacher and the students form a relation with each other and the subject matter with which they are dealing. In these relations there will always be feelings … of success, of inadequacy, of boredom. In formalized education, teaching and learning is deeply dependent upon each other. Teaching without anyone learning is pointless, and learning (school) science without teaching is very difficult.

In the process of writing this thesis, I have become increasingly ambivalent to the school system. I see formalized education as necessary to cope with living in a modern society. In addition, the objective of school to include all and to marginalize none is amiable. However, the objective and the reality are on a collision course. To me it seems that school is becoming more instrumental, what is seen as important is that you can tick off the box 'have done'. The quality of what is done is not equally important. In my darker moments, I think school is just about 'keeping up appearances' by teachers and students to satisfy somebody else's (the System) notions of appropriate teaching, learning and knowledge. This is, of course, not so simple, students want to learn (they are human :) but the school system is perhaps not making use of the full potential in this. Perhaps one of the reasons is that the school as an institution was designed in another age for a different society. Dealing with knowledge is becoming profoundly different when technology changes. Students can read, write and copy information by using personal computers or their smart phones. Modern communication technology diminishes the authority of textbook and teacher as the source of knowledge. How to connect facts, relate critical to information and generate new knowledge needs to become a more important aspect of education. School must (?) be conservative in one sense as it has a purpose of transmitting cultural values, but school cannot be out of touch with the contemporary (i.e., the youth), if so the communication will break down.

However, I have tried to avoid the 'educational researcher trap': 'what I know – they *ought* to know and I know best'. In other words, I have tried to suppress my normative inclinations as best as possible. In a research project, this means to suspend judgement and evaluation and let the participants' actions come forth – but of course, I have made the selections according to my interests. So, whether or not I have succeeded in avoiding the trap is for the reader to judge.

# 2. RESEARCH APPROACH DURING FIELDWORK

*StudentResearch* aims to develop school science practice as well as generate theory. This requires an approach to research that is practice based. When approaching 'the field' in practice based research one has to consider *which* 'field' and together with *whom* –and *how*.

This chapter deals with *how* – in other words, with research approach and ethnographic methods for gathering empirical material during fieldwork. Further, reasons are given for choices of school, teacher and students (*whom*). The chapter also provides a brief account of research issues in the beginning. After the fieldwork ended, I redefined the scope and approach of this Ph.D. project. This redefined project will, however, be addressed in chapter 4. At the end of this chapter, there is a section on ethical considerations.

## 2.1. Initial Research approach

*StudentResearch* set some conditions for how to approach the 'field'. In the project description, action research was explicitly given, but the research team had a pragmatic stance regarding how action research was to be understood and performed (Knain & Kolstø, 2011). The first part of this section is about my deliberations and choices in an action research approach.

The second part of this section is about collaboration with the teacher. As *StudentResearch* had established a partnership with some schools and teachers, it was only to be expected that my collaboration with a school and teachers were chosen among these. I chose Hill upper secondary and Ellen. The other projects in *StudentResearch* collaborated with several science teachers. However, as I had little research experience and absolutely no experience in leading development processes, I was very reluctant to work with more than one teacher.

### 2.1.1. Action research

Action research is an umbrella term for different approaches, which has emerged from different traditions (Herr & Anderson, 2005; Kemmis & McTaggart, 2005). In this thesis, I will not provide a thorough overview of the different approaches, giving a brief account of those approaches that I considered when designing the project.

In the self-study approach, the 'I' is important for actions and change (see, e.g., McNiff and Whitehead (2006)). A different approach is grounded in the teacher reform movement where Elliott (1991) advocates that teachers themselves and their experienced problems, have to be the starting point for the research. The teachers will be in control of the research, both by formulating questions and determining the process. The role of an outside researcher is to facilitate this process. Carr and Kemmis (1986) have a more 'active' role for the researcher in their approach to critical participatory action research (PAR). PAR concerns with oppressed communities and attempts to act as a catalyst for social change (Grant, Nelson, & Mitchell, 2008).

In the design of this project, I rejected the self-study tradition, because 'I' was not the issue here and also I saw some methodological problems in this approach. It is, of course, never possible to be absolutely objective in research, as all descriptions and interpretations are made from a position. On the other hand, total subjectivity is not the only alternative. The 'teacher change' approach seemed much more feasible as it was directed toward change in teaching practice. However, there were two problems related to this approach when designing this project. First, Elliott (1991) emphasizes the importance of teacher-initiated research problems. I had a more active role in the research project. Ellen did not decide on what to research (although she initiated the spark) and did not do much of what one would traditionally call research. The constraints of being a teacher regarding time and perhaps also not being used to 'put things in writing' limited her as a 'teacher-researcher'. The second problem with this approach is more methodological. Since the starting point is a teacher's experienced problems, this can lead to a technical approach to improve practice (Herr & Anderson, 2005), as there are constraints on teacher time and means for reflection (Dale, 1993). As an insider, it is difficult to analyse the historical and cultural tradition of which one is part and teaching must be understood in terms of this tradition (Engestrom, 2001).

The PAR tradition (or traditions, as there appears to be different strands of PAR) is an emancipatory project where social interaction (practices) is paramount to changing actual practices (and not abstract practices) (Kemmis & McTaggart, 2005). Kemmis and McTaggart (2005) emphasize that PAR is collaborative and reflexive, they also states that PAR

> Aims to help people recover, and release themselves from, the constraints of irrational, unproductive, unjust, and unsatisfying social structures that limits their self-development and self-determination.
> Aims to help people recover, and release themselves from, the constraints embedded in the social media through which they interact – their language (discourses), their mode of work and the social relationships of power…
> (ibid. p. 282)

As I never have perceived that Ellen needed my 'help' to release herself from the constraints of real-world teaching-practice, I find the PAR tradition would have been somewhat patronising in this case. Also, as there is no way of being outside the constraints of language when describing and explaining social practices (Law, 2004), the best we can hope for is to question both teacher and researcher's chosen perspectives.

The approach I chose in the end was something similar to pragmatic action research described by Levin and Greenwood (2001). Pragmatism, with its roots back to Dewey (e.g. 1998), has two central features. First, knowledge is generated through action and experimentation. Second, pragmatism emphasizes participative democracy. Levin and Greenwood's understanding of pragmatism is that it

> unites theory and praxis in an integrated knowledge construction process. Its central meaning construction process is linked directly to cycles of reflection and action that focus on the outcome of acting on material and social factors in a given context. (ibid. p. 104)

This stance offers some implications. First, action research is context-bound and addresses problems that occur in that context. The wholeness of the situation must be taken into account. Second, participants and researchers co-operate and different contributions are given serious deliberation in the process of generating knowledge. This means that diversity is enriching the process of action and knowledge construction. Third, the meanings produced lead to action and construction of new meanings – until the problem is solved to the satisfaction of those involved.

In action research the cycles of planning, acting, observation and reflection are crucial (Altrichter, Kemmis, McTaggart, & Zuber-Skerritt, 2002). The linking of acting and reflecting in a continuous and iterative process is perhaps one of the most central aspects of action research – apart from participation. However, there are some problems linked to the cycles (some view it as a spiral). All parts of the cycle are part of a larger whole (Levin & Greenwood, 2001). The transitions between the phases: plan, act, observation and reflection, are not greatly problematized in action research literature, nor does action research literature seem to be much concerned with the problems of observation. Observations are bound to a 'frame of reference' as one's beliefs and theoretical perspectives greatly influence what one observes (Berger & Luckmann, 1966; Law, 2004). This means that the different participants will observe and put weight on different things, also because of the multifarious interactions in a classroom. The perspectives of the researcher and the teacher will thus be different. Another source of difference is the conditions for observations for teacher and researcher. The teacher will be busy teaching and will thus not emphasize observations during lessons, while the researcher has the possibility to focus on observation. This creates a difference that might be a problem regarding the power relation between teacher and researcher. One way to remedy this problem can be to video tape the lesson and observe the tape together. (I do not regard video as a neutral tool for observation, see section 2.3.2.). However, when using video, constraint from the 'real-world' impacts teacher's time to watch and discuss. The ideal of democracy might be hard to achieve when the preconditions are so unequal. In this project, the division of labour between Ellen and me created an unequal-ness regarding the possibility to observe and thus to reflect over what happened.

Even so, there seems to be a positive outcome for teachers involved in action research projects as the projects provides a possibility to become more aware of their practice, choices made and perhaps become more confident about trying new teaching strategies (O'Connor, Greene, & Anderson, 2006). Reporting from one of the 'sister-projects' to *StudentResearch,* Postholm (2009) claims it took a quite long period of time before teachers developed a research stance toward their practice where theoretical perspectives were informing their practice.

In action research literature reflection is much emphasized (see, e.g., Robertson (2000)). However, since observations are bases for reflection, there might be a danger that reflections become 'thin' because the teacher usually will be more constrained regarding time to observe than the researcher will. This also weakens the ability to scrutinize and think through the actions. Further, since re-planning and new actions hinge on reflection of previous actions, it might be problematic to make the relevant and good changes. If the wholeness of the situation and the values imbued are not part of the reflection, there is a danger that the action cycle is reduced to 'social engineering' (Dale, 1993; Herr & Anderson, 2005). 'Good' reflections can thus be seen as a systematic and deliberate way of thinking through practice and connecting this to theoretical perspectives.

The role of theory in action research differs. Carr (2006, 2007) sees (research) theory in education as an attempt to take an objective and decontextualized stance to education – as he rejects the possibility for objectivity he also reduces the role of educational theory.

> Educational theories can indeed have a very real practical influence but this is no different from the kind of influence that is exercised by *any* discursive practice that has been appropriated as an instrument of rhetorical persuasion. (Carr, 2006, p. 152, emph. in original)

In the critical approach to action research that Carr and Kemmis (1986) advocate, they see critical action research as a means for sustainable social change of practices where ecological, economic, moral as well as discursive elements are incorporated (Kemmis, 2009). Further, they regard technical action research as a way of changing practice without questioning the object of change and practical action research as a form of research where, even if the object is questioned and the participants are 'equal', this form of action research lacks the perspective of emancipation (Carr & Kemmis, 1986). In a critique of *Becoming critical* (Carr & Kemmis, 1986), Elliott does not agree with this hierarchy of 'technical', 'practical' and 'critical' action research and he argues that critical reflection is also a vital part of practical action research. Further, he states that science in general is a part of the endeavour to make life better and continues:

> Nor is there any 'deep split' between theory and practice, since 'all so-called theory which is not wordplay is always already practice'. Theories are simply descriptions of the world that open up new possibilities for action. (Elliott, 2007, p. 371)

Levin and Greenwood (2001) view theory as the knowledge created through active experimentation on real life problems. The criteria for deeming a theory 'good' is its workability in the democratic practice. This implies that a "*theory cannot exist unless it is grounded in warranted praxis and is understood to be of value by those affected* *by the problems*" (ibid. p. 108). In action research there is an acknowledgement that knowing can take different forms such as practical (how to do) and propositional (knowing about something). As well as in a research setting the more unusual forms of knowledge – knowledge connected to direct perception and presentational knowing (aesthetic forms of expressing oneself) (Heron & Reason, 2008).

The Norwegian philosopher Jon Hellesnes has verbalized a critique of the stance where theory is solely linked to practice.

> If one understands action research as a contrast to a discussion of theoretical foundation and means that action research takes away the 'academic desk speculation' and 'abstract theorizing' and is directed toward pure PRACTICE, then action research leads to an empiricist, activistic and spontaneous dead-end.[2] (Hellesnes, 1992, p. 143, first published 1975 - my translation)

Further, Hellesnes argues that material considerations must also be taken into account when deliberating over practice. He exemplifies material possibilities and constraints as, e.g., resources for learning and building as well as the economic structure of society. His scope for reflection on practice is thus much wider than what is usually reflected in action research literature, as he links what is worthwhile (the greater objective of education) with material considerations.

Seen in hindsight, the reflections after actions were of low quality in this project, and thus provided a feeble starting point for new actions. This has something to do with the constraints on Ellen, as well as me not inquiring thoroughly into the practice. The result was incoherent 'reflections', often purely descriptive. Following Hellesnes, this led us into unsystematic actions linked to practice. Our goal became to find 'technical' solutions in the particular situations. However, I do see the value of gaining insight into the wholeness of classroom practice. In addition, being close to the practice provides a possibility to describe and explain it in all its richness. Therefore, in a sense, some of the perspectives from action research are still prevalent in this thesis. For me, it has been necessary to collaborate with a teacher to be able to describe and explain this school science practice.

### 2.1.2. Collaboration with Ellen – the teacher

Collaboration in an action research project is research *with* people and not *on* people (Heron & Reason, 2001; Herr & Anderson, 2005), although the form of collaboration may vary during the project (Herr & Anderson, 2005). When beginning to collaborate, trust is essential (Grant et al., 2008) in building a relation where there is enough 'sameness' so that the participants speak of the 'same'. However, the collaboration must also allow for difference (McArdle, 2008). As an outsider, the

[2] Om ein forstår aksjonsforskning i motsetning til teoretisk grunnlagsdrøfting og miner at aksjonsforskning fører bort fra såkalla «akademisk skrivebordspekulering» og «abstrakt teoretisering» og i retning av rein PRAKSIS, då fører aksjonsforskninga inn i ei empiristisk, aksjonistisk og spontanisisk blindgate.

researcher can adopt a querying attitude to practice (Herr & Anderson, 2005) and clarify own position as part of making difference non-threatening.

In the beginning of the collaboration with Ellen, we went to a conference together where there were plenty of opportunities to discuss school, students and school science. I could 'meet' Ellen in many of the issues she brought forth as we had many similar experiences as teachers in upper secondary school, but there were also differences between us. The formal differences are our education, as we have specialized in different science subjects, and our work experience. Ellen's work experience has provided her with practical knowledge of how to perform school science with not very interested students – which I have not. During my work experience as a teacher educator, there has been more emphasis on reflections on teaching and learning science. In addition, we (probably) have some differences in our stances toward students, subject matter, teaching and learning. It takes time to build trust. In our collaboration, it took time to determine our stances. I attempt(ed) not to meet Ellen and her teaching with a 'normative' stance by assessing 'good' or 'bad' teaching practice, although I frequently shared my speculations and views.

Ellen and I worked together for two years. During the first year of our collaboration I had the idea, based upon classroom observations, to facilitate students' talk in science so there would be more exploratory talk (Mercer & Littleton, 2007; Mercer & Wegerif, 1999). However, facilitating talk was my problem – not Ellen's. I did not have concrete ideas for implementing 'exploratory talk' that convinced her to try it. In addition, I obviously did not have good enough arguments for why talk amongst students is important for learning. In action research, it is seen as important that the problem belongs in the practice and is perceived as important by those who deal with it every day (Elliott, 1991; Heron & Reason, 2001). Beginning the second year of our collaboration, I was not sure on what to focus and I did not discuss this thoroughly with Ellen. During the autumn, Ellen read an article by Knain and Hugo (2007) about different forms of representing science phenomena which she found very interesting. I coupled this with a multimodal social semiotic view of communication. Together, we then agreed to focus on how to use different learning resources to support students' meaning-making in practical work in science.

During our collaboration in the classroom, our roles altered, for example, in the start of the second year Ellen left some of the teaching to me while she observed. As Ellen was much better than me when it came to classroom management, our roles settled into Ellen was responsible for teaching and I 'researched'. We thus established a division of labour by acknowledging each other's strengths and responsibility domains. The consequences of this might be described in two ways. First, Ellen perhaps did not regard herself as a co-researcher which is an objective in action research (Heron & Reason, 2001). Second, regarding the power relation we saw this as an opportunity to learn from each other and thus share power (Grant et al., 2008). Together we talked about plans for lessons and mostly (depending upon Ellen's schedule) we talked after lessons. In these conversations, Ellen and I can be described more as colleagues than as teacher and researcher. Although Ellen had the final word in planning lessons, I often brought forth ideas on what and how to do.

The planning sessions were often creative in the sense that we toyed with various ideas. However, we did not necessarily 'land' any of them. Some of the planning sessions were more structured especially when we made long-term plans. According to Herr and Anderson (2005), there is a continuum of positionalities in action research and they may vary during the project. Perhaps the largest problem with my decision that I only wanted to work with one single teacher is that it made it more difficult for Ellen to involve her colleagues at Hill in the project.

In the beginning of the second year of our collaboration, we (mostly Ellen) expressed the aims for teaching. These objectives also gave direction for planning and evaluation, although we did not use the aims systematically throughout the year. The aims expressed that teaching should be conducted in such a way that school science became relevant and varied for the students and that it should bring forth some of the themes that occurred in contemporary media. Further, that the aims stated that students should be able to speak about science, think critically and that all students should feel emotionally secure in the science classroom. The overall purpose was to provide students with a science course where they learned a great deal.

### 2.2. Students – choice of class and group

The class was not chosen as such. This was Ellen's class. However, the students in the class are an important 'type' of students, as they are not very interested nor typically high achieving. This means the teacher has to consider consciously both science content and pedagogical approach more so than if the students were 'future scientists'. In science education literature there are few references to students of this 'type'; an excellent exception is Yerrick's (2011; 2000) research on lower track students. As the students in question have not selected a track, I will, however, not use the term 'lower track'.

I chose to follow a group of students more closely. In the group, there were three girls: Sheila, Beatrice and Ingrid. Practical considerations such as one researcher and one video camera restricted the number of students' groups (students always worked together when doing practical work). As physical artefacts are important in practical work, it was seen as necessary to capture this on video. Audio material alone would not provide justice to what they did. The primary reason for choosing these students was because they talked. Through trial and error during my first year in Ellen's classroom, I had learned that some students talked little (science) during class and when students do not talk, there is little to interpret. This group of students was amongst themselves good at asking questions, seeking explanations and inventive in the use of resources for learning. I never really asked about their grades, but my impression was that they were about average. This means that they were 'quite good at science' compared to the rest of the class (there were students getting better and worse grades, I believe). Another reason for choosing these girls was that they usually did what they 'should' – when Ellen initiated some work these girls worked with the task, and compared to other students in the class they must be described as quite conscientious. However, students do get sick or do not attend class for other reasons. Only one of the students, Ingrid, participates in all the cases. In the practical work connected to the heat pump, there was one other student (Peter) in the group. At the 'budding researcher day', two of the girls in the group had an exam so Ingrid worked together with Fiona with whom she had not worked together previously in science.

Some of the students in the class did reserve themselves to participate in the research project, which had some implications for gathering material and ethical considerations, see section 2.5.

## 2.3. Methods for gathering data

The fieldwork has many resemblances to ethnography, as it was conducted over a long period of time and data collection was quite 'unstructured' for most of the time. This means that there was no fixed research design at the beginning of the fieldwork, and the interpretative categories were made after the fieldwork ended. An ethnographic study usually contains a few cases and weight I put on how to interpret these cases with regard to the context. This is consistent with Hammersley and Atkinson's (2007) description of ethnography. According to Erickson (2011), an effective data collection includes as many sources as possible. To gather my empirical material, I used observations and field-notes, audio and video recordings of teacher and students in class, as well as audio recordings of interview with students and conversations with the teacher. In addition, I gathered a range of the products students handed in.

### 2.3.1. Observations and field-motes

Observations are not descriptions of reality, rather they are interpretations of this reality made by the researcher and observations are thus mediated by interest – and perhaps also prejudice (Gobo, 2008). As a former teacher in upper secondary school, I was well acquainted with teaching and science education. Much had happened, though, since I left upper secondary school in 1998. Students' approach to school work was different, curriculum was new, and students in upper secondary have personal computers as a tool in their learning. After the first period of observation – where much seems 'different' or 'new', it is a problem for the researcher to stay in an estrange 'mode' (Gobo, 2008). To continue to be estranged is important, because if 'the field' becomes too familiar, it is hard to maintain a querying attitude. This constant estrangement can be achieved by constantly asking questions such as 'why' and completing thought experiments such as 'what if…'. Sometimes, pauses from the fieldwork may also help to refocus and 'stay on track' (ibid.).

According to Hammersley and Atkinson (2007), the narrowness of what is to be observed is closely connected to how detailed observations can be. A more general observation of a class will thus result in many, but not very detailed, descriptions. A clear focus in observations could have helped me not to become too familiar with the practice and thus been more conscious about what to observe. However, I chose an unstructured approach to observations as the primary purpose of observations was to provide input to a description of context.

Writing field-notes from observations are a selective process, as everything cannot be written down. To help the researcher's memory, it is recommended to jot down key words, exact statements of what is said, drawings, etc. (Hammersley & Atkinson, 2007). During class, I always had my field-journal with me, and sometimes I wrote some words, statements and short reflections. The problem with making notes in a field-journal is that the participants may become unsure of what the researcher actually writes – and it might perceived as an intrusion and thus make the participants more guarded in their behaviour and speech (Hammersley & Atkinson, 2007). I tried to jot down notes after 'incidents', but sometimes I also jotted down while the 'incident' was occurring.

Gobo (2008), referring to Spradley's *Participant Observation* from 1980, gives three principles for writing field notes:

- Different groups of people have different ways of expressing themselves, discourse organisation, what they see as important, etc. The ethnographer needs to find out what it means. This can involve asking questions and asking about purpose.
- As a consequence of the above, there is a need to record accurately what people say (and how they say it) as the words and sentence structure that are used are important in understanding what was meant. This is especially important when the participants express themselves differently from the researcher. There is a problem according to this, however, if it is not recorded by audio or video and the researcher does not want or cannot write down exact formulations – the exact statements easily get distorted (Hammersley & Atkinson, 2007).
- Practices should be described in a concrete language. This means that the ethnographer should avoid professional terms and evaluative expressions.

As I early on in the project knew that I would use audio and video material for close-up analysis, I was not particularly concerned about participants' accurate formulations. Nevertheless, I always tried (to the very best of my ability) to keep the field-notes concrete and as close to the actions as possible.

After observation it is important to write out the field-notes as soon as possible (Hammersley & Atkinson, 2007). I wrote the field observations on the train journey home from Hill after each of my visits. I revised the notes later that day – or the day after to insert (parts of) descriptions that were left out or added more reflections. The notes were organized in descriptive sections and in sections (which I marked by italics) which contained theoretical, methodological and emotional statements and questions – this is in line with recommendations by Gobo (2008). I also tried to be clear when memory failed me or when I was uncertain on formulations (exact formulations were sometimes written during class). According to Hammersley and Atkinson (2007), it is important when writing field-notes to be clear about inaccuracies.

When a researcher is doing fieldwork for a long period of time, he or she obtains a substantial impression. Not all of this information is recorded, but the researcher has an insight that sometimes is hard to express intelligibly.

> The ethnographer acquires a great deal more tacit knowledge than is ever contained in the written record. He or she necessarily uses 'head notes' or memory to fill in and recontextualize recorded events and utterances. One should not become totally wedded to the fieldnotes, as if they were the sum total of available information. (Hammersley & Atkinson, 2007, p. 147)

This tacit knowledge can be a challenge when writing about the context, because many things that seem obvious to me are not so for the reader. This is partly a problem of 'projecting' a three dimensional world onto a two dimensional piece of paper, as well as a problem of choosing which parts that contain the important information for others as well as the right level of details.

### 2.3.2. Audio and video

Audio and video recorders might be seen as intrusive in a social setting, but at the same time people get used to being recorded and do not necessarily think much about it (Gobo, 2008). In this class, I often audio recorded by leaving the recorder at the teacher's desk or beside the group of students. One of the problems with audio recordings from classroom is that the recorder does not discriminate between sound and noise (Gobo, 2008). This might make it hard to hear and thus interpret what has been said, especially when I put the recorder at the teacher's desk. Some of the more soft-spoken students are impossible to hear when they ask questions or make comments. In addition, the audio recorder does not capture material objects and gesture (Hammersley & Atkinson, 2007). In hindsight, I see that I could have used the video recorder more to capture teacher Ellen's introduction to practical work, as she used her hands (and objects) more in the introduction than I anticipated. So, some of Ellen's introductions are only audio recorded. I recorded video of students' practical work to see how they used gestures and the scientific equipment as part of their meaning-making. When video filming, it is essential to be aware of such mundane aspects as light, angle and zoom (Roth, 2005). What to focus on depends thus on the research questions and analytical focus, which in the initial research project focused much on students' use of learning resources. The video recordings are also partial as they are focused on something and not everything (Hammersley & Atkinson, 2007), however, relative to field-notes video can be replayed and analysed in different ways (Derry et al., 2010). According to Derry et al. (ibid.), a video will contain many events and these events are on different time-scales. This means that when students do practical work some of the things they do relate to previous actions such as their own decisions or Ellen's introduction. Video contains much information and ideally clear criteria for selection are needed (Derry et al., 2010). This will be dealt with in section 4.5. Transcriptions of video (multimodal transcription) and audio recordings will be dealt with in section 5.8.1.

Interviews and conversations were audio recorded. As part of the gathered material, there are approximately 18 hours of conversations between Ellen and myself as well as one conversation that is more like a semi-structured interview (Kvale, 1996), as I had prepared some themes. However, there was no proper interview guide as this would have been a peculiar intrusion on our relation. Our other conversations were structured around lessons, planning and evaluating. Both conversations and the interview were conducted (mostly) in a secluded room not to be disturbed.

At the end of the school year, I interviewed three students; Ingrid, Beatrice and Sheila. This interview lasted for approximately 45 minutes and I had made an interview guide in advance, which mainly dealt with how the students had perceived the use of different representational resources. In the preparation for this interview, I had considered how to elicit views from them about what they thought of science, the use of resources and transduction between different resources. I chose to interview this group of students together because then they would have an opportunity to elaborate on each other's views and they would perhaps feel more emotionally secure when they were together. Sometimes I had noticed that they did disagree during lessons, so I was not afraid that they would not speak their meanings openly. However, this meant that I, in the preparation phase and the conducting phase of the interview, had to be conscious about giving space for all three voices. According to Kvale (1996), it is important to brief interviewees in advance as well as conduct a debriefing. In this case, the briefing was satisfactory, but the students wanted to leave immediately after the interview so there was no time for summing up other than 'Have a nice holiday and good luck'. The interview was conducted in a small and not very 'cosy' room connected to the science lab where we could be undisturbed.

### 2.3.3. Surroundings, material products and objects

According to Hammersley and Atkinson, ethnography has, to large extent, relied upon oral information and descriptions of social actions; this means that material artefacts have been more or less excluded from traditional ethnography (Hammersley & Atkinson, 2007). Doing practical work in science is almost impossible without material objects. These artefacts are part of the social interaction of practical work. In addition, documents of various types play an important role in school science, for instance, the teacher's hand-outs, students' reports, or pages written on the class wiki (hypertext). As it is rarely clear as to what documents and products are to become useful in analysis (Hammersley & Atkinson, 2007), I collected a great deal of students' and the teacher's documents concerning practical work and documents connected to the subject matter of the cases (Heat pump, DNA, and Budding researcher). The physical artefacts that were used during practical work and inquiry were not collected as such; they were video-filmed.

Hammersley and Atkinson (2007) state that physical surroundings are important to account for, as the surroundings both constricts and makes social interaction possible. Surroundings are not only a part of context, and they continue:

> Rather, we ought to pay serious attention to the material circumstances that constrain social activity, how a sense of place is reflected in the individual

and collective identities, and how places are used by social actors, just as they use any material or symbolic resources. (ibid. p.136)

Physical surroundings are important in practical work. Teacher and students have to assess where they can do their practical work. Do they need a sink or a power socket? In addition, if everybody needs to be close to the three sinks in the lab it will be crowded. As students move more freely about during practical work, they also inhabit the room in a different way. I had no possibility to investigate this thoroughly because of only one camera and some students were very conscious about *not* being filmed.

## 2.4.Overview of data material for this thesis

There is a wide range of sources used to construct context and cases in this thesis.

| Type material | Format |
|---|---|
| Planning, evaluation and conversations between Ellen and Gerd | Audio<br>Approximately 18 hours |
| Interview with Ellen at the end of school year | Audio<br>Approximately 2 hours |
| Interview with three students at the end of school year | Audio<br>Approximately 45 min |
| Field notes from science days | Written<br>21 documents |
| Teacher presenting, explaining or introducing practical work | Audio<br>Approximately 4 hours<br>Video<br>Approximately 3 hours |
| Students doing practical work<br>(audio is of students working with reporting after the practical work) | Video<br>Approximately 1 hour and 40 minutes<br>Audio<br>Approximately 1 hour |
| Task sheets | Written<br>2 documents |

**Table 1: Overview of empirical material**

There is also some material that was gathered but not used; video of lessons following practical work (which was not completed) and audio recordings of lessons that was not connected to the topics described in this thesis. Student products were over a wide range (tests, essay, presentation, wiki, log), but these are not connected directly to the scientific topics described in this thesis. However, I have watched at and listened through this material so it is part of my 'tacit' knowledge of this classroom practice.

## 2.5. Ethical considerations when doing research in school

This section is divided into what is seen as different aspects of ethical considerations. The first is more technical, as it deals with the formalities of ethics when doing research, and the other is a bit harder to pinpoint, as it deals with ethical considerations regarding intrapersonal relationships.

*Students as Researchers in Science* was approved by NSD (Norsk samfunnsvitenskapelige datatjeneste), which is the agency that manages approval of research, ethics and data handling and storage. The consent from NSD included this Ph.D. project. NSD gives guidelines for how to address participant consent and storage of empirical material. I have followed these guidelines.

When doing research, informed consent is of vital importance, as those who participate should understand of what they are a part (Derry et al., 2010; Hammersley & Atkinson, 2007; Kvale, 1996). This can be easier said than done, as full consent would mean that the research project is completely defined and clear. Many qualitative projects and perhaps especially ethnographic approaches evolve during the research process. Also, if the researcher is very explicit on what the research is about, then it can distort the investigation (Hammersley & Atkinson, 2007). When introducing the project or explaining it to students, I usually said something such as: "*I'm researching teaching and how students use resources in their meaning-making*".

All students in the class received a formula, which was a standard formula for *Students as researchers in science.* In this formula, it was made clear that students could withdraw from the project any time if they wished. Four students did refuse to participate in the project. This limited the use of video recordings as I always had to be aware that none of these students was in the shot. There might, of course, be many reasons for students not wanting to participate. However, from my first year at this school I saw that students who were not very interested in science or received low grades did not feel very comfortable when the recorder was on. We all want to expose ourselves when we are at our best. Many of the students in this class, but not all, were not very interested in science and perhaps not very motivated for school. It is thus important as a researcher to balance two different considerations: not exposing students (and the teacher) to unnecessary embarrassment and at the same time provide a truthful description of their dealings with science (Erickson, 2011).

All of the students who appear in the cases gave their consent, and none has withdrawn it. The five students who appear in the cases are the only students who retain their name throughout the thesis. All other students are randomly named, e.g. John might be used for any boy. So both Per and Espen might be called John – and in another situation Per might be called Kevin. This means I do not keep track of which student said what at a particular time. This is defendable also from a research point of view, as it is the classroom practice that is under scrutiny and not the individual student.

All the students are given traditional English names. Not all the students in this class were born in Norway and some of the students had 'foreign' names, but all students spoke Norwegian well. By re-naming students, I also re-culture them as I take away some of their identity and add on the cultural images of 'John' and 'Kevin'. It is defendable from a research point of view as this thesis is not about the individual student. Another aspect of re-naming students is an effective way of anonymizing students. On the individual level, the cultural background will of course have an impact on how one approaches school science (Aikenhead, 1996). In addition, Ellen is re-named, and Hill is not really called Hill. Because of anonymity, I have tried not to divulge specific locations or specific information about the participants. This is the reason why there is no footage in this thesis.

In many ways, ethics in the interpersonal domain is much like ethics when we deal with other persons in normal settings, but there are also some aspects that need to be specially considered (Fog, 2004). There is the matter of trust, as a researcher one is trusted with information and as a participant in a practice. Trust implies confidentiality (Kvale, 1996). For me, this meant that what Ellen said or what the students said was not brought to the other and if so, only in general terms. I could discuss my observations of students with Ellen but for example, I did not specify the amount of time some students used playing games on the computer. I did not discuss grades with the students or the teacher. Grading of students was the teacher's domain. Respecting the privacy of the participants is important (Hammersley & Atkinson, 2007). In this thesis, this is not very difficult as the theme is school science (not a very private topic). However, at times, students and Ellen talk about private matters that are neither transcribed nor referred to. Although, it is possible that the 'private' could have influence on the participants' performance.

Making meaning from research and writing out the thesis is about trying to provide an impartial account of 'what's going on' (Hammersley & Atkinson, 2007). The stance chosen is of course partial, but at the same time it is important to tell the 'truth' as seen from this perspective. This might be a problem as sometimes the truth is not necessarily pleasant (Fog, 2004), or it might be that the researcher over-identifies with the participants and thus is in danger of losing the critical perspective (Kvale, 1996). A possible solution to this is to share all evidence with all participants (Groundwater-Smith & Mockler, 2007). However, in a project such as this, that would mean to involve both teacher and students in an analysis of 'evidence'. This is time-consuming and impractical. As a compromise, I have chosen to let Ellen read parts of the thesis (draft of chapter 3). We have had some meetings to discuss the findings and explanations. The students are even less involved in the meaning-making of the results. This is because when I write this, they have hopefully finished upper secondary. The other more important reason not to involve them in analysis is that as the system works today, the teacher is more 'important' for planning and conducting teaching-learning situations.

The ideal of participatory research in the field is transparency (Groundwater-Smith & Mockler, 2007), which can be hard to obtain as a researcher. As a 'budding researcher' myself, I had not the experience of what to tell participants that would be sufficiently clear. Nor did I have a sufficient overview of what I was doing while I carried out the fieldwork. This probably made me unclear when I talked about the project with students or the teacher.

## 2.6. Summing up the research approach

During the fieldwork, the approach was action research. I was working close with a teacher, Ellen, for two years planning and evaluating lessons. The first year was a trial year to find common ground and feasible methods for gathering empirical material. During the second year, the research focus was on resources that would support students in their meaning-making of subject matter.

I was present in almost all science lessons during these two years, which provided a substantial impression of the practice in Ellen's science class. In the last year, I followed one group of students. These students were chosen because they collaborated quite well and talked and discussed the subject matter while working on it. I used ethnographic methods to gather empirical material and I wrote field-notes from all lessons. There is audio material of conversations with Ellen and an interview with the students. I also collected the students' products (writings and drawings etc.). However, the primary bulk of empirical material is video and audio recordings of Ellen's teaching and students' working with the subject matter. The material thus gives possibilities for a thick description of this practice and provides the input to descriptions and interpretations in chapter 3 as well as the empirical chapters 6-8.

The close-to-practice research approach has allowed for a perspective that influences the structure of the thesis by giving primacy to this school science practice.

# 3. WHAT IS GOING ON IN SCHOOL SCIENCE?

This chapter provides a description of the Norwegian science curriculum, Hill upper secondary school, the science practice and students as well as Ellen's (teacher) verbalizing of some aspects of this practice. Students do not exist in a void, so I give a brief review of literature on being a young person in contemporary Norway. The purpose of this literature section is to furnish a background to interpret the students' actions and I seek to make an impression that the students in this class are quite 'ordinary'. A literature review on Norwegian school science is also provided. The purpose of this is to establish that the practice that is focused upon in this thesis is not very extraordinary in a Norwegian context. There will be a short discussion at the end of the chapter where I bring together the main points from practice and literature and formulate some of the questions this practice left me with after the fieldwork ended.

Practice is temporarily defined as what students and the teacher do (together) in the classroom. The 'doing' is seen as a result of rational choices made in the situations. The term practice will be further elaborated upon in section 5.2.1. The political side of the school system is not dealt with, nor is school management.

The overall purposes of this chapter are to elucidate the problem area and to discuss the backdrop for the cases presented in chapters 6-8, as well as provide an input to the final discussion in chapter 11. However, this chapter also serves as a welcome to school science. Welcome!

## 3.1. Norwegian science curriculum

As these students have been in school under two major curriculum reforms there is a need to describe the reforms and the impact they have had on school structure and content before proceeding to describe the contemporary general science curriculum.

Two curriculum reforms have had direct impacts on the science subject as it is today. First, there was a reform in upper secondary school in 1994 (Reform 94). This reform was a major structural change of the upper secondary school system. It provided all students with a right to go to upper secondary school albeit not necessarily for the line of study they primarily wanted. To some students, general studies might be what you do if you are not sure what you want to do. It can be claimed that there are 12 years of compulsory school in Norway, as there are few choices for those who do not want to continue in the school system. Another aspect of the structural reform was a simplification of the introductory courses, as the number of different courses was reduced. In general studies, this change was not very noticeable as the structure remained much the same. A new national curriculum was made with emphasis on student active methods for teaching and learning (Klette, 2004). The core curriculum was kept when the next curriculum was implemented in 2006, 'The knowledge promotion'. The core curriculum deals with the major objectives of Norwegian education.

There are some vital aspects of 'The knowledge promotion' that needs a review. First, it introduced a linear approach to subject matter, while all earlier curricula had a spiral approach to subject matter. It is expected that the subject matter the students worked with in lower classes is usable knowledge for later stages of their education, perhaps after a short repetition. Second, the competence aims are explicit in the sense that they emphasize the verb (the form of understanding that is required) but the entity (what to be worked with) is fairly open for interpretation. I will come back to interpretation of curriculum in the presentation of the three cases. Third, 'The knowledge promotion' leaves decisions on methods for teaching to the teacher and school. So one may say that this curriculum provide a larger opportunity for teachers to decide how to teach, while the outcome of what is taught is restricted or made clearer (word choice depends on how you look at it) compared to the previous curriculum. Fourth, this curriculum emphasizes basic skills (reading, writing, oral presentation, numeracy (basic mathematics) and ICT). These are to be incorporated in every subject. In the subject specific curriculum these skills are concretized in the context of the subject.

The curriculum gives guidelines for teaching hours and there is a locally prepared oral examination with practical elements that are graded locally.
The objectives for school science (all levels) formulate a stance to school science (Utdanningsdirektoratet, 2006).

> Natural science is the result of human curiosity and our need to find answers to questions about our existence, life and life forms, and our place in nature and the universe, and in this way it becomes part of our culture.
>
> The laws and theories of natural science are models of a complex reality, and these models are changed or developed through new observations, experiments and ideas. In our general knowledge it is important to realise that natural science is developing, and that research and new knowledge in natural science and technology have great importance for societal development and the environment in which we live.

Further, the objective to learn science in school is stated as

> Knowledge on, understanding of and experiences in nature can strengthen the will to protect natural resources, preserve biological diversity and contribute to sustainable development.
>
> Natural science shall also help children and young persons attain knowledge and form attitudes that will give them a considered view of the interaction between nature, individuals, technology, society and research. This is important for the possibilities the individual has to understand various types of natural science and technological information and shall give one the basis for participation in democratic processes in society.

It is also made explicit that school science is both to prepare for further studies as well as life-long learning both in work and leisure. The objectives also say something for which values school science aims:

> Practical and theoretical work in laboratories and in the field using different theses and research questions is necessary to gain experience with and develop knowledge of the

methods and approaches in natural science. This may contribute to developing creativity, the critical eye, openness and active participation in situations involving natural science knowledge and expertise. Varied learning environments such as fieldwork in nature, experiments in the laboratory and excursions to museums, science centres and business enterprises/industries will enhance the teaching in natural science and impart a sense of wonder, inquisitiveness and fascination.

For each subject, basic skills are given. Also in science, these skills are to be incorporated into the subject matter, as they are part of what is seen as competence in the subject. The description of basic skills is presented before the actual competence aims, so how they are integrated in the everyday practice is partly up to the teacher's judgement and partly how each competence aim is formulated.

- Being able to express oneself orally and in writing. In science this means being able to write reports, formulate questions and hypothesis as well as being able to use scientific terms and so on, also:

  Arguing for one's own assessments and giving constructive feedback is important in the natural science subject.

- Being able to read is seen as being able to collect information, interpret and reflect upon it by the use of different sources (books, newspapers, internet, etc.) and different representations (e.g., tables and graphs)
- Numeracy in science is presented as using numbers and calculations, using (mathematical) models and  interpreting various types of data
- Being able to use digital tools is linked to tools for exploration, measurement, simulation as well as documentation.

One of the main competence areas is 'The budding researcher'. In the start of the curriculum (and thereby not directly related to upper secondary science), a stance to science as process is formulated:

There are two sides to the teaching of natural science: it is a product showing the knowledge we currently have, and it is a process consisting of natural science methodologies for developing knowledge. This involves the formulation of hypotheses, experimentation, systematic observations, openness, discussions, critical assessment, argumentation, grounds for conclusion and presentation. *The budding researcher* shall work with these dimensions of education.

(Utdanningsdirektoratet, 2006)

This objective can, of course, be discussed in relation to how school science is perceived in the science education community. I will return to this in chapter 10, Science and education.

The competence aims for 'The budding researcher' in the first year of upper secondary are:

*The aims for the education are that the pupil shall be able to*

- plan and carry out different types of investigations in cooperation with others where you identify variables, estimate uncertainties of measurements and assess possible sources of errors
- carry out and interpret animations og simmple computer simulations to illustrate natural phenomena and test hypotheses
- explain and assess what can be done to reduce uncertainties of measurements and avoid any possible source errors from measurements and results

- assess the quality of presentations of own and others observation data and interpretations

(Utdanningsdirektoratet, 2006, misspellings not corrected)

The other main subject areas in the science curriculum in the first year at upper secondary school are: Sustainable development; Nutrition and health; Radiation and radioactivity; Energy for the future; and Biotechnology. In these five main subject areas, there are 31 competence aims. Some of these aims are a 'compound', i.e., they contain more than one verb, e.g., 'carry out and explain'. Twenty aims refer to more than one entity, e.g., *"(assess important environmental aspects of) consumer choices, handling waste and using energy"* (Utdanningsdirektoratet, 2006). Consumer choices and handling waste is seen as different entities, although there might be some overlap when it comes to assessing them. The verbs in each competence aim specify what the student should be able to do. One way to obtain an overview of what is required of students and teacher is counting the verbs.

| Verb | Frequency |
|---|---|
| Describe | 6 |
| Provide/give examples/overview | 3 |
| Elaborate | 11 |
| Examine | 1 |
| Carry out/make (practical work) | 5 |
| Explain | 12 |
| Assess | 4 |
| Discuss | 2 |
| Analyse | 1 |

**Table 2: Verbs in the science curriculum**

The curriculum states that the subject contains 140 hours during the school year. In reality, some of these hours will be lost for teaching because of tests, exams and extra-curricular activities such as, e.g., winter-sport day. To sum up, there are 51 verbs including those in 'the budding researcher', 34 of these are connected to more than one entity. Many aims also require an understanding of underlying terms such as, e.g., atoms and ions for explaining redox reactions.

## 3.2.Being a student in Norway

Students do not exist only in school: they live in a society. Although I did not explicitly address students' life outside school during my fieldwork, I think it is important to include some perspectives on what it means to be a young person in Norway.

School has a more important role to play in young peoples' life than before. Not only do they stay in school for a longer period of their life, but school is also 'the ticket' into society. Until the 1980s, it was possible to start in a regular job at 16. Not so today. This means that students (especially boys) who are tired of school, and stand at risk of failing or falling out of school, are more likely to be marginalized as grown-ups (Frønes & Strømme, 2010). The completion rate for boys in general studies after five years is approximately 80%, for girls it is somewhat higher (OECD, 2011). Girls do better in school than boys, and are thus less likely to be marginalized (Frønes & Strømme, 2010).  An evaluation report of the current curriculum indicates that there are increasing differences in learning outcome between students, measured by final grades in secondary school. Students who come from families with higher socio-economic status perform increasingly better than their peers who come from families with less income and lower educational levels (Bakken & Elstad, 2012).

Norwegian students have many choices on what to become. However, making choices and staying on the decision requires a plan, and this involves self-discipline. This is opposed to the area of manual labour where work colleagues would shape your action and attitudes (Frønes & Strømme, 2010). In a study by Elstad and Turmo (2007), girls tend to have more self-discipline than boys in science.

In the Norwegian debate about school and education, there is a mix-up of the terms 'education' and 'competence'. This leads to an idea that you have to have a long education to get competent (Frønes, 2011). Upper secondary school is perceived as part of the primary education system, even if it is 'voluntary'. This allows some challenges that were not there when upper secondary school (general studies) was part of the elite education system. This challenge consists of providing support to those students who need more help to pass the subject and to those who are doing (really) well. The Norwegian school system seems to fail both these groups of students (ibid.).

The ideal of the Norwegian family is one of a democratic family, where all members are heard and can argue for their opinions, but the parents usually decide (Frønes, 2011). Norwegian parents spend quite a lot of time with their children, presumably more than they did in the 1960s. In addition, there is a strong emphasis on supporting the children in their development and in school. Here there appears to be a division among Norwegian parents. Those parents with a longer education themselves often encourage their children more and help them more in their schoolwork. This can also be seen among some ethnic minorities were parents have little formal education, but where education is an important mean to 'better oneself' (Frønes, 2011). Although there is a general approval of education among young people (Krange & Øia, 2005), not all parents support their children in the schoolwork. The democratic ideal is also part of school system, at least when it comes to the relations between teacher and students. The teacher no longer automatically has authority because of position, but through knowledge and personality (Frønes, 2011). Frønes (2011) claims that the Norwegian school is more oriented toward personal relationships rather than relations towards subject (knowledge). This he relates to the individualization in the relationships between student and teacher. Further, this can lead to an unclear view of the student's role, what the duties and rights of students are – what it means to be a student. This he claims will largely negatively affect those students who are vulnerable and most in need of a clear structure.

Everybody in Norway are (heavy) consumers, also its young people. Many students work part-time in addition to school to be able to afford the life-style they want to have. Whereas many activities were free of fees in 'the good old days', this is not so anymore. You just do not meet up at the corner to play ball anymore, you belong to a team, which costs a fee and then you have to pay for equipment (which is expensive), because you cannot just turn up in some old clothes... Artefacts and clothes provides signals for who we are, and young people are very conscious about sending the right signals (Bjurström, 2005), which is also in regard to the consumption of media (Frønes, 2011).

### 3.3. Description of Hill upper secondary school

The school, Hill upper secondary, is located in a suburban community near Oslo. There are several upper secondary schools in this area. These schools compete for students, so a popular school will get the academically interested students. At Hill, there are different departments and some vocational studies in addition to general studies. Hill is not the most popular school in the area so it attracts students with lower grades from secondary school, and of course also some students who live close by.

School management and staff were not part of my research interest, so I have no empirical material to support a description. This can of course be seen as a limitation because school management and professional knowledge, or the school 'culture' (Barnett & Hodson, 2001), have impacts on classroom practice.

Hill looked very much like any other school. It was easy to recognise as a school building by the rows of windows and the entrance where some students stood around during breaks. The surroundings were nice with trees and footpaths, so you hardly noticed the surrounding roads. Hill had a large entrance hall with staircases leading to the first floor and the hall had some tall coffee tables with bar stools. Sometimes you could see students sitting there talking, especially at breaks. Hill had, as do most other upper secondary schools a canteen where students could buy food, sweets and soft drinks. There was also a small library where students could find relevant literature for projects, as well as other literature such as comics. During science projects students often used the canteen or the library rather than the classroom. There were staff rooms, classrooms and rooms for specific purposes. Two of the rooms are important to describe, as they are the rooms where most of the teaching took place, the science lab and the classroom.

The entrance to the science lab was to the right and behind the board so the teacher could not see students (if she is standing by the board) before they were well into the room. The first objects that met the eye of the student were desks where students two by two could be seated. These desks were placed in twos or threes, so four or six students could sit beside each other. There were three rows of desks behind each other. This meant that there were more seats than students, so students could choose where to sit. All the desks and chairs were facing the board.

The students often arrived early to put away their stuff, to mark off their territory so to speak, and to be able to sit together with those they wanted to. Some of the boys tended to sit at the back. The next impression that met the eye was the 'science-ness' of the room, there was a ventilation cupboard, three sinks along one of the walls, an emergency shower, fire extinguisher and rows of cupboards. Most of the cupboards were empty and all of the scientific equipment was stored in the teachers' preparation room. There was a door into the preparation room on the right side of the science lab. In the preparation room there is a workbench that all science teachers could use as temporary storage. This sometimes made it a bit difficult to find chemicals or other equipment because it had 'vanished' into one of the other teacher's 'private' preparation space. Students were not 'allowed' into this room. This was never explicitly said but students never tried to get into the preparation room. It was a teacher space. This means that Ellen prepared all equipment in advance of practical work and she usually placed it on a trolley at the right side of the science lab. There was also a connecting door to the next classroom at the back of the room. Sometimes the next-door teacher popped in to ask Ellen a question. The science lab was equipped with a PC, a projector, speakers, smart board, screen and an overhead projector. This school year Ellen did not use the smart board, but she often used the computer and projector. The smart board was primarily used as a white board. In front of the board, there was a large teacher's desk on a small podium. The teacher's desk was 'nailed down' which made it suitable for demonstrations but, as it was quite large, it required that Ellen walked around it to be able to stand close to the class. From time to time, other science classes' project posters were seen on the walls. I never saw any students reading these posters.

This class had its own classroom where the students spent most of the week. There were just enough desks and chairs for the students, and they had no personal desk or place, at least not in science. Therefore, if they were late they had to sit wherever there was an available desk. Some students moved their desk closer to friends even if they arrived too late. The students were sitting in 'lumps', those who liked to work and talk together. In the front of the room, the teacher had a desk twice as big as the students', and the teacher's chair was of a better quality than the students' chairs. The classroom had a blackboard (green), a screen, a projector and speakers. Along one wall, there were windows that made the room seem light, especially as the walls were white. The walls were usually bare but sometimes posters from projects were hanging on the wall (not science projects).  The room had some, but not enough, power sockets and these were located around the walls so many students had to run the computer on the battery, which led students to exclaim: "*I have no more power*". There was also a row of lockers, and students often kept their science textbooks in them.

The science lab and the classroom were located on different floors. Students had to bring all their belongings with them when they relocated from classroom to science lab.

Because of the research project and Ellen's work situation, science was taught once a week, alternating for four or six school hours. So, I refer to these as science days. Lessons are the periods between breaks, officially 90 minutes, but often Ellen gave the students a short break mid-lesson.

Students worked on different tasks during the year. Here, 'task' means all teacher-initiated subject matter activities that students are supposed to do, also including practical work. The tasks can vary in length (time) and tasks can have different organization of students; group or individual or a combination of these. When the task has a group organization, the product students were supposed to create is a joint product/document. In other words, students may sit beside each other and talk, and this is not group work if they hand in individual products. The (supposed) outcome of tasks varied over a wide range of modalities and combinations of modalities.

## 3.4.The practice: Science and class

This section presents a description of the practice and an interpretation of how the students dealt with being students in science. The first part is descriptive and the account is based upon field-notes. The presented situations are chosen because they provide a 'look into' the regular practice. After observing this class for a year, there are many interesting 'stories' to tell. I have chosen three. Two of these are related to practical work and one to an open task the students did. The described situations are from early autumn to winter, and from the period before I started to gather material for the cases. They thus form a background for the cases. Since the 'look into' the practice, or the 'snap-shots', are based upon field-notes, there are few references to what students actually said during class and some references are to my own impressions and reflections on what I encountered in this class. The next part is a more systematic description and interpretation of the practice divided into themes, which are relevant for the discussion in chapter 11. Where I have exact wording or am using the interview, this will be referred to explicit. In addition, there is a literature review of research from (other) Norwegian classrooms. My purpose with this section is to show that what is going on in this classroom is likely to be quite 'normal', i.e., nothing exceptional.

There were approximately 20 students in this class and they were all approximately 16 years old. Some students moved to other schools during the autumn and some students were transferred from other schools/classes during the year. There was approximately an even division between girls and boys. Some of the students knew each other – but most of them were new to each other when the school year started. Students were given a computer (on loan) when they began in upper secondary (as are all other students in Norway). I started observation after the students had been at school for two weeks (start of September).

### 3.4.1. Snap-shots of students working with science

In this section I will present three ‘snap-shots’. They are ordered chronologically and are:

- Berit’s menu – an open literature inquiry in September/October
- Making facial cream – a practical work (recipe) in October
- Half-life – a practical work (simulation) in December

*Berit’s menu* (September)

This is a summary from field-notes taken September 8th, 15th and October 6th. As part of the topic nutrition and health, Ellen gave the students a relative open task (literature inquiry). This topic Ellen and I thought was a good start for students, as it ought to be highly relevant for the students’ life here and now and in the future. The task was to make a menu for Berit who had been ill for a period. Ellen had introduced proteins, fat, and carbohydrates on the board over several lessons. This had partly happened before I arrived and on September 8th fat was introduced. Students were introduced to an online table (September 15th), which showed nutritional values for different types of food. Students worked with this literature inquiry for two science days (September 15th and October 6th). They also completed other tasks on the topic during this period. The first day students worked with ‘Berit’s menu’, they were working in groups, organized by Ellen. Some of the students talked together and tried to find out what food to give Berit, whereas other groups scarcely talked together. To me it seemed they were working ‘in parallel’. Most students seemed engaged in doing the task but two or three students were openly (loudly) diverting the work or making unserious comments. The next science day the students were to finish the task individually and to hand it in on It’s Learning (the learning management system). Mostly students were working quietly, but they asked questions, e.g., what is the weight of a slice of bread? After some students had started to ask these questions other students suddenly understood that you need to calculate the nutritional values, you cannot simply copy from the nutrition table. One of the boys said (under his breath) “*Shit, this is stressing*.” (field-note October 6th.) Other students were also ‘grumbling’ because it was difficult. The perceived stress and ‘grumbling’ did not prevent some of the students to ‘dive into the computer’ to play games or visit social websites.

*Making facial cream* (October)

In this situation, from the beginning of October, the students were to make a facial cream (to make a cosmetic product was a competence aim). This is a summary from the field-note dated October 6th. It was after break and the students had moved from the classroom to the science lab. They were aware of that they were going to make a skin cream because Ellen had told them so in the introduction earlier. Ellen divided class into groups of 4-5 students, and she gave them a written recipe and talked for a short while using the board. The students were first to collaborate on making the basis of the skin cream and then do the rest individually. Ellen said that students had to assess how much of each ingredient they needed, as the recipe was only a guide, so they had to assess for themselves the consistency of the cream (e.g., how much water they needed). The product was to be placed in a plastic box and the students were meant to make a list of the ingredients on the lid. Ellen said she was going to assess two aspects, their product and how well they tidied up after themselves. Students were not supposed to hand in a report afterwards.

The students grouped together along the bench where there were power-sockets and sinks. They needed power-sockets for the hot plate. The rest of the students had to work on another bench at the back of the room where there was no sinks, and they also grouped together. I observed one group of students (four girls) more closely to see how they collaborated. There was a division of work between them, which meant that one of the students did practically nothing except for fetching a beaker with water. She and her friend (also in the group) sat talking off-task for a long time. She later asked me if she could take a break. When I replied that is not possible in the middle of a 'practical', she did not look very pleased by my response. A short while later she went to the toilet. It took some time before she was back. Her friend started to participate in the practical work when she had no one with whom to talk off-task. The two other girls took almost all the responsibility for making the basis of the cream. After they had finished the collaborative part of the 'practical', all four students made their own cream. When finished they did not tidy or put everything away, the hot plate was left on the bench and the bench looked a bit messy.

There were two other incidents during this practical work that are interesting. First, one of the students asked me how to use an analogue thermometer – "*which bit am I to stick into this?*" She was referring to the compound. Perhaps the student was making a joke, but thermometers might be difficult instruments, see also chapter 6 (Heat pump case). For the second incident, Ellen had by mistake taken out gelatine instead of baking soda (the packages look very much the same). One group of students had not read the label and were 'mildly annoyed' with Ellen because she had not given them the correct chemical.

All the students had finished by lunch. When the students came back after the break Ellen asked "*who have not washed their equipment?*" Some students had obviously 'washed' their beakers without using soap. Ellen also commented that some parts of the bench were messy. The students started (once more) to wash and tidy up. When they did so, I heard comments such as 'this is not mine' and 'I have done that so you can to the rest'. To me it seemed that many of the students were reluctant to do more than their share.

A reflection from the field-note this day:

> *The students seem to enjoy doing practical work, although they don't seem to think much about health and safety or use of equipment. Perhaps it is important to think about how the room should be used – the spacing of students.*
>
> *(field-note, October 6th)*

*Half-life simulation* (December)
I will provide a descriptive summary of another practical activity done December 1st. The practical activity was to throw dice in order to achieve a simulation of half-life. (Under the previous curriculum, this was a typical 'doing' for first year physics students in upper secondary school.) The class had worked for some time with artificial nuclear radiation and were now starting on natural nuclear reactions. Ellen talked for a brief time about half-life and she related this to carbon-dating. She also drew a half-life graph on the board and talked about having 100% matter in the beginning. One student then asked how one can know how much carbon-14 is left in the material and if it is totally random. Ellen replied by referring to the practical activity and by noting something such as: you need many throws and then it will 'even out' statistically. There was no written recipe or hand out.

The students were given dice. Ellen told the students that when the throw showed one, the nucleus had split. She made a table on the board and said that everybody was to throw their (10) dice eight times and they were to take out those which showed one, add together the rest in their group and make a note of how many remained. This number was to be inserted in the table on the board.

> The students spend a lot of time figuring out how to do this. They do not have paper and pen to make notes – so they have to throw 'simultaneously' and add up in the group. One of the groups is just fooling around … Ellen tell them to do this on the teacher's desk in the front.
>
> (field-note December 1st)

After all the groups had inserted their numbers in the table on the board, they made a graph in Excel. This took some time as the students were having trouble making the axes on the graph. Ellen talked to some of the students and her impression was that the students did understand and she was satisfied with the students converting numbers in the table to a graph i.e., between different forms of representation. I talked to some other students while they were working on their graphs. One said she did not know what 'one' on the dice meant so I tried to explain. I also asked a pair of boys how they could read half-life out of their (nice) graph. They did not know. I then asked what half-life meant and they had no reply (but when I asked what they thought of when they heard the word half-life there was a glow in their eyes and they figured out how to read the graph). The group I observed most closely did not hand in the report afterwards.

### 3.4.2. Thematic discussion of students working with science

In this section, I want to emphasize some aspects of teaching and learning in this class. In the interpretations and discussions, I will draw on the 'snap-shots' given above as well as corroborate these with other observations of the class and the interview with the group of students. The themes that structure the discussion are:

- Structuring and managing tasks
- Student collaboration

- Classroom dialogue
- Dealing with subject matter and resources for learning
- Doing practical work

These themes say something of how the teacher and students relate to each other and to science. The themes are entangled and thus not entirely separable. How students do their work and relate to subject matter will also impact the teacher's approach to students and taught subject matter.

#### *3.4.2.1. Structuring and managing tasks*

Some of the students' 'craving' for learning might be described as somewhat low. Ellen seldom directly approached those students not doing anything. This did not change much during the year. My impression was that if the task became difficult or unmanageable for the students they easily became distracted. Unmanageable could mean that the task would be 'big' and they had to work for a (long) time on it, i.e., a problem of structuring the time. If students had, e.g., 40 minutes to do a task, some of the students would first spend time doing something else (playing games, etc.) before they started to do their task. Then they 'hurried down something'. However, not always. Many students did not hand in what they were supposed to. This had no formal consequence. Students probably knew there would be a final test at the end of the year if the teacher did not have sufficient information on which to assess them (Norwegian educational policy at the time).

As I see it in hindsight, the transition from one activity (e.g., the teacher presentation) to another (e.g., students doing a task) was 'critical', where some students easily 'faded out'. The most important source of distraction was the computer. Those who started the school year playing games (mainly boys) or using social web sites (mainly girls) continued to do so throughout the year. Students often small talked during lessons. Roughly half of the class was easily distracted in the start of the year and still was at the end of the year. In mid-October, Ellen watched my introduction on global warming. One of the things she observed was that some of the students drew their attention to the computer when the sound level rose (the rest of the class became less concentrated), but when the other students started to pay attention to the subject matter, students with 'their nose in the computer' were also attentive. Later in the year ($17^{th}$ of November), Ellen asked the students: "*what do you think about grown-ups using Facebook at work?*" One of the students promptly replied: "*They ought to get sacked*." Another student said: "*It's quite ok, as long as they do their job*." Ellen did not follow this up. Ellen was very conscious that the students were not to use the computer all the time. Sometimes she said "*just you sit and listen*" or she could say "*I want you to take notes on paper*". However, few students brought pen and paper with them to class so Ellen had to provide some. Many students had become reliant on the computer as the primary (only?) tool for their work.

In the interview, I asked the three students: "*Would you want to participate more in decisions about what is to happen in class, that is, how to work and what to work* *with?*" The three students agreed that they had sufficient influence on what to work with and how to do. Beatrice said: "*She (Ellen) knows exactly when to involve us, and when not to. That is good*." So according to these three students, Ellen had found the right level of student involvement in decision-making.

All in all, most of the students in this class were probably not very interested in science. In the interview, I asked the students "*Do you think you will need science in your future?*"

| | |
|---|---|
| Sheila: Det kommer an på hva du skal bli.<br>Ingrid: Når en skal lære barna sine å (ler)<br>Beatrice: For eksempel hvis du skal imponere sjefen på jobb<br>Sheila: Man kan jo få bruk for det, men jeg har ikke tenkt så veldig på at jeg kommer til å bruke det. Jeg vet ikke. | Sheila: It depends on what you are to do (work with).<br>Ingrid: When one shall teach ones children (laughs)<br>Beatrice: For instance if you are to impress the boss at work<br>Sheila: One might need it, but I have not thought very much on using it. I do not know. |

They couple the usefulness of school science with future work, helping their children with homework. However, it seemed not to be a question about which they had really thought much. After this, I asked a follow up question, if they thought they needed what they had learned in biotechnology. To this, they replied yes, this was important and school science equipped them so they could understand better. They did, however, not link this to a possibility to participate in decisions about future society.

Some of the students were very conscientious about their obligations as students, whereas others seemed to want the science subject to be 'easy'. In the interview Beatrice said something about this:

| | |
|---|---|
| Det er egentlig bare å ha en metode som gjør at alle syns det er gøy å lære, ikke sånn vanskelig å lære ting | Really, it is just to have a method that makes all think it is fun to learn, not that difficult to learn stuff |

To the students it seemed to be important that science was easy and fun.

##### *3.4.2.2. Student collaboration*

The collaborative skills obviously varied between the students, as some were often asking questions of other students and trying to reach agreement about what to do, whereas others primarily deployed a 'task-management' strategy by dividing tasks within the group. This did not change much throughout the year when the students got to know each other better. When the students in November had an oral group presentation on the topic radiation for medical use, it became very clear in the presentation that some of the groups had simply divided the task and did not know what the other group members were going to say. This pattern was repeated later in the school year, those who did not collaborate well in the autumn continued to divide tasks in March. Another aspect of student collaboration was, as it seemed to me, that if one student was 'taking charge' this meant that the others could 'fade out' of the activity (e.g. field-notes from February and March).

> *Once more one sees the collaboration – or the lack of such. Four students are sitting in a row. Two of them are talking together (on task). But to me it seems very unclear what the other two are contributing with.*
>
> *(Field-note, 09.02)*

However, this is not the whole picture. Some groups did talk about the questions and formulated common answers. Those students I followed are an example of a group that talked and discussed their tasks. Ellen very seldom intervened directly in how students collaborated. Ellen did sometimes encourage students to collaborate, but often in a general manner, e.g., 'it is important to talk together'.

The lack of collaborative skills that some of the students displayed is interesting, as the Norwegian school tradition has put much emphasis on working in groups. The previous curriculum, which these students had until they were approximately 10 years old, specifically mentioned projects and group work, but I never asked if the students were used to collaborating at primary and secondary school. One may speculate about whether this low ability to work together was because the students were not feeling emotionally secure in the group. Perhaps there was an element of competition that made the students unwilling to share information? Or perhaps because they were so focused on their own subject matter shortcomings that they felt they had little to contribute. If they regarded the subject matter as fixed and learning as the only outcome (and not also process) this might strengthen the students' feelings of falling short when it came to sharing knowledge or information. Perhaps they did not see their peers' contributions as a (possible) source of valuable learning. Another possible explanation is that dividing-tasks-style of management is very efficient. It produces the 'required' outcome (i.e., the product Ellen wanted) with minimum effort.

#### 3.4.2.3. Classroom dialogue

Students asked quite a lot of questions, and this surprised me when listening to the recordings, as I could not remember the many questions. In the full class, students mainly asked about practical things, e.g., "*what is written on the board?*", "*shall we take notes on this?*" There were few questions with direct subject matter relevance in whole class situations. Perhaps this should be surprising as many students did have problems with the subject matter. The lack of subject matter questions is also consistent with findings in PISA+ (Ødegaard & Arnesen, in progress). However, students did ask questions about science when they were talking directly to Ellen or me.

When Ellen presented something on the board or gave instructions, she frequently checked for the students' understanding by, e.g., asking 'okay?' I never heard students saying out loud that they did not understand even if they later had problems doing the task. This might of course be because the students themselves did not perceive this as a problem during the instruction. However, it might also be because saying aloud 'I don't understand' requires quite a lot of courage.

Ellen gave students tests (homework) on It's Learning (learning management system). The tests were often multiple choice or 'click on the correct part of the image'. These tests had a double function: to consolidate what was worked with the previous science day and to prepare for the next science day by activating previous knowledge. Some questions had answers that could be directly copied from the textbook, while others required that students found information on the Internet or other sources. Ellen often included some 'trick questions' so the students had to relate critically to the questions. Many of the students enjoyed the 'sport' of identifying 'trick questions'. The tests were usually read out aloud by one of the students at the beginning of the science day and then the rest of the students could give the correct answer. This created some talk among the students and Ellen. The questions were mostly factual and Ellen provided the correct answer if there was any doubt.

There were few whole-class discussions during this year. However, in the spring, connected to the topic heritage (biological or social), there was one. The students had first seen an episode of a television program about intelligence and heritage, which at the time was focused on all Norwegian media. Then they sorted some claims about genetics and heritage into 'true' or 'not true' and were asked to provide suppoert for why they had sorted this way. In the end of this, there was a whole-class discussion or summary. There were many silly statements and some boys were quite loud. I have written the following reflection in my field-notes:

> *It was not meant to be super-serious. (But) At the same time it is important to learn to listen to what other people say, that one speaks at the time as a part of learning to behave in discussions.* (field-note, April 13th)

Ellen made no attempt to sort the arguments and claims. However, relating to 'the unsure' in science is not easy for students or the teacher. This is what the next part discusses.

#### 3.4.2.4. Dealing with subject matter and resources for learning

Managing uncertainty in science tasks was problematic for most of the students. This is an excerpt from one of my field-notes in September:

> *It seems to me that the students have problems with open tasks where not all information is given, to think for themselves and to make approximations are obviously something they are unfamiliar with*.

Some weeks later, when the students were having a test on nutrition, there was some dissatisfaction among the students because the teaching on the topic had not been good enough, difficult concepts (e.g., fat, proteins and carbohydrates) were not sufficiently explained, and the textbook was not used (enough). Students felt unprepared for the test. Ellen listened to the students and replied that the topic was taught and she had given example test questions on It's Learning (learning management system). After a discussion with Ellen, the class took the test. Later in the autumn, one of the girls (who did quite well on tests) asked Ellen if the textbook could be used more. The textbook (Bønes & Fløttre, 2006) had primarily short response questions (half of the questions were pure recall). My interpretation was that the students were used to a textbook approach to science from their previous school experience. In other words, a subject that was organized through the textbook and required them to recall and answer short factual questions:

> *(To me) It seems that it is difficult for Ellen that the students want more textbook tasks, where they can answer by "copying some words from the book". That the students wish for a more factual (right answers) focus in the subject seems to be recurring today. Ellen thinks that the (text)book is too focused on details and not very well suited for these students – if they are to do rote learning the connections (the whole) will be lost.*
>
> *(field-note, 10.11)*

Sheila said something about using other means for learning rather than the textbook (interview in June):

| | |
|---|---|
| Det var en morsom måte – og litt vanskelig måte av og til fordi siden vi er så vant til boka. Vi har jo brukt boka i naturfag i flere år så det var litt uvant, men det *(Hun avbrytes)* | It was a fun way – and a bit difficult sometimes, because we are so very used to the (text)book. We have used the textbook in science for many years so it was unfamiliar – but it *(She is interrupted)* |

Ingrid and Beatrice agreed that it was more challenging, but more 'fun', to use other ways of presenting science. Beatrice had also a school history where the textbook was prominent. Ingrid did not say anything to contradict Sheila or Beatrice.

When the students in this class did experience 'another type' of school science, it perhaps made them feel unsure. What was to be expected? School science became, in Sheila's words, "*a bit difficult*". The subject and learning process became perhaps too diffuse and unmanageable for many students. Perhaps students had problems understanding the purpose of the tasks. Why do it like this? An approach to subject matter focused on a textbook need less explicit purposes as this was (is) the tradition.

During the year, the students worked with tasks that had differing degrees of openness; students could or could not decide what resources to use; subject matter as factual (i.e., the canon) or subject matter decisions partly left to students; in some tasks Ellen had specific structures for organizing the tasks, whereas in other tasks students could decide how they would organize their work. Towards the end of the school year, students had another attitude toward more open tasks or tasks that relied less upon the textbook. The last task they did, 'The Island', was a literature inquiry quite similar to Berit's menu. This task was only loosely connected to the textbook. 'The Island' met no opposition and the students seemed quite eager to do it. In the end of the year interview Sheila claimed that open tasks led to more 'learning'.

Most students seemed to perceive science as difficult. In the interview I asked the students what they or Ellen could have done so that the guidance Ellen gave would help the students more when making their products. Sheila replied that Ellen could have used simpler words. But Beatrice partly disagreed and said that Ellen often used quite simple words, but it was difficult to understand the topics. Further there was a general consent among the students that there was much information and they forgot what Ellen said.

The use of different representations in science, or the 'tools of the trade', especially those with mathematical connotations, were a problem for most of/all(?) students. Reading or making tables (on a computer or manually) was problematic, see also the case 'heat pump' (chapter 6.4.2). In the situation given above with 'Berit's menu', it became obvious that many students did not have the skills to perform simple ratio calculations. On the other hand, students did like tasks where they worked with pictures, although some did not enjoy drawing and felt that tasks such as making a cartoon (protein synthesis) were difficult because of that. During the year students made several presentations by using photo-stories and they used images downloaded from Internet sites.

I asked 'my group' of students about making multimedia presentations – and they began talking (interview June):

| | |
|---|---|
| S: det er en litt morsom – kul måte å lære på da, når vi får lov til å lage en sånn ting da. Det er litt morsommere da og da sitter vi ikke bare å leser<br>I (avbryter): En kan lage naturfag på en humoristisk måte (ler)<br>S (fortsetter på Idas): … som vi alltid pleier å gjøre<br>..<br>B: det er bare på grunn av metoden Ellen bruker for å lære oss på som jeg synes, eller før jeg byttet klasse liksom så syns jeg naturfag var, jeg syns fortsatt det, et er en av de eh-em fagene, men den andre klassen brukte veldig mye bok - det var veldig vanskelig fordi jeg – det er noen begreper jeg sliter med og jeg syns det var veldig sånn rart, men samtidig spennende når | S: It is a bit fun – cool way of learning, when we are allowed to make such stuff. It is a bit more fun and then we're not only sitting reading<br>I (interrupting): One can make science in a humorous way (laughs)<br>S (continues): …as we always do<br>..<br>B: It is just because of the methods Ellen uses to learn us that I think, or before I changed class then I taught science was one of the uh-um subjects, I still do, but the other class did use the (text)book a lot – that was very difficult – there are some concepts that I struggle with and I thought it was very odd, but at the same time very exiting when I started in Ellen's class … So she is a good – methods to learn stuff |

| | |
|---|---|
| jeg begynte i Ellen sin klasse …Så hun er flink -måte å lære ting på altså. | |

Although these students obviously enjoyed the use of multiple representations where they could use their creativity in the production, there were problems. One of the problems was related to the process of transduction – or 'translating' from one mode to another. This will be further described in the cases.

Interestingly, when Beatrice in the interview claimed: "*science is a creative subject – even if it is very much (to learn)*", Ingrid and Sheila disagreed. "*(It is) Really not (creative). It is just us that have had (trails off)*." These students did not perceive science as creative as such, but the way they had worked with science in class provided more 'space' for creativity.

#### 3.4.2.5. Doing practical work

There are a number of interesting aspects that can be discussed regarding practical work in this science class. What is the learning outcome from practical work? What is the correct level of directing students? How interested are the students in doing practical work?

The two 'snap-shots' of practical work in section 3.4.1 intended very different learning outcomes. The main aspect in 'making facial cream' was to follow a procedure and enhance lab-skills, whereas in 'half-life' the simulation was meant to give an understanding of the term half-life. When making facial cream, it became obvious that the students were not used to practical work, so it was reasonable that Ellen emphasized procedure and tidying up. In spite of her emphasis on tidying it did not work too well in this situation. Later in the year tidying was no problem (or presented fewer problems). Even elementary lab skills must be learned.

In the 'half-life practical' students spent much time on deciding and figuring out what to do. Was this well spent time? Perhaps. Maybe it made students aware that they needed to pay more attention to the instructions and ask questions if something seemed unclear to them. When decisions are left to the students this can be a way of strengthening students' autonomy. On the other hand, as the point of this practical work was to make a joint table, it was important that that all groups did some parts of procedure exactly the same (the repetition of the sequence: throw – take out the 'split-atom' dice – count the rest – and make a note of that count). If some groups did not do this, the simulation would 'fail'. If it failed it could of course have been made a subject for a discussion of methods. In my field-notes, I have not written down any episodes where the class was engaged in a discussion about methods or methodological problems.

In the 'making facial cream' situation, the students had a written recipe to guide them, and they used it frequently by asking questions such as 'where are we now?'. Students became unsure when the instructions were not explicit enough and it was Ellen's 'fault' that the students did not read 'gelatine' on the package label. They made the assumption that they could rely entirely on the teacher and thereby there was little need for them to assess (think?) for themselves.

In the interview I had with the group of students at the end of the year, they were well aware of some of the problems in doing practical work. In the interview, I linked their view on practical work to the heat pump practical (chapter 6). (Ingrid and Sheila are at times finishing each other's sentences.)

| | |
|---|---|
| G: hva syns dere egentlig om å gjøre forsøk i naturfag?<br>S: det er gøy, men noen ganger kan det være vanskelig å forstå…<br>I: hva man skal gjøre<br>S: hva man skal gjøre og sånt, men vi skjønner det alltid til slutt da, så…<br>G: Hvorfor kan det være vanskelig å forstå hva dere skal gjøre<br>I: Man ikke skjønner helt hva det dreier seg om, om det man skal gjøre (ler) 'og nå skal dere ha forsøk'<br>S: Kanskje vi tenker at det er veldig komplisert, selv om det ikke er det så veldig komplisert som vi tenker.<br>G: hvis dere nå kunne – vidundermidlet – gi meg et tips hva kunne gjøre det lettere å forstå det dere skal gjøre<br>B: Bilde av ting<br>S: bilde Ellen kunne vise oss<br>I: Forklaring på barnehagemetode – hva som egentlig skjer, ja | G: What do you really think about doing practical work in science?<br>S: It is fun, but sometimes it can be difficult to understand..<br>I: what one is supposed to do<br>S: what to do and so, but we always understand it in the end<br>G: Why might it be difficult to understand what to do<br>I: One doesn't understand completely what it is about, of that which one shall do (laughs) 'and now you are going to have a practical'<br>S: Perhaps we are thinking it's too complicated, even if it's not that complicated as we think<br>G: If you could – the wonder cure – give me a tip what might make it more easy to understand what you are to do<br>B: picture of things<br>S: picture Ellen could show us<br>I: explanation in a kindergarden way – what really is happening, yes |

My interpretation of what the students said is that they did not always understand what the practical work was about. I think the students are both referring to the missing purpose of the practical work and understanding the procedure. Ingrid's last statement can also be interpreted in a direction of the problem of liking results/observation and explanation. When the purpose is unclear, the instructions might seem 'meaningless' to students who do not have the teacher's understanding of subject matter or scientific procedures.

Although some of the students had poor laboratory skills, such as tiding up or health and safety matters, there was more smiling and animated talk amongst students while they were doing practical work. This class liked to do practical work. Most students were 'serious' and did what they should, whereas a few 'fooled around' and some did not participate in a more quiet way. Did some of the students regard practical work as a 'free-time' where it was ok not to do anything (much)?

In any class, the learning outcome will vary between students. So, who the teacher talks with during the practical work is important for the teacher's opinion on how well it goes. In 'half-life', Ellen and I talked with different students and we thus made different impressions of how much students had 'learned'. (It was merely a coincidence that Ellen talked with those who 'understood' and I with those who did not.) But what does it mean to understand? In the 'half-life' simulation, many of the students did manage to do the technical part, to produce a nice graph on the computer. However, could they use the graph to interpret results?

### 3.4.3. Summing up the practice

The students started at Hill upper secondary school when they were approximately 16 years of age, and were mostly new to each other. Although they were very different persons, there were some common traits, such as few were interested in science and their subject matter knowledge from previous schooling was somewhat low. Students were easily distracted and had some problems staying on task. They were slow to begin tasks, they had strategies to minimize work, and they did not always hand in what they were supposed to. To me it seemed they had problems seeing the relevance of the subject matter, although in many situations Ellen tried to make the subject matter relevant by, e.g., assigning tasks that were connected to everyday experiences (but not always).

There were few/no disciplinary problems in class. The students were nice.

Approximately half of the students were good at collaborating, whereas the other half divided work and talked little of the subject matter with each other. Students in general did not pose subject matter questions in the full class, but they did ask subject matter questions directly to the teacher.

Students seemed to perceive science as difficult and they wanted, perhaps, teaching methods that made it easy to learn and were (more) fun. They seemed to be used to an approach to science based upon the textbook. Ellen did not want to use the textbook much and students worked with many different tasks representing the subject matter in multiple ways. Some of these tasks were process oriented, with the teacher providing feedback before the students handed in the final result. Students seemed to like the creativity that they could apply in making, e.g., cartons or writing on the wiki.

In practical work, the lab skills varied between the students at the start of the year. Most of the students seemed to enjoy practical work, although the meaning-making of the practical work seemed not to be focused and the students had some problems understanding the purpose of the practicals. Practical work was structured by a recipe that should be followed. There were at times implicit choices student would have to make, but there were very few explicit choices. There were not any whole class discussions on, e.g., methods and differing results.

My overall impression was that this was a practice that worked quite well under the given conditions.

### 3.4.4. Literature on Norwegian school science practice

Learning demand seems to be quite low in many Norwegian classrooms. In the PISA survey approximately one third (33%) of students answer that 'the students don't start working until a long time after the lesson has started' (Throndsen & Turmo, 2010). Although this was the students' response connected to Norwegian lessons, it is not unreasonable to believe that the situation is similar in science, as slow start on tasks might be understood as a form of resistance from students. PISA results indicate (student responses) that there is noise and disturbances during many lessons (39%) and one fourth of students think that 'students cannot work properly' (24%) (lessons in Norwegian). Approximately two thirds (66%) of students also respond that 'the science teacher has high aspirations for students' and 76% of students respond that 'the science teacher encourages students to work a lot' (Throndsen & Turmo, 2010). In the PISA+ study, students (a total of 69 grade 9 students) were interviewed after science class. Among the questions asked students was 'What did you learn this lesson?' Most students responded that they had learned something new but most were not very explicit about what they had learned (Arnesen, in progress). This might be due to the lack of summarizing by the end of lessons or connecting lesson content to previous lessons (ibid.).

Students' learning strategies are important to how they understand their learning, and if they have poor strategies for learning they may attribute the lack of result to teaching, the teacher, test form or their own low ability. There is a real danger that they give up (Hopfenbeck, 2008). A survey of 500 16 year old students in science Elstad and Turmo (2007) found that girls more often use memorizing techniques in science, boys use more elaboration techniques. However, girls reported that they expected better results (grade). Perhaps this indicates that memorizing techniques are what are successful in many classrooms?

The use of textbook and short factual questions can be seen as a way of making the subject matter manageable for students. As a teaching strategy, this might be seen as suitable when students are lacking interest or previous knowledge required for the task (Mestad, 2009). In an interview study, Knain (2002, 2003) found that students in general studies in science (upper secondary school) were generally quite satisfied with their textbook. The six students he interviewed preferred the factual presentation of science and that history of science is not needed for students who are not going to study science. Referring to the general track science students, Knain writes "*these students talked about the textbook in terms of how effective it was for learning purposes at school*" (2002, p. 59).

According to Frønes (2011), there seems to be a different type of digital divide among young people. Previously the divide was connected to whether or not you had a computer. Now it seems to be connected to how you use the computer. The computer can be a very useful tool for organizing the learning work and to retrieve information from 'the net'. The reliance on traditional sources for information (teacher and textbook) has thus subsided. However, computers can also be used to playing games and visiting social web sites. Elstad and Turmo (2007) reported that girls seem to be more distracted by the computer than boys, or perhaps boys do not perceive that they are being distracted?

In the PISA + project, a video study of 45 lessons at six different secondary schools in Norway showed that much of the time was spent on teacher introduction (dialogic) and students' individual work to fulfil their individual task-plan (Ødegaard & Arnesen, 2010). So, perhaps students were not so used to collaboration as presupposed. As part of an evaluation of Reform 97 (the previous curriculum for compulsory school), 30 Norwegian classrooms (grades 1, 3, 6 and 9) were each observed for a week and different teaching methods were recorded (Klette, 2004). In this study, there are some interesting findings concerning the students' collaboration. In grade 9, approximately 10% of the time was spent on group work. Students' seating arrangements cannot be linked automatically to the way they work, i.e., students may sit in groups but work individually. Therefore, students' seating arrangement is very loosely linked to group work as a method of teaching and learning. Moreover, the teachers did individual supervision of students even if they were working on a group task, i.e., the teacher did not perceive the group as a learning community (Klette, 2004).

The PISA+ video-study indicates that 'science language' is used less than 20% of the time in teaching and learning activities. 'Science language' is defined as where students and/or the teacher use scientific concepts and language (descriptions, explanations and generalizations). The teachers seemed to choose an 'everyday form of language' in class, perhaps to make science easier for students (Ødegaard & Arnesen, in progress). This can be seen as the problem of translating from everyday terms to usable science terms.

In an evaluation study of the previous curriculum, few classes at level 7 used practical work 'often' or 'almost always', and most used practical work 'sometimes'. However, nearly all students and teachers wanted to do more practical work (Almendingen, Klepaker, & Tveita, 2003). As this was a questionnaire survey of 167 classes and their teachers, there are of course problems with how each individual interprets 'often' and 'sometimes', and there is some difference in the teachers and students' response (teachers mean that there are more practical work than students do). PISA + reports some of the same tendency. In their findings, approximately 10% of the time is used for practical work (Ødegaard & Arnesen, 2010). In addition, it is worth mentioning that if the teacher has a low competence in science, he or she seems to use less practical work (Almendingen et al., 2003) – albeit there are some secondary teachers with no/little education in science that frequently use practical work (ibid.).

Results from the PISA + video-study indicate that teachers do not necessarily use the potential of the practical work in conversations with students and, to a small extent, draw lines between practical work and textbook knowledge. Also, there seems to be emphasis on descriptions to the expense of explanations (Ødegaard & Arnesen, in progress). There are some problems as students see it, that sometimes the teacher has not or does not take the time required to answer students' questions (Ødegaard

& Arnesen, 2010). As students seem to be reluctant to ask subject matter questions in the whole class (Ødegaard & Arnesen, in progress), the teacher has to be beside their desk to get any questions.

Some students seem to enjoy practical work as the students can be active and some students even look at practical work as "*not having a lesson*" (Arnesen, in progress). In a study by Klepaker et al. (2007), they asked 12 year old students in 167 classes (questionnaire) how often various teaching methods occurred. The students also answered questions on what they liked to do, how they liked the subject and the teacher. Their findings made it possible to group the different classes into four clusters. The largest cluster was those classes who had a low level of 'student-active teaching practice'. Two clusters had high level 'student-active teaching practice', one with emphasis on practical work and the other on projects, role play, etc.

> The students state that teachers who allow more practical activities make science more interesting and the students also feel they learn more from these teachers (Klepaker et al., 2007, p. 54)

So, practical work might be perceived as interesting by students and they perceive they learn from doing it. But do they 'learn'?

PISA has correlated a construct value for practical work and students' scores. They found no correlation. The construct value is based upon three questions: how often students do practical work, draw conclusions from practical work and follow the teacher's instructions in practical work (Kjærnsli, 2007). This should mean that there is no direct connection between 'how well' a student performs and practical work. However, practical work comes in many varieties. If students are used to follow a recipe type of practical work and there is not much emphasis on meaning-making after the practical work, there is only to be expected that students do not 'learn' much. Findings from the PISA+ project indicate that a teacher spends a large amount of time organizing and generating interest for the practical work rather than giving students time to do the activity (Ødegaard & Arnesen, 2010). This may indicate that the teacher emphasizes procedural aspects of practical work and to lesser extent the students' meaning-making. In an older interview-based study, findings indicate that practical work is guided by step-by-step recipes, the 'cookbook' variant of practical work (Kind, 2003).

## 3.5. Teacher Ellen about practice and students

This section is a presentation of Ellen and what she said about students, teaching science and facilitating practical work. The teacher has an important role in the classroom as a facilitator and as the person who sets 'the standard' of what science is. It is therefore necessary to explore her stance and rationale for teaching science to these students.

The first part of the section is a presentation of Ellen's stance, mostly expressed with her own words. I will, to some extent impose my interpretations on Ellen's statements. However, I provide lengthy excerpts so Ellen's voice can be heard. Of course, I have chosen these excerpts so my interest will be in the 'background'. The presented statements are drawn from our conversations in the period February to June. Statements made in one situation might be given another form and meaning in another situation (Kvale, 1996), thus the meaning is situated, see e.g., Gee (2008). For a teacher this can, among other things, imply that talking about practical work and teaching depends upon how one perceives the students (that day). In the last part of this section, I will, however, provide a short interpretation.

Part of the empirical material for this thesis is approximately 20 hours of audio recordings of interviews, planning and evaluation of lessons with Ellen. This provides a very rich material to draw from when presenting her and her stance in a few pages. It is quite a challenge to present a teacher's view of the practice of teaching science. The practice itself is complex and so is the teacher's notion of it (Barnett & Hodson, 2001). Often, when Ellen and I talk about teaching and learning, she gives examples from teaching or learning some other subject matter. This might also be a way for her of concretizing teaching and learning. Very often, her examples are from the subject in which she has a master degree, not this course - general science.

The audio material was transcribed. Some of the transcripts are 'rough', especially when the topic is 'pure' science. Then, it is given only a brief summary of the discussion in the transcript, e.g., when we are explaining a term or a process. Planning and evaluation is about subject matter *and* students *and* teaching. This generates a need to have some criteria for sorting and presenting statements from our talks. The transcripts were coded in four main categories. These categories are following Barnett and Hodson's model for pedagogical context knowledge (2001). Pedagogical context knowledge consists of four different forms of knowledge:

- Pedagogical content knowledge (PCK): this is knowledge about how to organize teaching; setting goals, how to present science content, how to carry out practical work etc. See also Schulman (1987).
  The teacher needs this knowledge to "*transform subject matter into forms that are more accessible to their students*."(Barnett & Hodson, 2001, p. 432)
- Classroom knowledge: this is a teacher's knowledge of students; how they work with tasks, their interaction with the teacher and each other, etc.
- Academic and research knowledge: this is 'formal' knowledge of science as well as an (perhaps more tacit) understanding of learning about science as well as knowledge about learning and teaching.
- Professional knowledge: This is a type of knowledge acquired through discussions with other teachers. It can consist of 'we do it like this- here' as well as useful tips no how to do something, e.g., how to handle an experiment that went wrong. This type of knowledge is based upon experience and sometimes it is counter to research in science teaching.

All these together make the knowledge base the teacher acts upon in the classroom. The following presentation will emphasize classroom knowledge and pedagogical content knowledge.

When selecting statements from the coded transcripts, I have used two criteria. First, I draw, to a large extent, from my interpretation of Ellen's stance in general. I have worked together with Ellen for two years; this means I know her practice quite well. I have tried to find statements that are 'representative' of Ellen. The process of selecting statements from such a large amount material is thus largely based upon my assessment of these statements in relation to my interpretation of her previous statements (not recorded) and to her practice in the classroom. Second, I have chosen to present contrastive statements that might provide a tension or create space for different interpretations. This criterion meets the situated and complex practice, as a teacher often does not just have one stance toward a multifaceted practice.

### 3.5.1. Academic and professional knowledge

Ellen is an experienced teacher, she has worked in upper secondary for 20 years and she knows Hill upper secondary well. She has a master degree in one of the science subjects, albeit physics is not really her strongest subject. During her time as a student or in her time as a teacher, Ellen has never had any formal introduction to history and philosophy of science. During her teacher training, epistemological aspects of science were not emphasized. Ellen has a great deal of competence as a teacher and she is eager to partake in development projects, to get new ideas for teaching and to enhance her understanding of the subject matter. This development attitude is perhaps not very common at Hill, and Ellen feels that she receives little support from school leadership towards professional development. The school initiated some projects, including teacher-peer observation and reflection, but they came to nothing. To me, it seemed that school leadership was not very interested in what went on inside the classroom walls as long as there were no formal complaints from students.

### 3.5.2. Classroom knowledge and relation to students

Developing good relations with students were/are very important to Ellen. She described some of the students in this class as "*tired of school*" (21.06 – in the evaluation of the year). In one of our talks in February (26th) she said:

| | |
|---|---|
| Jeg tror at mange av disse elevene har et negativt forhold til øvrigheta. Du kan lett komme på kant med dem | I think many of these students have problems with authority. You can easily fall out with them. |

When building relations to students, emotional security was important for Ellen, but this takes time to establish, as students were new to school, the teacher and each other. Ellen said it was important to make teaching and the subject matter structured for students (21.06 – evaluation of the year). However, she meant that building relations were slowed down or hindered by the fact that I was present, this created uncertainty and she did not develop the relation she wanted in the start of the year (21.06 – evaluation of the year). Ellen stated that creating a positive learning environment was important, but when I asked her what that meant, it was hard for Ellen to give a description:

| | |
|---|---|
| Det er nok enklere å se når det ikke er der, da holder de på med andre ting – det gjør de nå også, men jeg syns de har vært mer konsentrert på det de skulle gjort. | It is perhaps easier to see when it is not there. Then they do other things – that they do now also, but I think they have been more concentrated about what they should have done |

(Excerpt: 26.02, talking about practice and good teaching)

In December, Ellen had a short conversation with each of the students in the class (this was a requirement from school leadership). Ellen later said (evaluation in June) that this had been a good experience for her and for the students. She also said that she referred to this conversation later to many of the students. She expressed the importance for the students to be 'seen' in their dealings with subject matter.

In creating relations with students, one aspect is how to manage unwanted behaviour. A previous headmaster at Hill had emphasized strict rules. Ellen told me she had loyally followed this. The result, as she expressed it, was a bad relations with the students that year. She said in one of our conversations:

| | |
|---|---|
| Men jeg vet også at jeg er lite flink til å legge merke til hva de (elevene) holder på med og jeg vet også at jeg er lite flink til å kommentere uønska adferd. Det har noe med at jeg er slik jeg er. Jeg har prøvd noen ganger, men jeg blir bare sur, jeg har ikke den evnen der. Det er jo noe med at en prøver å utnytte sterke sider ved en selv. Jeg tror jeg er god til å få til dialog med elevene. | But I know that I'm not very good at perceiving what they (students) are doing and I know I'm not very good at commenting on unwanted behaviour. That's something about who I am. I have tried, but I only get sour, I don't possess that ability. It is something about taking advantage of strong sides with one's self. I think I'm good at getting a dialogue with the students. |

(Excerpt: 26.02, talking about practice and good teaching)

When we are talking about students' (failing) learning outcome, Ellen said:

| | |
|---|---|
| Vi (lærere) har veldig lett for å legge skylda på elevene på veldig mange ting. Det syns jeg er litt ugreit. | We (teachers) very easily put the blame on students for a lot of stuff. This I think is a bit problematic. |

(Excerpt: 26.02, talking about practice and good teaching)

This can be related to her view of teaching, see below.

In the evaluation in June she emphasized the importance of providing support structures for students in the beginning of the year. This structures were primarily to make the subject matter manageable for students. Making the subject matter manageable was important for her.

| | |
|---|---|
| Bare tenk på disse elevene – jeg mener du skal ikke gjøre mye før det blir for | Just think about these students – I mean that you shall not do much before it |

| | |
|---|---|
| mye | becomes too much |

(Excerpt: Planning 11.03)

### 3.5.3. Pedagogical content knowledge

Ellen had developed her teaching to include a wide range of different resources/products that students could work with; class wiki, cartoon, storyboard, writing essays, photo story presentation, sorting claims, concept maps, film (fiction and directly subject matter related), physical representation and of course practical work. Some tasks and activities were of a short duration, whereas others could be stretched over several science days. There was also 'traditional teaching' where Ellen presented the subject matter on the board and students took notes.

When talking about teaching:

| | |
|---|---|
| Gerd: når syns du undervisninga di er god? Hva er det som gjør den god?<br>Ellen: hva som gjør den god – det er jo den responsen du får fra elevene – jeg tror det stort sett dreier seg om det. Jeg er slik at jeg må ha respons for å kunne undervise.<br>Da er de med på det jeg holder på med | Gerd: When do you think your teaching is good? What makes it good?<br>Ellen: What makes it good – it is the response you get from students – I think that is what it is mostly about. I'm such that I need a response on my teaching. Then they are with me in what I'm doing |

(Excerpt: 26.02, talking about practice)

Ellen elaborated on this a bit further and said that good teaching was about making a clear path through the subject matter, from the simple to the more complicated. She contrasted this with an example of lectures where the lecturer was not interested in the response from the audience.

Finding the correct level when presenting something to students is difficult, in both subject matter choices and how to stage the presentation:

| | |
|---|---|
| Det er en ting jeg tror at vi gjør alt for mye feil. Vi snakker for fort, tanken vår er to setninger framfor det den skal si – og elevene er to setninger bak. Dermed så blir det ugreit. | It is one thing I believe we do wrong. We talk too fast, our thoughts are two sentences before what we are to say – and the students are two sentences behind. So, this becomes unsatisfactory. |

(Excerpt: 11.03 planning)

Here, Ellen comments on the problems of communicating the subject matter to the students. The different timing between her and the students become a hindrance in the communication.

To Ellen, there was a mismatch between the students' and the curriculum's approach to the subject matter. The curriculum has a linear approach to the subject matter. This means that which is taught previously is understood by students.

However, students' interest and what students actually bring with them into science class differ from the 'ideal state'. The linear principle in the curriculum was causing problems when students had few of the basic terms in science (21.06 evaluation of the year). Ellen further said:

| | |
|---|---|
| Så kommer kunnskapsløftet med fokus på fag. Og egentlig så tror jeg kunnskapsløftet hadde passet på elevgruppa som var før reform 94. Jeg tror ikke de har tatt inn over seg at det er en ny elevgruppe. Og det er helt riktig (som du sier) at det er fokus på fag og elevens prestasjoner er synonymt med lærers prestasjon | Then there was the launch of The knowledge promotion with focus on subject matter. And really I think The knowledge promotion would have suited the group of students previous to Reform 94. I don't think that they have contemplated that there is a new type of student. And it is correct (as you say) that there is a focus on subject matter and that students' achievement is synonymous with teacher performance |

(Excerpt: 21.06, evaluation of the year)

In Ellen's view, this curriculum would have been better suited when upper secondary was an elite education (before 1994). She stated that this implies an even greater importance of the teacher when it comes to conveying the subject matter. The teacher becomes a 'deliverer of the curriculum goods'. The exam at the end of the year regulated much of what happened in the classroom. Ellen saw it as important to prepare students for the exam. In a conversation (11.03) about solar cells, Ellen said this about why she had chosen to go so deep into the details:

| | |
|---|---|
| Jeg har undervist littegrann i forhold til en eventuell eksamen. Jeg bare tenker at hvis de kan referere en solcelle med et p-lag og et n-lag, med et hull som vandrer og et elektron som vandrer – tenk deg da i hvilken grad sensor blir imponert | I have taught a bit for a possible exam. I just think that if they can describe a solar cell with a p-layer and a n-layer with a hole wandering and an electron wandering – think to what degree a sensor will be impressed |

(Excerpt: 11.03, planning)

Concerning this focus on learning and exam, she later related (evaluation in June) to the incident where students had made an official complaint in the start of the school year that they felt they did not learn what they should. The students had felt unprepared for the first test (see also section 3.4.2.4). To meet the students half-way she focused more on structured explanations of subject matter - and facts.

In our conversations, she returned several times to the problem of conveying the big ideas in science to students. The subject matter has to be adjusted to the students, but then teaching and learning might become instrumental. It all becomes a matter of 'remembering 100 details'.

| | |
|---|---|
| Ellen: da blir man (jeg?) litt | Ellen: then you (I?) become a bit |

| | |
|---|---|
| instrumentalistisk og elevene blir veldig happy fordi at du klarer å få de til å gjøre dette her. Men jeg syns det er en litt ugrei situasjon.<br>…<br>Gerd: Noe av det jeg syns jeg hører du beskriver er ønsket om å få eleven til å oppleve mestring kanskje er på kollisjonskurs med de store ideene?<br>Ellen: ja, ikke sant, det er egentlig det jeg beskriver | instrumental and the students are very happy because you make them able to do this. But I think it is a bit difficult situation.<br>…<br>Gerd: What I think I hear in your descriptions is that your wish to make the students feel they master perhaps is on a colliding course with the big ideas?<br>Ellen: yes, that's what I'm really describing |

(Excerpt: 26.02, talking about practice)

When she perceived that the students lacked previous knowledge, Ellen wanted the students to feel that they have learned something even if it is more or less meaningless details. When we started talking about what could remedy this instrumental approach, we stated that time is an important factor and Ellen said that things would have improved if students did their homework.

Sometimes we did not agree on an approach to the subject matter, as the excerpt below shows. I had talked about the main principles in the heat pump, moving energy from one place to another because of the difference in temperature. Indirectly, I wanted Ellen to take this approach when explaining. She replied that this would be too 'airy' for students.

| | |
|---|---|
| Gerd: Åja, så du vil starte i detaljene og så bygge den store forklaringa?<br>Ellen: ja, jeg vil starte i det teoretiske<br>Gerd: jeg ville starte i det overordna teoretiske og så knytte på detaljene<br>Ellen: jeg vil gjerne ha det teoretiske først, de små detaljene og så komme med problemene for da kan det hende at de (elevene) klarer å være med, for hvis du tar det overordna så har de ikke snøring på hva de skal være med på<br>Gerd: det er greit, det er<br>Ellen: mitt valg | Gerd: So, you want to start in the details and then build the big explanation?<br>Ellen: yes, I will start with the theoretical<br>Gerd: I would have started in the theoretical principles and then combine it with the details.<br>Ellen: I really want to start with the theoretical first and then bring forth the problems then it is possible that they (students) are able to follow because if you take the principals then they have no idea what they are to join in on<br>Gerd: It's ok, it's<br>Ellen: my choice |

(Excerpt: 11.03, planning - how to explain practical work. The heat pump case, chapter 6.)

In this excerpt, it seemed that Ellen was thinking of each of the minor processes in the heat pump as theory and not the basic or main processes as theory. However, in a previous conversation, she stated:

| | |
|---|---|
| Selv om jeg har holdt på med den ene | Even if I have done this one chemical |

| | |
|---|---|
| kjemiske greia så har jeg alltid tenkt prinsippet. Hva er prinsippet for dette her? Når du har skjønt prinsippet i en galvanisk celle så kan du også si noe om andre galvaniske celler. Det er det som er min tankegang. Det er kanskje fordi dette er såpass enkelt – når vi holder på i kjemi så er det meninga at elevene skal lære seg prinsipper, men jeg er ikke sikker på om elevene lærer seg prinsippet – men bare detaljer. | thing I have always been thinking about the principle. What's the principle here? When you have understood the principle in a galvanic cell then you can say something about other galvanic cells. That is my perspective. It is perhaps because this is fairly simple – when we are doing chemistry then the point is that students learn some principles, but I'm not sure if students learn the principle – but only details. |

(Excerpt: 26.02, talking about practice related to previous topic redox reactions and batteries)

So, thinking about content and how to present it seems situated. It depends upon students and the topic. The physical principles in the heat pump were perhaps not tools for Ellen's thinking, whereas the principles in redox were. Once, I think, she became slightly provoked by my academic view of science and the, for me, important objective of explaining phenomena (solar cells) for students. She said:

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| Vet du hva, hva jeg ville sagt dersom det var noe viktig – hvordan skal du koble dette – hvor mye strøm får du ut av dette – hvor mye lys trenger du for å… Alle de tingene som går på de praktiske tingene. I stedet for konsentrer vi oss om slike tullegreier om oppbygninga av solcella – hvorfor gjøre vi det?<br><br>Du skal være litt på forklaring også, men hvis forklaringa er så komplisert at du havner bare på forklaring og ikke kommer til hverdagen – så blir naturfaget feil som allmennfag | You know, what I would say if there was something important – how do you wire this – how much current do you get from it – how much light do you need to… All those things which are practical. Instead we concentrate on such silly things as the inner construction of the solar cell – why do we do that?<br><br>You shall be a bit in explanations also, but if the explanation is so complicated that all you do is explaining and never approach the everyday – then science becomes all wrong as general science/science literacy[3] |

(Excerpt: 11.03, talking about practice and planning solar cells and heat pump)

My interpretation is that Ellen wanted a more practical science course where everyday utility would be central.

School science uses many terms. Many of the scientific terms have a precise definition within a science context, but perhaps another meaning outside of science (e.g., heat or energy). Science descriptions and explanations also strive for clarity and precision. In one of our talks, we talked about learning and related it to language and the importance of students using scientific words.

[3] There is not a good translation for 'allmennfag', which has its roots in the Bildung tradition.

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| Ellen: De har et lite eksakt språk, det er ikke noe rart heller de er ikke øvd opp i det heller<br>Gerd: kanskje et provoserende spørsmål, hvis man klarer å uttrykke seg et i et litt sånn cirka-språk – er ikke det godt nok?<br>Ellen: nei, det tror jeg ikke. Jeg tror det er litt av problemet – elevenes problem med å kunne uttrykke seg godt nok. (…) Det å øve seg i en presis måte å snakke på - den er ikke enkel. For spørsmålet er: øver du deg i å være presis når du gjentar det andre har skrevet? At det er det som blir det presise språket? – jeg tror ikke man får noe bevisst forhold til det før man blir eldre | Ellen: They have an imprecise language, that is not so strange, they are not practiced in doing it either<br>Gerd: perhaps a provoking question, if you make yourself understood in a kind of round-about language is that not good enough?<br>Ellen: No, I don't think so. I think that is part of the problem – the students' problem with expressing themselves satisfactory (…) To practice a precise way of talking – that is not simple. The question is: do you practice to be precise when you repeat what others have written? That is what becomes the precise language? – I don't think that one gets a conscious relation to it before one gets older |

(Excerpt: 11.03, talking about practice)

She developed her thoughts on being precise and how to practise this in teaching by relating to working with text processes. She further stated that she had not had the time this school year to go the required 'rounds' with students' texts. I added that it takes time to develop a precise way of talking and writing and that precision depends upon understanding of subject matter. Ellen replied "*Yes, but how you are to have a precise language when textbooks are not precise either?*"

*Practical work*
We were talking about providing students ready-made simple explanations of practical work. I asked the question if providing explanations to the students before they had tried to make their own might be pacifying. Ellen said:

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| Det er som du sier, at de ikke får svaret med en gang for da blir de veldig passive. Det er veldig passiviserende. Det er jo det som er litt av problemet med skolen, det er den passiviseringa som vi lærer de opp til, men samtidig er de ikke modne nok til å gjøre noe annet heller. | It is like you say, they (should) not be given the answer at once because then they get very passive. It is very pacifying. That is a part of the problem in school, we teach them to be passive, but at the same time they are not mature enough for anything else. |

(Excerpt: 11.03, talking about practice and planning heat pump)

The role of the procedure in relation to supporting the students' meaning-making was not very easy for Ellen to explain. She used an example from her own subject to explain what she meant. She said:

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| Jeg vil at selve prosedyren skal være grei. Hvis vi går gjennom prosedyren, men så må det kanskje være noe de kan undersøke litt selv (…) De skal ikke henge seg opp i sånne ting som egentlig ikke er det de holder på med – tror jeg | I want that the procedure itself to be easy. If we go through the procedure, but then it must perhaps be something they can investigate a bit for themselves (…) They shall not get caught up in things they are not really doing – I think |

(26.02 – we are talking about how to support students in the heat pump practical work)

In the evaluation of the project (21.06), we both agreed that the students liked to do practical work but that there were also problems. In the next excerpt, we are talking about the small practical work that was connected to the heat pump.

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| Ellen: du så jo forrige gang – det var jo et vanvittig enkelt forsøk – til og med dette her ble for komplisert. Så tenker jeg, hvis det her er en prosedyrebeskrivelse så følger de prosedyren og så slutter de å tenke. Jeg vet ikke hvorfor, men slik er det alltid. Og så tenker jeg at det å la det være litt kaos – det var litt kaos – men jeg tror de aller fleste kom i mål<br><br>Ellen: og så er det noe med å gå rundt å spørre undervegs – jeg var i alle fall borte hos noen grupper og spurte om hva som skjer og sånt noe – det tror jeg er viktig. Det er viktig at det ikke er for komplisert – det er i alle fall min formening om ting - og at man gjør et etterarbeid. Jeg tror etterarbeid er vel så viktig som forarbeid. Forarbeid er (for?) at eksperimentet skal gå fortest mulig. Og så skriver elevene rapport. Det er ikke sikkert de har skjønt så veldig mye av det. Jeg tror det etterarbeidet som vi har fokusert på er veldig viktig<br>…<br>Gerd: hva syns du er gode måter for etterarbeid?<br>Ellen: det å ta det opp i undervisninga slik vi skal gjøre nå med varmepumpe | Ellen: You saw last time – it was a ridiculously simple practical work – even this became too complicated. So I think, if there is a procedure recipe then they follow the procedure and stop thinking. I don't know why, but it is always like this. And then I think to let it be some chaos – it was a bit chaotic – but I think most of them managed<br><br>Ellen: And then it is something about walking around and asking during the practical. I was at least in some groups and asked about what happened and that stuff – that I think is important. It is important that it is not too complicated – that is at least my opinion - and to do post-practical work. I think post-practical work is more important than the pre-work. Pre-work is to make the experiment be as efficient as possible. And then the students write the report. It is not certain that they have understood very much. I think the post-practical work we have focused on is very important.<br>Gerd: What do you think are good methods for post-practical work?<br>Ellen: to take it up in the teaching like the way we are about to do in the heat pump |

(Excerpt context: 11.03, we are talking about the small 'practicals' connected to heat pump.)

Ellen did not seem to distinguish between simple to do and simple to explain in this excerpt. These practicals, which will be analysed and discussed thoroughly in chapter 6, were perhaps simple to do but they were far more difficult to explain. Ellen regarded the pre-work before the practical as a mean for the practical to run smoothly so it could be done without problems. The work done after the practical work was important to Ellen. Here she linked this post-practical to her teaching, i.e., to her upcoming presentation of the heat pump on the board. Later in the year, Ellen said she had put more emphasis on post-practical work than she had previously (21.06) and this became easier to do when the lessons were organized as science days. However, post-practical work is not always easy:

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| Gerd: ble oppsummeringen av øvelsene og det som var feil med de – ble det for mye sittende hos deg? Eller<br>Ellen: Jeg fikk det ikke ut. Jeg hadde følelsen av at dette fikk jeg ikke ut – det er jeg fullstendig klar over<br>Gerd: det er jo slikt som er et vanlig problem. Sett i etterkant hva kunne du tenkt deg å ha gjort annerledes?<br>Ellen: jeg lurer litt på om jeg i etterhånd – at jeg ser på det de leverer av rapporter og sier at – for her har jeg vært lite inne og veileda de undervegs mens de holdt på. | Gerd: the summing up of the practicals – and the problems they entailed – did it belong mostly just to you? Or..<br>Ellen: I didn't get it out. I had the feeling I didn't get it out – I'm well aware of it.<br>Gerd: This is a common problem. Seen in hindsight what could you think of doing differently?<br>Ellen: I think I afterwards will look at the reports they hand in – and tell that – because here I have not guided them much during their work. |

(Excerpt: 25.05, evaluating 'The budding researcher day')

In the evaluation of the project in June, I returned to discussing results and problems in practical work with students (excerpt is slightly shortened).

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| Gerd: for det er kanskje en ting som jeg ser i ettertid, de sekvensene i timene dine har blitt veldig korte; alternativer, det å diskutere feilkilder eller der ting er avvikende<br>Ellen: det har du litt rett i. Det du egentlig påpeker – er at man eventuelt kunne vært litt mer alternativ enn det man er … du har en sånn linet opp (plan) som du vet du skal gjennom fordi at det er tradisjonen … når du går inn i lærerrollen så har du med deg faget ditt som du ønsker å formidle og faget finner du ofte i ei lærebok ..og så har du en gruppe elever som skal ha undervisning. | Gerd: It is perhaps one thing I see in retrospect – those sequences in your lessons has been very short; alternatives, discussion of sources of error, or when things are deviating<br>Ellen: that's a bit right. What you really are pointing out is that you (I) could have been a bit more alternative…<br>You have a kind of lined up (plan) you know you have to go through, that is the tradition … when you enter the teacher role then you bring your subject with you want to present and the subject is found in the textbook and then you have a group of students which are to be taught. |

(Excerpt:21.06 evaluation of the year)

When Ellen explained why she had not dealt much with ‘problems’, such as deviating results, she calls upon tradition. The tradition she portrays is ‘teacher – the presenter’ and not ‘teacher – the discussion partner’. When dealing with sources of error, deviating results, etc. discussion is a ‘must’. Ellen further explains that this has never been a topic in her teacher education so she feels a bit left alone in doing this.

### 3.5.4. Summing up Ellen’s stance

To me it seems that Ellen would want another science course for the students. The present course would have been more fitting for the students in the old elite system, i.e., before the reform in ’94. Ellen would perhaps have put more emphasis on practical utility and less on academic explanations. This science course is at odds with these students. The problem can be linked to students not doing the work they have to do (e.g., homework) in order to learn. The students are passive but Ellen does not want to put the ‘blame’ on the students. The science curriculum has too many and too difficult themes. When she means that the students are satisfied with learning facts (only) or this is what is within the reach of the students, she settles for instrumentalism. However, Ellen sees clearly the problems of teaching atomized facts and she want to connect facts to overarching structures. When she spoke about the exam, she spoke about students able to retell details in an explanation, and that this will impress an external examiner. In my interpretation, a prospective exam reinforces the stance on learning atomized facts, at the expense of the major ideas. To make the science course manageable for students, Ellen portions out the subject matter, as she means these students need a structured approach to the subject matter. It can easily become too much for the students. I link this to her view of teacher performance as vital for students’ achievement. The teacher becomes greatly responsible for what the students learn. The teacher has to be aware of the pacing and the structuring of the subject matter so the students can ‘hang on’.

As I interpret Ellen, her relation with the students is most important. To her it is not an option to be very strict. She regards the students as tired of school and perhaps some have problems with authority. She avoids being a ‘nagging’ teacher. She wants to be a teacher with a good dialogue with the students. It is important for her to ‘have the students with her’ when she teaches. To me, it seems that Ellen to some extent regards the students as immature, e.g., precision in the use of terms and students’ passive attitude (they are used to being told). However, it also seems to me that Ellen has no explicit strategy to transfer responsibility to the students and thus ‘develop’ more mature students. There are, I think, aspects of teaching and learning that Ellen is unused to putting into words. I interpret Ellen’s stance toward teaching and the subject matter as things she controls in the classroom. For instance, she uses the word teaching often synonymously with presentations on the board (the use of ‘presentation on the board’ is non-existent).

To Ellen, the post-practical work has become more important during these two years. This must also be connected to the science days, which make it possible to have the summing up of practical work the same day as it is carried out. She is, however, not very comfortable with methodical discussions after practical work. This is to her 'outside' the textbook or transmission tradition (she has been brought up in). The pre-practical work (or introduction) Ellen sees as a means for the practical work to be carried out efficiently and it is important to her that the practical work is easy to do.

## 3.6. Summing up and brief discussion of this school science practice

When comparing this classroom practice to other research findings from Norwegian school science, it seems that this practice is just about 'normal'. The most unusual aspect of this practice is perhaps the small extent of textbook use and that the science course was organized in days (not lessons).

Students can be described as not very interested in school science. The students in the interview saw little relevance of the science subject. Perhaps one might even say that the students feel estranged in their relation to the subject matter. There were students in this class that might be categorized as potential school dropouts. Students with low grades, little interest in the subject matter and strategies to minimize work effort might end up in a downward spiral. Within the school system, they might be seen as vulnerable. With the increased attention to dropout rates, there is (political) pressure to keep the young in school, and that they pass. Ellen said that one easily can fall out with these students and she chooses not to 'nag' at their behaviour or their reluctance to work at times. This can be connected to the roles of teacher and students. It is seen as important that students 'can have their say' and social relationships are much valued (Frønes, 2011). It is perhaps a consequence of the democratic ideals and low social distance in contemporary Norway. In the interview, the students said that they had the appropriate amount of influence on what happened in science class. To Ellen, it is important to have a good dialogue with the students. As teacher and students are to work together, it is not unreasonable to put weight on a good relationship. But according to Frønes (2011), the orientation toward personal relationships are at the expense of subject matter.

How is school science adapted to ordinary but not very interested students? The science curriculum is compulsory for all Norwegian students and can thus claim by definition to be science for all. The curriculum objectives state that the subject "*shall give one the basis for participation in democratic processes in society*." (Utdanningsdirektoratet, 2006). The subject shall also prepare for future studies (in science). There is perhaps a conflict between an academically oriented science course and school science for those students who will not continue with further studies in science. The science curriculum choice of objectives and themes will be a starting point for the literature chapter on science and education (chapter 10) and the implications of the curriculum will be discussed in chapter 11.

Ellen's intentions are to make the subject matter structured and manageable for the students. She does this partly by 'building brick upon brick'. Ellen's statements indicate that she means the students do not have the background knowledge the curriculum presupposes. The curriculum contains many competence aims and many of these are on a low taxonomic level. The students indicate in the interview that there is a lot to remember – and they forget. All the ‘details’ to remember are perhaps part of making the subject ‘difficult’. In response, it seems that school, by focusing on recall questions in textbook (Knain, 2002), or teacher-led classroom dialogue (Mestad, 2009), strengthens the ‘detail’ approach. Perhaps this is why students (in the interview) state that science is not a creative subject. Ellen is aware of the dilemma between the ‘whole’ and ‘details’. However, as a part of making the subject matter structured for students and preparing students for a prospective exam, she often emphasizes details. To her the students seem to ‘like’ the instrumentalism connected to facts and practical work based on recipes.

In Norwegian schools, there appears to be a rather low demand for learning (Throndsen & Turmo, 2010). This might be connected to the findings in PISA + (Arnesen, in progress), where what is learned is not made explicit. In the practice of this classroom, students often worked with larger tasks (than the ones in the textbook). However, Ellen seldom intervened in students’ (collaborative) work processes. It was much up to the students on how to do the appointed task. At some incidents, Ellen facilitated students’ meta-reflection by asking them to write a log over ‘what I have learned’, however, this was not done systematically.

Students rarely ask subject matter questions in this science classroom, at least in full class. Some of the students also seem reluctant to collaborate on tasks. Talking science in class is thus mainly left to the teacher. According to findings in the PISA+ (Ødegaard & Arnesen, in progress), the ‘science language’ is not much used in the classroom and teachers seem to prefer an everyday language in class. In the interview, the students are a bit divided on the issue of Ellen’s use of ‘difficult words’. To Ellen, it seems to be important that the students are precise in their use of scientific terms, but she also regards students as immature and that precision is something one needs ‘age’ to see the necessity of. Ellen also raises the important question if rote learning (retell) of definitions is equal to precision.

Ellen facilitates the use of many different representations of science. Students (in interview) find this challenging but fun. In this way, science becomes a more creative subject. However, some of the traditional representational resources in science such as graphs and tables are undoubtedly a problem to many of the students.

Students like to do practical work in science. They perceive they learn (Klepaker et al., 2007) and it is almost like not having a lesson (Arnesen, in progress). In this class, students may move around the room and most of them (but not all) are active during practical work. Ellen introduces most of the practical works by giving a stepwise recipe. This recipe has, to her, the purpose of making the practical work run as efficient as possible. However, Ellen states that students tend to be mechanical about the procedure: “*I don’t know why, but it is always like this*.” However, I have no recording of Ellen trying to explain the ‘mind off’-effect of procedures in practical work.  Students do not always seem to understand the purpose of the practical work and how it is connected to the (other) subject matter. I interpret students in the interview that they perceive practical work both as difficult to do and difficult to make meaning from, although they are a bit 'hazy' on this point. Ellen is also a bit 'hazy' on the difference between 'do' and 'make meaning' when it comes to practical work. She connects her intentions of making the practical work easy with easy to do. The 'do' is given in the recipe. Moreover, she sees the post-practical work as important. She connects the post-practical or summary of practical she (at least partly) to her presentation on the board after students have carried out. Issues concerning procedure or methods are rarely if ever discussed in class. These types of discussions are to Ellen not part of the traditional teacher role in science.

This chapter will form a backdrop for the analysed cases of practical work and inquiry (chapters 6-8), as well as provide input to the final discussion in chapter 11.

After the ending of the fieldwork, this classroom practice in science left me with some questions:

- Is practical work connected to subject matter (theory)?
- Are there really so few references to methodological issues?
- Why this emphasis on recipes?
- Might this practice help students to be citizens that can draw upon their understanding of science and scientific methods when needed?

To construct a classroom practice is a joint venture among teacher and students. What counts as science is thus established through their practice.

> What counts as science education is not just science topics. It never has been, and, indeed, the content for any school or university course is never 'just the subject'. Implicit (and sometimes explicit) in the way the subject is taught are reasons or purposes for students to learn it – curricular contexts in which they are to understand the subject.
> (Roberts, 1988, p. 32)

So, what explicit and implicit messages are given in this practice?
In other words:

**How might this practice be understood?**

This is what the rest of the thesis is about.

# 4. REDEFINING THE PROJECT

Chapter 2 dealt with the research approach during the fieldwork. This chapter addresses research design *after* fieldwork. The transition from the initial approach to the research approach after the fieldwork requires explanation before the 'new' design is elaborated, and this is the issue of the first section. Then aim, research questions are presented as well as delimitation of this project. Next is a section that aims to clarify some core terms used in the research questions. Section 4.5 is about case studies and how the three cases were selected. At the end of this chapter, the question of quality in research is addressed. The issue of quality is important, but alas almost impossible to give a good answer. This leads to the last section where I try to identify some of the weaknesses and strengths of this project.

## 4.1. Explication for redefining the project

This project began as an action research project with the goal of implementing resources for learning that supported students' meaning-making in science (section 2.1). In the action research project, Ellen and I thought it important to make science relevant and meaningful for the students. In short, we had a 'science for all' perspective. The previous chapter dealt with an interpretation of what science in this class was. An important issue in this practice was the focus on *doing* practical work and the rather loose linking of doing and meaning-making. Making meaning seemed to be vague for students both in relation to science as product and to science as process. Process aspects of science were not discussed in class (see sections 3.4.3 and 3.6). The experience of the fieldwork left me with a need to understand what was going on in this science class. How could the practice be understood? Was the practice supporting the intended 'science for all'? In hindsight, I was not convinced. However, then, what is school science and what should it be? These are important but 'big' questions and in this thesis, the 'answer' is linked to students who are not very interested in science. This led to the fundamental question: What 'image' of science is and should be created through practical work and inquiry in school science?

I probably never would have noticed this as an important issue in this particular practice had I not had such a long and close-to practice fieldwork. The fieldwork thus created a need to explain the practice. One of the primary factors for the transition of interest was my research stay at the Institute of Education in London where I had Gunther Kress as supervisor. By watching some of my video material and asking questions, he provided a great deal of input in this process. He pointed me in direction of rhetorical framing and Bernstein's regulative and instructional discourses. These perspectives will be explored in the next chapter, chapter 5. These new perspectives meant that I left the rather technical approach to resources for learning, read new literature and reworked my own perspectives. As this was done without consulting Ellen, I can no longer claim that this is action research. This research project was not 'ours' anymore – it became mine. The research project was redefined with new research questions, a case study using multimodal discourse analysis. This is what this (and the next) chapter is about.

## 4.2. Aim of study

This study seeks to explore and explain how the communication between Ellen and her students generated a practice that gave primacy to *doing* practical work and inquiry at the expense of meaning-making and procedure discussions. Why does 'mostly doing' become rational in this practice? To explore and explain the communication in the classroom, I use rhetorical framing as an analytical term. School science is rhetorical. It involves choices of *what* subject matter to present and *how* to present it. These choices are political. School science cannot be 'neutral' as it conveys what is seen as worthwhile and thus provides a particular position/stance toward science. However, perhaps teacher and students represent science in a form that makes it seem as the subject matter is 'neutral'. Teacher and students jointly construct the rhetorical framing throughout the school year, although the teacher has the main responsibility as the person who sets the standard for how school science is communicated. The rhetorical framing is inferred from the norms that constitute practice, the physical surroundings, resources and the curriculum (formal and operationalized) that provides possibilities as well as constraints for the practice. The rhetorical framing is seen as semi-stable and bound to context. Students and teacher might change their interest and expectations, and curriculum content and the resources will change from situation to situation.

I will use the term 'rhetorical framing approximately as Selander and Kress (2010) use 'framing', although I perhaps put more weight on the political aspects of communication and I see rhetorical framing as a 'device' for looking into how social relations, resources and subject matter are put into play in the actual situations. For a more thorough description of rhetorical framing, see section 5.5.

**The aim of this thesis is to explore and explain how rhetorical framing of practical work and inquiry in this science class realize learning science, doing science and learning *about* science in a 'science for all' perspective.**

The simplified version of the aim is to explore what 'image' of science is communicated through practical work and inquiry and explain why it is like this.

The purpose of this thesis is to understand the rationale for the practice. To change practice and the norms constituting the practice, it is necessary to obtain a fuller understanding of the practice. This means to make interpretations of the complex science classroom practice in order to "*make it possible to assist practitioners in changing practice and aid policy makers in setting a better policy*." (Anderson & Helms, 2001, p. 12). To understand a practice is vital if one seeks sustainable change.

## 4.3. Research questions

There are two main assumptions behind the research questions. The first assumption is that the communication between Ellen and her students generated this 'mostly do' practice. However, their communication on subject matter is made possible as well as restricted by their interest, expectations and other factors such as curriculum and the physical space.

Second, norms are embedded in speech and written language (Lemke, 1990), as well as actions. Thus, it is possible to infer the norms from speech, writing and actions. Norms are both that which is the normal practice – 'the practice as we do it' – and norms provide direction for practice – 'the practice as we believe it should be'. Norms and practice constitute each other; practice establishes norms and norms establish practice. Practices are social human action. Each individual has his or her agency, purpose and goal. The participants can influence what is done and what should be done. Norms functions as ideology in practice. This is more thoroughly dealt with in section 5.5.

The research questions are tied to the context of Norwegian upper secondary school and general science.

**How does the rhetorical framing of practical work and inquiry reflect 'science for all'?**

To be able to answer this question, the two following subordinate research questions are asked:

I. **What norms are embedded in the teacher's rhetorical framing of practical work and inquiry?**
II. **How do students adapt to and transform these norms in their practical work and inquiry?**

The primary research question is a how-question that is explanatory (Yin, 2009). It deals with rhetorical framing across three different cases separated in time and there are different subject matters and procedures in these cases. This calls for a cross-case discussion which seeks similarities and differences.

The two subordinate questions seek to explore the practice as it is. The first of these has a teacher's perspective and the analysis is based upon teacher introduction of the practical work and inquiry. In the introduction, the teacher frames the inquiry for the students. This question will thus seek a description of the rhetorical framing and the norms embedded. The second question has a student perspective, as it seeks to describe the practice from the students' position. As the teacher directs the practical work and inquiry more or less directly, the students will have to deal with this direction/guiding. That is, over an amount of time the students will have an impact on how the teacher does her introductions and thus how she frames the practical work. However, in each of the particular situations, the students have little direct impact on the framing.

The two subordinate questions will be answered in chapter 9 while the primary research question will be discussed in chapter 11.

Neither norms nor rhetorical framing are directly observable in the empirical material. However, I base this work on the assumption that norms are embedded in speech and action. In this case study, the unit of analysis is the physical and verbal actions during practical work and inquiry, where unit of analysis is the smallest possible unit of the phenomenon (Matusov, 2007). Physical actions are often in practical work and inquiry a way of making meaning by using props or instruments. In addition, the use of hands (gestures) might be a part of expressing subject matter. Verbal actions are in practical work often the spoken language and to some extent the written language. See also section 5.2.1 on semiotic actions. It becomes a problem when that which is analysed is treated as a self-contained and isolated whole, also called horizontal reductionism (Matusov, 2007). In this study, I have tried to avoid horizontal reductionism by not treating the participants' actions as isolated. The actions are connected to each other in a social practice. To avoid horizontal reductionism analysis has to be related to other processes that are occurring. This can be done by seeing human activity as processes on different planes (e.g., personal, interpersonal and community processes) that are connected and mutually constitute each other. In analysis, there is a focus upon one of the planes while the others are in the background, and during analysis the focus may change between the planes (Rogoff, 1995). Rogoff's notion of foreground and background planes can be compared to the notion of text vs. context in discourse analysis, see section 5.6.

Research questions focus that which is under study. There are some parts of the practice that are backgounded or not dealt with at all. What this thesis has *not* foregrounded are:

- Affective aspects of practical work will be dealt with only briefly. Students' emotions in practical work and inquiry are backgrounded.
- Student-student relation is superficially deal with.
- Learning outcome in a traditional sense. There will not be any emphasis on whether students learned the heat pump and DNA coding or not.
- Assessment as a tool for directing and regulating learning.
- Students and teacher's espoused beliefs about the nature of science. There is no interview or survey material on their stance on this matter.
- Efficiency in teaching and learning.
- The influence from school 'culture' or what might be called professional knowledge (Barnett & Hodson, 2001) on the teacher's choice of action.

The limitations given above can be linked to the critique of this study, see section 4.6.1, as there are vital aspects of the practice that are left out. However, there is a need to delimitate the research field, which is a considerable challenge in studies of educational settings, as 'everything is connected to everything'.

## 4.4. A very brief introduction to school science

This section provides a very brief account of school science to ease the reading of the cases and to give some background for the research questions. School science will be more thoroughly addressed in chapter 10.

### 4.4.1. School science (for all)

General science is for all students in upper secondary (vocational studies have a lesser version of the curriculum and fewer teaching hours). This means that general science in Norway is supposed to be 'science for all'.

'Science for all' rests on a belief that meaningful learning of science can be extended to all (Smith & Gunstone, 2009). 'Science for all' might be linked to a vision of science literacy which emphasizes science for citizenry (Roberts, 2007), opposed to science for the elite (only) and science education solely on the terms of 'real science'. There is a connection between science for all (citizens) and Bildung (Fensham, 2002). In the Bildung-tradition, responsible action, critical awareness and solidarity are important values (Werler, 2010), which are seen as transcending subject matter.

What school science is seen as gives implication for the chosen content and how it is presented, as well as the arguments for why to learn science in school. Science for citizenry emphasizes an ability to relate critically to science as opposed to uncritically (total acceptance or refutation). This requires some knowledge in and about science.

School science can be divided (analytically) into four parts (Hodson, 2009):

- Learning science: the product of science, its laws, theories and facts
- Doing science: practical work and inquiry
- Learning *about* science: epistemology and ontology of science, making the methods and language of science explicit. Learning *about* science also involves science as a social enterprise with its norms for discussion of findings and reporting. History of science is seen as an element of this.
- Science for socio-political action: to be able to use science as one of the elements for acting (e.g., decision making) in society.

Although school science draws heavily on 'real' science and its products and ways of knowing, school science cannot be 'real' science. The limitations in form of time, equipment and students' knowledge make this impossible. This means that there will always be political deliberation on what school science is to be. There will thus be a question of what is the 'good' or 'important' image of science that is to be reflected in school.

### 4.4.2. Practical work and inquiry

Practical work and inquiry are seen as an integral part of science (Duschl & Grandy, 2008; Hofstein & Kind, 2011). There is partial overlap between these two terms. Inquiry generally involves student-generated questions and a (student made) plan for the investigation. The investigation might be (partly) practical or based upon literature. The usual notion of practical work is that the teacher directs the work to a greater extent than for inquiries and that it involves some 'hands-on' activity (Millar, 2010). When a practical activity is strongly directed by the teacher it is often called 'lockstep' or 'recipe' practical work. If the teacher directs practical work to a lesser degree, it might be seen as an inquiry. In practical work and inquiry, the product and processes of science meet. The content (what to do) will provide some direction for processes (how to do). How explicitly these are linked in the teaching and learning situations is another matter. The purpose of practical work might be conceptual learning, learning practical skills or generating interest (Lunetta, Hofstein, & Clough, 2007). If the intended learning outcome of practical work is scientific terms, there will perhaps be less emphasis on reflection on procedure. However, in both practical work and inquiry there is a possibility to make learning *about* science explicit and, even if learning *about* science is not made explicit, it will be embedded in choices made in the situation (Roberts, 1988).

I adopt a multimodal approach to practical work and inquiry. Particularly, the modes of action (with props) and talk are important while doing and making meaning of practical work and inquiry. The multimodal approach provides implications for analysis, see section 5.6 for the overall analytical strategy and chapter 5 for analytical framework.

## 4.5.Case study

According to Yin (Yin, 2009), the scope of a case study is to:

> A case study is an empirical inquiry that
>
> - investigates a contemporary phenomenon in depth and within its real-life context, especially when
> - the boundaries between phenomenon and context is not clearly evident.
>
> (Yin, 2009, p. 18)

Yin continues, as there are more variables than data-points in a case study, the case study must rely upon multiple sources of evidence by using triangulation. The case study benefits from development of theoretical propositions to guide data collection and analysis (Yin, 2009). As the case usually focus on a complex phenomenon it is not possible to pinpoint the phenomenon exactly, and to some extent the phenomenon will remain undetermined and the 'evidence' inconclusive. This implies that it is hard to make generalizations from a case study (Thomas, 2011; Yin, 2009).

The case is not a method in itself, as a case study may apply a wide range of different methods, but the case provides focus on one phenomenon (Thomas, 2011), or the 'heart' of the study (Miles & Huberman, 1994). (Yin (2009) sees this differently as he states that the case is a research method.) The focus of study is a real-life phenomenon that is embedded in a context. This means that also context has to be accounted for. To define the focus, there is a need to establish the boundaries of the case (Miles & Huberman, 1994; Thomas, 2011). In this thesis, the focus is practical work and inquiry that was carried out in an upper secondary school science class. Practical work and inquiry are delimited in time and physical space. The context is the science teaching and learning in this class. Moreover, education is bound to a cultural tradition, the 'wider world' outside the classroom. To some extent, the world outside the classroom was presented in the literature reviews in chapter 3. The problems of clear boundaries will be more explicitly dealt with in the next section and in the introduction of each case.

There are different types of case studies, ranging from single cases to multiple cases. A case study can also be nested (Thomas, 2011) or embedded (Yin, 2009), which means that there are case(s) within case. The advantage of single case studies is that it is possible to explore the phenomenon in depth and there is no confusion when reporting from the study, i.e., on which case results and arguments rely. Whereas the multiple case studies can become problematic to report from, they have the advantage that they add confidence to findings. The precision and stability of findings will increase (Miles & Huberman, 1994). In a multiple case study, each case must be analysed as if it was a single case before one can compare findings between cases (Thomas, 2011). When studying something in depth and in context, it limits the number of cases (Thomas, 2011). In this thesis, there are three cases each with a bit different approach to practical work and inquiry. Two of the cases are typical or traditional practical work activities in science classrooms (Hofstein & Kind, 2011), whereas the last can be categorized as a partly inquiry (Asay & Orgill, 2010).

A case study aims at describing, exploring, explaining or evaluating this phenomenon not as a singularity but as a part of a larger whole. The case study aims at holism according to Thomas (2011). In this thesis, the phenomenon is the practice of practical work and inquiry and I seek to explore and explain the practice of practical work and inquiry as part of the context, science in this class.

The critique of case studies has been put along different lines. First, there is a possible lack of rigour. A case study carried out in a sloppy manner is easily biased (Yin, 2009). The reasons for bias might be that not enough material is gathered to inspect the case properly or it might be that the researcher is 'jumping to conclusions' by not suspending judgement and finding possible rival explanations. To create a good case study, there is a need for extensive data material, which often is time-consuming to analyse (Yin, 2009), and this strains the researcher's ability to create connections in a large amount of material. Second, some critique has been directed at the problems of generalizing from case studies, as there is no way of performing a statistical generalization. On the other hand, there is much to be learned from an example (a case) (Flyvbjerg, 2001). The 'problem' of case studies is that it starts out in the social sphere which is changeable and there is no outside position, i.e., no neutral or objective stance (Flyvbjerg, 2001). This will be further addressed in the end of this chapter (4.6), where quality of research is considered.

### 4.5.1. Selecting cases

To summarize so far: This is a multiple case study consisting of three cases defined by practical work and inquiry in school science.

There are several reasons for choosing practical work and inquiry as the 'heart' of a study in science education. First, problems have been reported with the ways practical work has been conducted and thereby the learning outcome for students over a long time (Abrahams, 2009; Abrahams & Millar, 2008; Hodson, 1993b; Kind, 2003). The second reason is closely linked to the first. One could argue that if practical work and inquiry do not lead to the desired outcome one could stop doing it. But practical work and inquiry are integral parts of science and, therefore, should be part of science education (Hofstein & Lunetta, 2004), and there seems to be much potential for learning (e.g., argumentation and learning about science) in practical work situations (Duschl & Grandy, 2008; Hofstein & Kind, 2011). There are, in addition, two other reasons for my research interest. *StudentRsearch* focused on the combination of practical work and inquiry and basic skills. The last but perhaps most important reason, are my own observations during the first year in the field. During this year, I saw how students struggled with practical work and how to make meaning of it. It seemed that there was a 'hands-on, mind-off' attitude towards practical work.

To select cases, there are different strategies, from picking an extreme or unique case to selecting a case which is representative or occurring for a long time (Yin, 2009), or with maximum variation, or even convenience (amongst others) (Miles & Huberman, 1994). As this thesis has its starting point in a particular science class, there is no way of telling whether these cases are 'typical' or 'extreme'. Although, the subject matter are commonly found in school science. Moreover, in chapter 3, I attempted to show it as probable that the practice in this science class was 'normal' within a Norwegian context. However, as there are few in depth analyses of practical work and inquiry, I can only assume that this is quite typical practice. So, cases are selected on the basis of criteria (Miles & Huberman, 1994).
These criteria are:

- All cases involve a hands-on element i.e. the students do some practical activity
- This practical activity is video-filmed, focusing on how students manipulate the physical artefacts (hands and artefacts), see section 2.3.2
- The practical work or inquiry is also completed with a reasonable successful result, i.e., the students carried out the entire activity but did perhaps not hand in required products
- There is data material of teacher introduction to this practical activity

These criteria rule out some literature inquiries that the students did during the months of data collection, and also rule out a whole-class practical work (each group does a part of the practical, e.g., solar cell), as I have no data material for all groups. Lastly, the inquiry project UV-radiation that was never completed due to an overcast sky on science days.

### 4.5.2. Case boundary

Case boundary is not always easy to define. To some extent, there has to be a judgement about what is to be focused on in close-up analysis, and what is presented in the context of this practical work or inquiry. How the boundary of each case is set will be thoroughly dealt with in the start of each of the empirical chapters. Practical work and inquiry are in these cases, limited in space. They all are carried out within the school building, students did not, e.g., use the Internet to find information. The boundary in time is more diffuse. When does the practical activity start? When does the teacher's talk 'drift' into introduction of the practical work? When is the practical work finished? When students are finished carrying it out – or when they have written the report? Perhaps it should be regarded as finished when teacher has made the final summary? I have included what is clearly the teacher introduction and students carrying out the practical in the focused case (analysed in detail), whereas summing up and students' post-practical work are seen as part of context. Ideally, post-practical work should have been part of the detailed analysis, but there are constraints such as students did this after school, poor sound quality makes it impossible to achieve the required level of detail in transcriptions and reports are not handed in.

I will operate with three levels in this case study:

- the focused case – which will be analysed in detail
- its close context – which will be described by using excerpt from the data material
- and the context of science class over the school year to provide perspective to the three cases

This will be more thoroughly dealt with in the next chapter when method for analysis, multimodal discourse analysis, is presented.

## 4.6. Quality in research

Research in education seeks to describe, (and/or) explain and often to improve education. To achieve good quality in educational research is not easy, as the phenomenon under study most often (always?) is elusive and bound to context. What is considered as good educational research differs between the paradigms within which the research is conducted. Action research emphasizes that quality is linked to democracy and collaboration in all phases of the process, ethics and teacher as catalyst for change in classroom (Groundwater-Smith & Mockler, 2007), self-reflection and value-for-use (Elliott, 2007; Feldman, 2007). Action research has a 'bottom-up' approach to research, emphasizing the practice as the pivot point for doing the research, but this does not mean that action research not include transparency or that action research does not seek to establish argumentation for why changes work (Feldman, 2007). In an article by Tobin (2007), he discusses a 'top-down' approach to educational change, where educational science is to supply teachers with best practice based upon evidence of 'what works', i.e., evidence is often statistical generalizations or based on 'controlled experiments'. Teachers' professional judgements are then reduced to 'folk-wisdom' and they become executors of 'programs' (ibid.). This 'top-down' research eliminates the situatedness of educational practice – but it has 'rigour'.

This thesis is placed somewhere in between these two traditions of educational research in some respects. There is a great emphasize of context and to understand practice as bound to context, but the teacher and students are not part of developing the perspectives in this thesis. This leads to two problems related to the outcome of research, usefulness and generalisation. This thesis is not directly useful for Ellen or the students, non for the Norwegian school system for that matter. However, perhaps it can participate in helping to explain some/one of the questions that have riddled science education for so long. According to Oancea and Furlong, research need not so much to concentrate on actual impact, which is hard to assess in short term, but on its potential value to contributing to understanding (Oancea & Furlong, 2007). Hopefully, this thesis has some potential value by studying the problem from a new perspective. Whereas evidence-based research seeks statistical generalisation and action research wants to change situated practice, the case study is left without hope of statistical generalisation nor does it (directly) change practice. So, what type of knowledge can be drawn from a case study? First, social actions "*must be seen in relation to the particular*" (Flyvbjerg, 2001, p. 70) and case studies produces this type of context-dependent knowledge. This gives the 'power of the example' as a desirable output (ibid.) and we can use case studies to reflect upon and expand our understanding of a phenomena. Law (2004) uses the expression 'how far it can travel' to say something about how far in time and space social knowledge can go and still be regarded as relevant and understandable.

Traditionally, reliability and validity have been applied as terms to establish criteria for good research. There has been some dispute whereas these terms are good in relation to qualitative research, see e.g., Eneroth (1987). There are several different approaches to address quality in qualitative research. Gobo (2008) states that underlying the term reliability (or the accuracy of measuring instrument) is that the object of research does not change between two measurements. This is not so in social activities, although they might be relatively stable. However, from a practical point of view he further claims that in studies that continue for a prolonged time it is possible to correct initial misunderstandings and the participants get used to the researcher and this reduces the risk of intrusiveness (ibid.). The researcher acquires thus a thicker description of the activities. The activities are what the participants normally do. They are not 'pretending' in front of the researcher. As I stayed with this class for a year (almost all science lessons), they got used to my presence and I acquired insight into their usual daily school science practice.

Validity concerns the 'truth value' of the study. Do the findings make sense? Findings have to be credible and provide an authentic portrait of the phenomenon and inferences made (Miles & Huberman, 1994). This means validity concerns if the study design investigate what it is intended to investigate. Kvale (1996) presents this as the 'craftsmanship of research', continually questioning, interpreting and checking. To check means to scrutinize the material and interpretations for bias and if data and interpretations are plausible and credible. Further, he states that criteria for good craftsmanship are negotiated and established as part of an on-going discussion among researchers (ibid.).

Trustworthiness concerns the strength of warrants between research process and its representation of the world (Oancea & Furlong, 2007). This is fine as long as one remember that the researcher always has a perspective and that the statements about the world are mediated. The researcher is thus a producer of reality (Law, 2004). This leads to the next point, to make the research process (in all phases) visible. Making the process visible includes to make choices and assumptions clear (Oancea & Furlong, 2007). Or perhaps, clear enough as writing about all deliberations would be tiresome for the reader. To make researcher's stance clear is also a part of transparency (Thomas, 2011), see section 1.4. When it comes to interpretation and constructing arguments it is important that the most prominent underlying assumptions are made clear and that one suspend judgement which means that rivalling explanations are made explicit (Thomas, 2011). In writing there should be clarity in terms and sentences (I add – the underlying norms in the text).

### 4.6.1. Critique of this study; problems – and strengths(?)

As this began as an action research project and not as a case study, there are some problems.

The design was intended for another set of research questions (about the implementation of semiotic resources that supported students meaning-making in science). This made me focus on tasks in general, not particularly practical work and inquiry. In the original design, it was not seen as very important to have video footage of all teacher introductions. Another problem related to the shift in research focus is concerning the selection of cases. I would perhaps have made a different choice as to what cases and when during the school year I should have documented practical work/inquiry. In hindsight, it would have been very interesting to have a case from the beginning of the school year, to be able to see if the rhetorical framing of practical work was 'stable' already then.

In a case study, there is a need to have a solid theoretical foundation before entering the field (Yin, 2009), whereas this is not equally important in action research where the problems for the investigation are to emerge from the practice and practitioners' needs (Bradbury & Reason, 2001; Elliott, 1991). This means that I did not make a thorough theoretically stance before I started to gather data material. According to Yin (2009), it is important to make propositions before one starts 'playing' with the data material. In some ways, I can claim I made propositions as I used a long period to make sense of data material and find perspectives that could illuminate data. However, my hypotheses were often tacit and based upon the impressions made during fieldwork.

Another problem is connected to the 'failing' of action research. This is perhaps the most fundamental problem during the process of 'learning to be a researcher'. I can only blame my own ignorance. I was not aware of how rigorous one must plan for implementing new tools and how important it is to have clear standards of 'success'. This meant that I did not 'push' Ellen in the planning sessions to make her thoughts explicit about how she intended to do the implementations, and I offered too little concrete input. A consequence was that our talks about resources for learning were shallow, but we did talk a great deal and I think both of us learned much. To restate this problem, it was about managing a collaborative research process as well as my own learning process that became too difficult for me to handle. This problem has an ethical implication. I have broken my 'contract' with Ellen, as I have ended up with an approach far from the one with which I started. To mitigate this problem, I have talked to Ellen about my shift in perspective.

Yet another problem is that this study is 'big' in the sense that it covers many aspects of teaching and learning science. This has especially been a problem regarding what perspectives to leave out. For example, assessment is not an important issue in this thesis, although it is important in teaching-learning situations. Another problem with the many aspects is concerning literature. There is a vast amount of literature concerning practical work, inquiry, learning the subject matter of science and learning *about* science. This means that the literature has to be chosen somewhat eclectically. However, the approach of integrating many aspects of science teaching and learning might also be seen as a strength, as teaching and learning are taking place in a cooperation between students and the teacher, thus the need to see what is going on between them. Teaching and learning through practical work also involves more than just nature of science, skills or scientific concepts. Thus, I see it as important to relate the practical work to the context of teaching and learning science in this class in general. The underlying view is that communication about practical work and inquiry is context dependent. According to Kelly et al. (1998), this calls for a more ethnographic approach combined with discourse analysis. They further claim that this implies that there, at the outset of research, are not any 'fixed' categories to apply to the material – however, there should not be lack of theoretical perspectives to inform the research.

## 4.7. Summing up

This is a multiple case-study consisting of three cases. Cases are defined by practical work and inquiry in one general science class in upper secondary school. The data material to construct the cases was gathered by ethnographic methods during the school year 2009/10 (see section 2.3).

This case study aims to explore and explain the practice of practical work and inquiry. Norms and rhetorical framing are analytical tools used to explore and explain. The theoretical framework for rhetorical framing and norms, as well as the methods for analysis, are the issues of the next chapter.

# 5. FRAMEWORK AND METHOD FOR ANALYSIS

In the previous chapter, the research aim and questions were presented. This thesis seeks to explore and then explain how practical work and inquiry in school science are rhetorically framed. What 'image' of science is given through practical work and inquiry? In addition, how do students and the teacher relate to each other? Through rhetorical choices, something is regarded as 'proper' and 'right', while other aspects of practical work and inquiry are omitted or suppressed. An underlying assumption is that norms are expressed in communication. Norms are embedded in the rhetorical framing. However, neither rhetorical framing nor norms are directly observable. The purpose of this chapter is to establish the 'toolkit' that makes it possible to infer norms and rhetorical framing. This chapter thus lays the foundation for the analysis of the three cases.

The chapter is divided in three main parts; the first part establish a framework of analytical terms, next a part presenting the analytical strategy which I label multimodal discourse analysis, and last a part about how the analytical terms and strategy were carried out in practice.

In the two first sections of this chapter, there is a presentation of what a social semiotic stance to communication entails (section 5.1), and some core terms from social semiotics that are part of the analytical 'toolkit' (section 5.2).

Rhetorical framing as one of the central analytical terms is presented in section 5.5. Norms, curriculum, resources, time and physical space have an impact on the rhetorical framing. Rhetoric (in this thesis) is about shaping students and their relation to science. Shaping involves power, resistance and solidarity as well as handling differences. Further, the norms embedded in rhetorical framing are divided into two analytical categories; regulative and instructional. As the rhetorical framing in this thesis deviates somewhat from Kress et al.'s (2001) approach to rhetorical framing (section 5.4), a distinction is needed to be made between the two approaches. The term 'rhetoric' needs to be explicated, as it draws on social semiotic theory rather than the Greek philosophers (section 5.3). Another analytical term is rhetor or the creator of a message. In the classroom teacher is the main rhetor.

The second part of the chapter addresses the analytical strategy: multimodal discourse analysis (section 5.6). This is a fusion of multimodal analysis and critical discourse analysis, both with their roots in social semiotics. The reason for combining these perspectives is that critical discourse analysis is established as a method to elicit ideology (norms can be seen as operationalized ideology) from verbal text. However, practical work and inquiry are not only verbal, they are also about physical action. To understand what is going on it is essential to look into how equipment is manipulated and gestures are part of making meaning.

The last part of the chapter is about how the framework and strategy are operationalized. In section 5.7, text features of the rhetorical framing are identified and in section 5.8, a description of how the analyses were carried out is given. This chapter ends with considerations on ethics in analysis (5.9) and presentation of cases (5.10).

## 5.1. Multimodal social semiotic approach to communication

I see communication in the science classroom as a complex social practice. The basis for describing and interpreting communication is that communication is ceaseless, multimodal and social.

> We say that all action is semiotic, and that all semiotic action is social; that social action changes both the actor and the 'acted-on' or 'acted-with'. (Kress & van Leeuwen, 2001, p. 36)

Communication, or semiotic actions, change the actor. In school science, this change is part of the shaping of students. Students are to learn science, in other words, they are to acquire new ways of expressing themselves and are to set their imprint on the subject matter. Hopefully, the science students learn in school will be tools for 'acting in the world'.

The social is twice represented in the process of communication. First, when a person is making a semiotic action, it is situated in a social context (Kress, 2010). The person has his/her purpose with the semiotic action. Within the social semiotic view of communication, the person's agency is fundamental. In this thesis, the terms interest and expectation are used to express (some of) the teacher's and students' agency. Second, the person making the interpretation does this based upon a particular social context (Kress, 2010). Interpretations are made on the bases of experiences, interests and expectations, in other words how the situation is perceived. We have no (direct) access to peoples' thoughts. However, we can interpret their semiotic actions. Moreover, the interpretation we make may not be what the other person intended when doing/speaking. As the interpretations we make are not identical to the original message, there is no direct transfer of meaning. In the term interpretation, there is not necessarily an acceptance or approval of the message. Seen from a science classroom perspective, this means that students do not 'understand' exactly what the teacher intend to express. As teachers, we know this – but we often forget it?

Students have an opportunity to express themselves and to make their interpretations of what the teacher says and dos, but at the same time, it is the teacher's allotted task to assess that students use scientific terms correctly and that they make the 'right' science connections. In school science, all of the meanings that are made are not equally 'good' or 'true'. Thus, the teacher will actively want to shape students' communication and meaning-making. To do this, she uses a wide range of modes, she speaks, draws, uses props, writes and uses gazes and gestures. In (school) science, there are some cultural-historical ways of expressing a certain subject matter, e.g., results from an experiment are presented in a table, not as a song. Verbalized meaning as well as other inscriptions has a special status, that which is assessed. If one is to be able to relate to science in the public sphere (e.g., in media), verbalized meaning is vital. A social semiotic approach is ”*by and large about the how of communication. How do we use material resources to produce meaning? But there can be no ’how’ without a ’what’*.” ( van Leeuwen, 2005, p. 93). The participants will also choose those resources they think are apt for expressing what in their view is important aspects of practical work and inquiry. In this thesis, both ‘how’ and ‘what’ are needed to analyse the empirical material.

The teacher has to consider her relation to the students, aspects of the subject matter and the means she uses to represent this subject matter to the students. The students have to make similar considerations. In the communication, the teacher and students constantly adapt to each other as they seek to understand each other, but this is not to say that the adaption is without friction.

> Communication requires that participants make their messages maximally understandable in a particular context. They therefore choose forms of expression, which they believe to be maximally transparent to other participants. On the other hand, communication takes place in social structures which are inevitably marked by power differences, and this affects how each participant understands the notion of ’maximal understanding’. (Kress & van Leeuwen, 2006, p. 13)

> In the interaction, the social divergences/differences between those who interact provide the generative dynamic of communication.
> (Kress, 2010, p. 35)

Teacher and students have very different starting points when communicating about science. There are e.g., differences in age and knowledge. As learners, the students are to some extent ‘allowed’ to be unclear and imprecise when dealing with science. From a teacher’s perspective, it is important to choose an approach to content and resources that she thinks is concurrent with the students’ previous experience/knowledge and what they are to learn. Difference is not enough for communication, there also has to be a (felt) need to communicate, to try to understand each other – “*only if there has been interpretation, has there been communication*.” (Kress, 2010, p. 35). If the difference becomes too great, there will perhaps be problems to interpret.

When a teacher asks ‘what is mRNA doing?’ this is not a question for conversation if it is situated within a science class. If the teacher asks it outside of class, it is possible she does not know the answer. However, inside the science class the teacher knows the answer to this type of question (if she did not she most likely would not ask). This is a question that typically marks the difference between the teacher and students. So, when a student has categorized the message as a question for the student to answer (not a ‘rhetorical’ question), the student has to interpret the question ‘who is this mRNA?’ and ‘what is it doing?’ – then the student needs to think about whether to respond or not and what the response should be. In making the response, the student makes something new, an intended re-making of resources for a specific purpose. Students' social interest will deviate somewhat from the teacher's interest, because of difference in knowledge base, and also because the social life amongst students in the classroom is complex. It is not necessarily an asset for a student's status to answer a teacher's questions. Moreover, as teachers, we know that students not always agree with what we say/do in the classroom, but they do not often directly oppose. This can be understood as part of the established power relation between teacher and students.

## 5.2. Some core terms in multimodal social semiotics

There are some terms that will be used throughout the thesis; semiotic work and semiotic action, resources and entities, mode and affordance, and transformation and transduction. In this section, they will be explained.

### 5.2.1. Semiotic work and semiotic action

Whether one is making interpretations, i.e., make inward meaning, or articulating, i.e., make outward meaning, one does semiotic work (Kress, 2003, 2010). Semiotic work is the work involved when (trying to) making oneself understood and (trying to) interpret others.

> Semiotic work names all processes which are part of the making of meaning – in the on-going process of semiosis, externally and visible, or internally and not (immediately) visible. (Kress, 2010, p. 120)

This means that both the students and the teacher are doing semiotic work when they are communicating about the subject matter (or anything else). The notion of semiotic work stresses the social orientation of communication and that there is an aim closely connected to communication. Work has an aim. The 'worker' has an intention of making him/herself understood.

> Work involves a worker, tools and that which is worked on. Work produces change, in the worker, in the tools and in that which is worked on. (Kress, 2010, p. 14)

Semiotic work changes the world slightly and it shapes the participants. The participants have agency when they participate in communication (ibid.). There is agency for realizing some meaning or other (Mavers, 2009). The participants' expectations and interests direct their attention and choices.

The term semiotic action, on the other hand, relates only to the output of the semiotic work, that which is expressed through the use of signs and sign-complexes in whatever mode (Kress & van Leeuwen, 2001). Semiotic action includes 'doing' (van Leeuwen, 2009). I see semiotic action as the outward part of semiotic work. I do this separation between the whole process of semiotic work and the outer process (the visible and audible part), i.e., semiotic action, because in analysis I only inspect that part of the semiotic work that is 'made public'. I have no means to inspect the inner aspect of semiotic work as I do not know what is inside the actors' heads (nor my own for that matter). Semiotic action has 'content' (the signified) and 'form' (the signifier). It deals thus with both *what* and *how*.

There is another term that I link to semiotic work and it is the term 'practice'. To me, the social practice of school science is culturally and historically tied, but we shape and reshape this practice through constant semiotic work. So one might say that school science practice is the result of semiotic work and it is reproduced according to the expectations and interests of the participants. Moreover, the practice is framed by physical surroundings, indirectly a result of expectations as to what school buildings should look and be like.

### 5.2.2. Semiotic resources and entities

In semiotics, sign is seen as 'double', it has a form (signifier) and it 'carries' meaning (the signified). The relationship between form and meaning is motivated. The meaning must be seen in light of the form – or the other way around (Kress, 2003). The signs are not arbitrary.

> (S)igns are always motivated by the producers' 'interest', and by the characteristics of the object. (Kress, 1993, p. 173)

The form of the sign (signifier) serves as a 'descriptor' of the meaning (signified). Signs are not equal or a direct depiction of the object we want to represent. Signs are man-made. The signifier (form) is culturally and historically shaped, as well as the signified, this means they are changeable. As new ways of representing the signifier emerge and as social conditions change, meaning may change over time. But this is not identical with a perspective of communication that implies that any change can be done anytime by anyone (van Leeuwen, 2005).

Theo van Leeuwen (2005) defines semiotic resources

> as the actions and artefacts we use to communicate, whether they are produced physiologically – with our vocal apparatus; with the muscles we use to create facial expressions and gestures, etc. – or by means of technologies – with pen, ink and paper; with computer hardware and software; with fabrics, scissors and sewing machines etc. Traditionally they were called 'signs'. (p. 3)

We communicate in various ways. van Leeuwen (ibid.) shows how, e.g., architecture of school buildings and dress (clothing) can be seen as semiotic resources that are part of the communication that surrounds us and shapes our lives. However, there is also a possibility for us to change our material and mental world. We choose from those semiotic resources we have at hand and we assess which semiotic resources will be apt in this (social) situation to express something.

> A person (sign-maker) 'chooses' a semiotic resource from an available system of resources. They bring together a semiotic resource (a signifier) with the meaning (the signified) that they want to express. (Jewitt, 2009, p.23)

The choice of resource is bound to context and it is socially regulated. It is not only a question of what resources are at hand at the moment, but also a matter of what is seen as apt in this social setting. This is important in the context of teaching and learning, as students learn that some resources are 'better' than others and their use of resources will be regulated by the teacher's assessment.

Different ways of representing provides (slightly) different meanings.

> In the semiotic view, there is no real phenomenon corresponding to the concept of energy: rather, there are only a great many complex material phenomena, which can be interpreted or construed according to various discourses and symbolic schemes, one of which uses the notion of energy. (Lemke, 1998b)[4]

There is thus a need for a term that covers the meaning (signified) across the use of semiotic resources. To write about kinetic energy-as-drawing or kinetic energy-as-mathematical-expression is perhaps more accurate, but cumbersome. The term 'concept' could have been used, but on the other hand this term gives a connotation of abstracts such as energy or force, and is not commonly used to express physical objects. In addition, 'concept' has a 'cognitive' past. In science, we also need to express objects, instruments, relations, classifications, processes as well as the abstract concepts. In the book *Explaining science in the classroom*, the use of the term 'entities' is justified by:

> One reason is that they are all new chunks of meaning. Just like real objects, abstract or formal ones get meaning from what they can do, what can be done to or with them, and what they are made from. The other reason is that they enter into scientific and classroom discourse in a similar way, as 'things' with which or about which to think. They are different, but the fundamental work of constructing and using them looks much the same. (Ogborn et al., 1996, p. 14)

An entity conveys meaning, so it can be seen as the signified. The coupling of entities and semiotic resources thus provides a wide range of possible expressions.

### 5.2.3. Mode and affordance

One of the important aspects of our assessment of a semiotic resource is its affordance. The term affordance says something about the possibilities or the meaning potential, as van Leeuwen (2005) calls it, which is inherent in a resource. Modal affordance "*refer to what is possible to express and represent easily with a mode*". (Jewitt, 2009, p. 24). The affordance of a mode is connected to the material (what is physically possible to express), as well as the cultural and historical traditions for expressing something (ibid.).

[4] In my version of this paper, there are no page numbers.

Before I can proceed to discuss affordance, ‘decoding’ the term mode is needed.

According to Kress (2009), mode must be able to represent some ‘state of affairs’ or what goes on in the world, i.e., to relate to the subject matter and to represent the social relations for those engaged in the communication and to form a coherent text. Mode must thus meet the criteria of the metafunctions – which will be addressed later (section 5.7). The texts produced must “*function as complete message-entities which cohere internally and with their environment*” (Kress, 2010, p. 87). This entails that there is a cultural-historical approach to what is to be considered a mode, texts will, e.g., cohere differently in different cultures (ibid.).

The texts which I will describe, interpret and discuss in this thesis, are primarily in the modes of: speech, writing, image (drawing), handling of artefacts and gestures. The artefacts will be dealt with separately in each case, as they provide different physical possibilities for what to express. For example, a measuring instrument such as the thermometer will provide some other possibilities than a sweet. Both thermometer and sweets were used as artefacts in, respectively, the Heat pump and DNA cases. However, the artefacts have different salient features and need to be treated separately. The teacher and students also used computers to write, draw, etc. The screen is different from paper and pen, and the tools for producing screen-based texts are different. The following summary of modal affordances is based upon Kress (2003, 2010).

Speech has time as an organizing principle and it is ‘restricted’ by the human voice. It matters what words and clauses are uttered first and last. Pauses play an important role in oral communication. Pauses allow the others as well as the speaker to think and respond. Time is an important feature of speech in a classroom as the person (usually the teacher) who is deciding how much time to ’give’ in a situation thereby also exercises power (van Leeuwen, 2008). Moreover, pitch, volume and speed can put more or less emphasis on what is said.

Writing is organized in time (and in space), when reading or writing the words, clauses and chapters they are arranged in an order according to the sign-maker’s interest and what the sign-maker believes is salient in this situation for this audience. There are no pauses as such in an alphabetical written text, but the reader has (usually) the possibility to stop, reflect and re-read. In writing, there are some features that do not appear in speech, such as punctuation and layout (fonts, bold or italic, etc.) Punctuation and layout contribute in organizing the meaning (substance) and emphasizing some parts of the content. Writing on the board has some special features. In this type of writing space is important, such as, in which part of the board is the writing placed and closeness to other writing or drawing. Writing on the board (often) lacks the consistency that is commonly found in writing on paper. There are not necessarily full clauses and punctuation is often ‘optional’. This is related to the interaction of the two modes speech and writing. Writing on a board is a text that is to be read together with the text of teacher’s spoken words (and actions).

Images/drawings (here I make no distinction between these) are organized by the principle of space, foreground and background. Perspective and framing can draw our attention to some parts rather than others (Kress & van Leeuwen, 2006). When students draw ’scientific drawings’, these are also ‘closer to’ the phenomena in question. There is a physical likeness and at the same time, students will represent what they believe are important aspects of the phenomena (Knain & Hugo, 2007).

Handling (science) artefacts and gestures I address as if they were one. They are not, but when it comes to affordance, they share some of the same traits. Both are organized in time *and* space. Pointing, touching or pulling the piston of a syringe are actions in time and space. It is important where the pointed finger is directed and what is first and last. In the analysis, I will deal with these modes more specifically, as they must be seen in relation to the object, pulling the piston of a syringe is different from arranging sweets on the table.

Communication in the science classroom is multimodal (Kress et al., 2001; Ogborn et al., 1996), and happens in more than one mode at a time. In this thesis, e.g., handling of artefacts is important. Students and the teacher do not only use words as a means to make themselves understood, but of course speech and writing have a vital place in lessons. Gesture and facial expression is important as they, e.g., can add information when teacher is asking “Okay?” – is the ‘Okay’ encouraging or impatient? The design of my fieldwork did not allow me to focus on facial expressions, and I could not follow the teacher with camera when she walked to the middle of the classroom. This limits my multimodal perspective, but the data material allow me to see how modes interact to create and ‘give life’ to the subject matter.

#### 5.2.4. Transformation and transduction

“*We cannot assume that translation from one mode to that (same) mode across cultures will work*.” (Kress, 2010, p. 83-84) This is an interesting perspective seen in the light of the translation from everyday talk to the ‘language of science’ that students are supposed to do. Students in science interpret the subject matter and they transform this subject matter when they present the subject matter in their own form. I follow Gunther Kress (2003, 2010) and divide this process in two; Transformation is when information is transformed by person but involves no change in modality; whereas transduction is the process where a person reorganizes the information into a different mode.

From a learner’s perspective, transduction is more complex or difficult because the learner must assess what is important in the information (as he/she sees it) and then choose which part of this information he/she wants to ‘retell’. Moreover, in the process of ‘retelling’, he/she needs to assess the modal affordances of the other mode. For example, if a student is given the task of making a stepwise instruction to an experiment after the teacher has been telling the procedure (teacher uses the mode of speech), this might prove quite a difficult task. If the students are to retell (mode of speech), they can be ‘supported’ by the words and structure applied by the teacher and they can use (some of) these words in the process of transformation.

However, if the task given (by the teacher) is to draw the stepwise instruction, there will be a transduction process for the student. The procedure needs to be laid out in space and divided into accessible chunks of information, at the same time there must be a sequence. The modal affordance of drawing makes it easy to depict the equipment, but that which is more abstract (e.g., time, units, etc.) is difficult to represent in a drawing. Therefore, I will claim that a transduction process is more demanding, as the person doing the transduction needs to be more independent of the information given. There is a larger 'interpretive space'. My experience is that this type of tasks may cause the students to feel they are 'in deep waters'. This can of course also be linked to the assessment criteria (not) given. If the student is to do a transformation, it is most likely that the teacher wants something that resembles the teacher's own presentation, but if the student is expected to do a transduction, then the student faces the problem of 'what does the teacher really want?'

When one is interpreting information and re-representing it, whether in a process of transformation or transduction, it involves personal choice such as; What is salient in this situation? What is the best way of communicating this content? These choices involve creativity. The social semiotic view of creativity is that creativity is ordinary rather than extraordinary (Kress, 2010). However, I would like to add my own account that there are degrees in creativity, some utterances are 'more creative' as they are more novel – in form or meaning.

### 5.3. Rhetoric

The assumption behind rhetoric[5] is that when a communicational situation is not well defined, the person making the message needs to make deliberations; what are the important aspects of the message; with whom am I communicating and how can I design my message. When the communicational situation is more clearly defined, there is less need to emphasize these aspects of communication. In an age of (communicational) stability

> the relations of power are known, predictable, naturalized – and so the frames of communication are stable, predictable and unchallenged. Usually there is little contestation of power in the social domain; the resources of representation and communication are aligned in relatively stable and predictable arrangements to ensure that this is so. (Kress, 2010, p. 45)

Rhetoric is always prevalent, but when there is stability we pay little heed to it. On the other hand, when we are communicating without secure social frames, rhetoric's becomes more important.

> In conditions of political and social instability, things are anything but predictable or known; the grooves of convention have been worn away or else the territory is in any case new so there are no grooves. Relations of

[5] To avoid confusion, I want to emphasize that this approach to 'rhetoric' is not the traditional (Aristotelian) approach, although, some of the core elements are similar (how to present a message to whom). I will not provide a comparison of these two approaches to rhetoric.

> power are uncertain, unknown maybe: they are contingent and unpredictable, subject to constant negotiation and challenge. Things are provisional. For every occasion of communication and interaction, social relations need to be newly assessed; the resources of communication have to be freshly considered in their utility for this instance. (Kress, 2010, p. 46)

There can be elements of stability, although there might be other elements of social instability alongside. This I think is the case for schools. In some ways, much is the same as before, but things have also changed, e.g., the introduction of personal computers to students and a new 'type' of students (see sections 3.2 and 3.4). This might give rise to uncertainties in communication. Another element not directly connected to social instability but with an impact on classroom communication is the fact that students are there to learn. This means that the teacher needs to deliberate on 'what' and 'how' more seriously than in an everyday setting.

Kress' view of rhetoric is 'the politics of communication' and he regards "*politics as the attempt to shape and regulate social relations by means of power*" (Kress, 2010, p. 45). Power relations seen in Foucault's perspective are immanent and dynamic processes. They can be productive (as well as unproductive), as power seeks to direct activity. Power relations produce reality – what is seen as true (Flyvbjerg, 2001). As power is seen as a relation there is 'an opposite' – resistance (ibid.). Power relations can be passed through communication in different ways, such as the words we use, the positions of our bodies and the physical environment. For example, a teacher has the right because of institutionalized power to command students (e.g., you shall…) and they can show resistance by working slowly. Further, this means that the position towards the subject matter is a 'political' matter. The view of science, practical work and inquiry, or what one may call the person's epistemological stance, is vital to how science is presented (Aikenhead, 2007; Roberts, 1988). How the subject matter is presented shapes and regulates the relation the teacher and students have to the subject matter and each other. The relations of power between the participants influence how subject matter is dealt with. Resources for communication and dissemination are not neutral either as they provide a specific form to meaning. The resources to be used are often decided by the teacher (and school) and when students use the resources, the teacher assesses the use.

This leads to (at least) three 'dimensions' where the rhetoric as the politics of communication is important for this work. First, it is how the teacher and students relate to the subject matter and how the power relations shape and regulate their approach to the subject matter, practical work and inquiry. Second, is to look into how the teacher and students relate to each other and third, how they utilize the resources available. The first is the most important here, but relations between teacher, students and resources are important to understand how the 'politics of science' is expressed. This will be further explored in section 5.5.

### 5.3.1. Rhetor: teacher as main rhetor in the classroom

Rhetor is the maker of a message and need thus to assess all aspects of the communicative situation (Kress, 2010). Kress (2010) makes a distinction between rhetor, designer of message and producer. Here I will make no such distinction since these positions are concurrent in classroom communication.

In the classroom the teacher has an important role in shaping the students' understanding and attitudes towards science, practical work and inquiry. The teacher acts as a 'model' for how to do 'proper' (school) science descriptions and explanations.

> The term rhetoric highlights that in attempting to shape students' conceptions of the world, teachers are acting rhetorically: they present a plausible, integral and coherent account of the world through the orchestration of a range of communicational means. (Kress et al., 2001, p. 20)

By choosing certain aspects of subject matter and the means to present it, the teacher highlights the importance of some aspects and suppresses others. To choose and weigh the subject matter within the frameworks of the national curriculum and to find the 'best' way of presenting it is a part of the teacher's job. The teacher cannot shape subject matter and students anyway she wants. There are limitations given by cultural-historical traditions, school policy and legislation. However, within these limitations the teacher has the power to decide what subject matter to work with and how to work. By assessing the students' work, she decides what counts as valid scientific knowledge and valid scientific methods within the classroom. This assessment can be seen as part of the power relation. The teacher thus influences what students see as important – or at least what they believe they have to do to get good grades. This implies that I regard the teacher as the main rhetor in the classroom. This is not to say that students not make rhetorical considerations. The process of shaping can be described as

> Although we see the teacher as central to this process, we envisage this rhetorical shaping as a dialogic process in which teachers (and the school) provide the ideological/rhetorical frame within which students are active participants in a dynamic process. (Kress et al., 2001, p. 19)

The teacher has to communicate science content in a way and by means that are agreeable for the students. This means that the teacher has to probe whether students think this is too difficult or too easy, and regulate the pace and structure of the subject matter accordingly. (If the students start a rebellion, there is little a teacher can do.) It is reasonable to assume that over time, be established 'patterns' of communication will be established: the way science is dealt with in this context. Both teacher and students have expectations as to what practical work and inquiry are and how they should be introduced and what the practice of science contains. These expectations direct the semiotic work for both students and teacher, and thereby the relation between them.

## 5.4. Rhetorical framing as used in Multimodal teaching and learning

As my notion of rhetorical framing deviate somewhat from the notion presented in *Multimodal teaching and learning* (Kress et al., 2001), I will start by presenting the authoritative source before I proceed to describe my own in the next section.

> The rhetorical frame is realized by a textual form of rhetoric, that is, it is identifiable by shifts in textualization – socially constructed ways of realizing the shapes of knowledge drawing on specific epistemologies. (Kress et al., 2001, p. 21)
>
> This framing is achieved through particular configurations of modes and means in the classroom. Shifts in the configurations of these elements result in different and distinct rhetorical frames, each of which impacts the teacher-student relationship and their relationship to science and learning. (ibid. p. 22)

*Multimodal Teaching and Learning* gives an example where the shift of physical position, body posture and speech type (exploratory to authoritative) marks the boundary between two different frames. The frames are thus identified from shifts in signifiers (sign form). The framing as such is linked to modes and means for communication. This, of course, provides an impact on what is signified (the meaning). The units of rhetorical framing were used to develop a descriptive language. The descriptive language focused on rhetorical function, i.e., for what the frames were used. By induction, I believe, they identified that "*Each of the general epistemological functions was textualized in particular ways*." (ibid., p. 23). I read this as: modes and means are linked to epistemological functions. Rhetorical (epistemological) functions are exemplified with: 'ontology of the everyday', 'see in a new way', etc. Exemplified, a teacher by using shifts in modes and means makes a transition from drawing on students' common (everyday) understanding to seeing the same phenomenon from a science perspective.

### 5.4.1. Critique

The book *Multimodal teaching and learning* is interesting as it focus on modal aspects of science (presentation), combined with a rhetorical perspective which opened a new way of understanding communication in the science classroom. It makes a shift from regarding communication in science as just talk and writing, to an understanding of how meaning is created through a range of different resources in different modes and how the communication is part of shaping students' relation to the subject matter. This shift towards a multimodal understanding of communication in science was needed!

However, reading this view of rhetorical framing left me with a problem. The problem is connected to method. I cannot grasp what is seen as sufficient shifts in modes and means to create a new frame. This is not clear to me. In the way I know school science I take for granted (or make an assumption) that we communicate differently when the ontological status of what is presented is different. For example, if I talk to students about their everyday experiences I will talk 'differently', using other words and perhaps other resources from when I am presenting the same phenomenon from a scientific perspective. Examples of this are given by, e.g., Mortimer and Scott (2003).

In a personal comment from Gunther Kress, he elaborates on the view of rhetorical frames presented in *Multimodal teaching and learning* (Kress et al., 2001)

> If the rhetorical frame is seen semiotically, then it is a signifier, the signified of which is the 'rhetorical stance' (which might include discursive / epistemological positions, but also social, interpersonal etc.). All these will have formal features which are recognizable ---- of course subject to interpretation themselves (Kress, 2011)

To conclude: the approach to rhetorical framing presented above is largely connected to the 'how' of communication. In other words, the term rhetorical framing is from this position largely connected to the signifier, to modes and means for expressing something. According to van Leeuwen (2005), a social semiotic approach is largely connected to 'how'. By linking rhetorical framing to modes and means, implies that the (meaning of) subject matter (or the signified) is back-grounded.

In my opinion, the 'what' and 'how' of rhetorical framing together constitute the practice of school science. Rhetorical framing as it is seen in this thesis is the issue of the next section.

## 5.5. Rhetorical framing in this thesis

In section 5.3, rhetoric was established as a term for 'the politics of communication'. In the science classroom, the politics is concerning the '*what*' and '*how*' of the subject matter and the relation between teacher and students. This section deals with establishing an analytical framework that allows for inspection of the framing process of the 'politics of communication'.

I regard rhetorical framing as an analytical construct - mainly. Few teachers think about political or ideological consequences when they give an introduction to a science inquiry. At the same time, the rhetorical framing is 'real', as there are ways of realizing science inquiry and practical work in the classroom that are considered 'proper'. Teachers, I suppose, do not (usually) deliberate on how to frame the inquiry rhetorically – they just do it. The framing is impacted by norms that shape the teacher and students' semiotic actions. Norms and semiotic action constitute each other: Norms give direction for how the practical work and inquiry are to be carried out 'properly', and semiotic actions confirm and strengthen norms – or break norms. However, the norms are usually not thought about. Artefacts and other resources, physical space as well as curriculum, are usually 'given' and not thought about much either, but they influence the *how* and *what* of practical work and inquiry. In other words, these factors are useful for analysing the rhetorical framing. Time is yet another factor that has an impact on the rhetorical framing. Everyone(?) who has taught knows that time has a large influence on what is going on in the classroom. So, I include time into one of the factors which impacts the rhetorical frame.

The word framing indicates an on-going process that divides something as 'inside' – and the rest of the world as 'outside'. The process of framing creates a space for the practice of science inquires and practical work: The rhetorical frame. From a social semiotic point of view, the rhetorical frame (the 'product' of the process) will not be static, as parts of communication will be 'negotiations with' and re-interpretations of 'the other' and of the subject matter. Social semiotic systems undergo constant transformation because of the interest of the participants (Kress & van Leeuwen, 2001).

The framing restricts the practice of science inquiries. It regulates what should be represented through semiotic actions, but the frame also provides possibilities to understand what it is about, a framing for interpretation of what is going on.

> Expectations and interest are socially framed and dependent of established use of language and established practices, but they also get their individual imprint by every participant … The space might also be understood as a resource in relation to expected activities.[6]
> (Selander & Kress, 2010, p. 48, my translation)

Expectations and interest are framed by established practice, but expectation and interest will also be part of creating the practice. The framing gives shape to an 'ideological space' (ibid.). (The ideological space is approximately the norms in the rhetorical frame in my terminology.) The 'space' will be interpreted differently by the participants even if there will be consistencies of interpretations between different situations. For example, if the teacher where to do an inquiry with chemists students on a more advanced level, the established practice would most likely be somewhat different. The rhetorical framing is thus constituted by the teacher and students' semiotic actions according to their interest and expectations and makes their semiotic work possible.

### 5.5.1. Rhetorical framing and norms (regulative and instructional)

Physical space, resources and curriculum are parts of the framing (Selander & Kress, 2010) – and time. Time is an important factor in practical work and inquiry, there has to be time 'enough' to do it. All these factors are important, but the norms that constitute practical work and inquiry are perhaps even more important.

[6] Förväntningar och intressen är socialt inramade och avhängiga av ett etablerat språkbruk och av etablerade praktiker, men de får samtidigt sin individuella prägel hos varje deltagare… Rummet kan också förstås som en resurs i relation till förväntande aktiviteter.

> One might express that norms, customs and rules, expressed aims and guidelines as well as resources of different kind constitute the premises for a social activity.[7] (Selander & Kress, 2010, p. 70, my translation)

Norms are that which are seen as important (valuable) in the science classroom, it is 'operationalized ideology'. Norms influence *what* is expressed and *how* it is expressed.

Berger and Luckmann (1966) describe the establishing of norms as part of the socialization process. A child learns that some semiotic action is approved or disapproved by primary caretakers. The child recognizes that 'everybody' takes the same stance. The norm is generalized to 'one does (or does not) this semiotic action'. There is thus an abstraction from the primary person or the significant other to a generalized other. 'Everybody' does it like this and I identify with them. Most of these socialization processes go unnoticed by our consciousness.

> Society, identity *and* reality are subjectively crystallized in the same process of internalization. This crystallization is concurrent with the internalization of language. (Berger & Luckmann, 1966, p. 153)

The students have a school history – this was their 11th year in school. They have expectations of the teacher, the science subject and school system. During all of those years in school, each student has developed ways of relating to the subject matter, teachers and school. Students have, thus, expectations of what school science *should* be like. The teacher has also her expectations of the students. She has been a teacher in general science at this school for quite some time, and she has experiences of what 'works' in the classroom. She has expectations of what she can anticipate from students who are about to do practical work and inquiry. What can she anticipate of the students' subject matter interest and how they behave and relate to others? However, an individual student's expectations and interest are not necessarily aligned with other students' (or teacher's) expectations and interests. When the students begin at upper secondary, there will be different expectations amongst students of how to do science. This means there must be 'renegotiation' of how to do science, to establish the practice of science 'as we do it'. I assume that if there is much variation between students and between students and teacher, there will be more 'renegotiations'.

The expectations and interest of students and teacher will act as a driving force for generating norms in the classroom for what is considered proper science (as we do it) and proper behaviour (how we relate to each other). The deliberations and choices involved in *how* and *what* to express are political in the sense that there are some ways that are considered better or more appropriate within the context.

[7] Man kan uttrycka det som att normer, sedvänjor och regler, formulerate mål och riktlinjer samt olika slag resurser, utgör själva förutsättningarna för en social aktivitet.

School science aims at shaping students' view of the world and, as any school subject, it partakes in the shaping of attitudes and behaviour, see section 3.1 for the objectives and aims in Norwegian science curriculum. The curriculum objectives and aims are political. Students are to become 'good' citizens with (some) understanding of science. The objectives and aims are quite open and there must, thus, be interpretations and 'negotiations' between students and the teacher about what is considered 'good' and appropriate within the context. These interpretations and negotiations are mostly tacit, and the teacher as main rhetor has an important role in setting the standard. In the actual school practice, the political aspect of shaping may be 'forgotten' and the norms may seem 'natural'. When the norms become 'naturalized', the practice of practical work and inquiry become 'just as we do it'. There is of course the possibility that the actual practice is more or less at odds with the objectives of school science.

As norms concerning how to relate to others (e.g. behaviour) and norms concerning subject matter deal with slightly different aspects of school science, there is a need to divide these. The social relations and subject matter depend upon each other but can be viewed separately. For example, if the students are accustomed to not paying attention to the teacher's introduction (and this is accepted), this will in turn give implications for the teacher's choice of semiotic action regarding the introduction and later to how the students deal with the completion of the practical work. To see how these two sets of norms 'play' on each other is important in this thesis in order to be able to explain practical work and inquiry in the science classroom. To explore these two sets of norms, I choose to borrow two terms from Basil Bernstein (2003); regulative and instructional. I will give a brief overview of what these terms seek to describe.

Bernstein divides the pedagogical discourse in two. The regulative discourse is concerned with principles of order, relation and identity and the instructional discourse is concerned with "*the transmission/acquisition of specific competences*" (Bernstein, 2003, p. 211). The instructional discourse deals thus with how to relate to subject matter, whereas the regulative discourse is about how to relate to others and to the structure and organization of the tasks. The objective of the regulative discourse is to get the student to behave according to the norms of school, such as sitting by his/her desk, raising a hand when he/she wants to speak, doing his/her tasks properly, etc. According to Bernstein (2003), the instructional discourse is always embedded in the regulative discourse.

Christie (2005) uses the same line of argument by applying different terms. Her terms are from a systemic functional linguistic perspective of language. She uses 'register', where Bernstein writes about 'discourse'. These different perspectives lead to different ways of analysing and drawing conclusions, but that is not the point here. In Christie's terms, the practical work or inquiry would be a curriculum genre, where genre is seen as social action which includes situation and motive (Miller, 1994). "*Operating within an instance of a curriculum genre there will be two registers, a regulative and an instructional*" (Christie, 2005, p. 136). The regulative register enables the instructional as the regulative deals with ordering and pacing as well as the regulation of general behaviour. When the teacher initiates a task (the opening of a genre), there will be emphasis on the regulative register (Christie, 2000, 2005).

> (T)he two registers will converge, as the teacher selects the instructional field to be used and guides its introduction and development, encouraging the students to use the field information in particular ways. Thus, the teacher paces the students as they learn, on the one hand, how to go about their tasks (regulative register), and, on the other hand, the 'content', topics and information (the instructional field) they are to use in order to complete their tasks. (Christie, 2005, p. 149)

Further, when students know what they are supposed to do

> the regulative register will disappear, though it will continue to operate tacitly as the instructional register comes to the fore. (ibid. p. 149)

When students know what is expected of them, the regulative register 'disappears', but if the students do not know what is expected, misunderstandings may result. The teacher's talk may then be restricted to regulative registers often in imperative form (R. Iedema, 1996). For the two registers to converge, there is a need for the regulative register to operate tacitly. This is, according to Christie (2005), a measure of success and the teacher can concentrate on the subject matter.

> Over time, much of the language associated with teaching and learning the acceptable classroom behavioural patterns becomes lost, as students acquire those patterns. That is to say, they develop regular routines so that the explicit expression of teacher advice and/or direction concerning a great deal of what is to be done simply disappears. (Christie, 2005, p. 137)

The explicit expressions of parts of the regulative domain of communication might be 'lost' (not explicitly present in these cases), but the practices remain, and by looking into actions, as well as what is said by students and the teacher it becomes possible to describe how students behave in the classroom and how the teacher regulates this behaviour. This means that during analysis it is important to look for that that is not explicitly expressed. When inferring instructional norms, there might also be tacit elements, e.g., parts of a procedure is not made explicit because it is 'obvious'. In semiotic work, we make assumptions and simplifications, otherwise semiotic actions would be tedious. However, in a teaching-learning situation, it is interesting to look into if important aspects of meaning are tacit and thus might hinder students meaning-making. Moreover, when teacher and students are not explicit this makes my interpretive space larger, and thus the inference will have a more speculative status.

There will also be norms among the students of what it means to be a student. This can, e.g., involve standards of how much work one should put into tasks, what types of questions that are okay to ask in full class and so on. As the empirical material for this thesis has no footage of all students in class, this will be a somewhat limited perspective in the analysis.

I make the assumption that instructional norms are embedded in regulative norms. As the norms are (usually) tacit, they have to be inferred from the participants' semiotic actions.

As a part of the iterative analytical process, i.e., through the first stages of analysis, I categorized norms into six different categories depending upon what the norm concerns:

Regulative norms concerning:

- Behaviour
- Task organization (e.g., division into groups)
- Task structure (e.g., purpose and aim, expected outcome)

Instructional norms concerning:

- Scientific knowledge
- Procedure and methods
- 'Scientific language' and communication of subject matter

These categories do not emerge from a strictly 'inductive' or 'deductive' approach. They are developed in an interplay between literature and the empirical material.

The analysis will emphasize how norms play a part in constituting the rhetorical frame for doing practical work and inquiry in science. The role of curriculum, time and physical space will be less prevalent in the text analysis. The norms will be interpreted in light of curricular aims, time and physical surroundings. The features of factors that impact the rhetorical framing are the issues in section 5.7.

### 5.5.2. Rhetorical framing: power, resistance, solidarity and difference

Rhetoric is seen as the politics of communication where politics is the shaping of social relations and social practices through the means of power (Kress, 2010). Establishing norms in the classroom involve power relations between the teacher and students.

> Activity to ensure learning and the acquisition of aptitudes or types of behaviour works via a whole range of regulated communications (lessons, questions and answers, orders, exhortations, coded signs of obedience, differential marks of the "value" of each person and of the levels of knowledge) and by means of a whole series of power processes (enclosure, surveillance, reward and punishment, the pyramidal hierarchy). (Foucault, 1994b, p. 338-339)

Power relations are conveyed through language (e.g., Hodge & Kress, 1993) and action (e.g., van Leeuwen, 2008). Power exercised through 'school system' is of course also there but not a focus in this thesis.

As main rhetor the teacher exercises power, or in Foucault's words exercises 'the conduct of conducts' (Foucault, 1994b). This means that the teacher leads and directs the students in what and how to do. The teacher thus structures what possible actions the students have (ibid.). This means that power is a constructive as well as a restrictive part of the student-teacher relation (Flyvbjerg, 2001). There is a need for restrictions for what practical work and inquiry entails. If these restrictions are severe, there will be few choices for students to make. To have several possibilities from which to choose might be good. One can then choose how and what to do. On the other hand, if one has too many choices it might become difficult to decide. So, when the teacher and students frame the practice, the degree of openness (how much choice) in the practical work and inquiry is of vital importance. These are deliberations that belong in the situated practice. However, perhaps the deliberations are not made explicit. One cannot rule out the impact of the teacher's and students' previous experience. When dealing with practical work and inquiry, teacher and students are drawing upon their understanding of scientific knowledge in general and scientific methods in particular.

Another aspect of power is resistance. When the teacher wants to direct the students' activity, the students always have the possibility to resist. They can do this in many ways, e.g., by delaying starting on the task, deliberately misunderstanding the teacher or openly protesting (Yerrick, 2000). Seen from a social semiotic perspective, inattention is a way of showing resistance. When inattentive, one stops making interpretations of the other person's message. One might say that the subject matter semiotic work halts, but students do other semiotic work. In the classroom, students are inattentive both when they are talking (off-task) to each other when teacher is presenting the subject matter and when they 'dive' into their computer for off-task activities, see section 3.4.

In the relation between teacher and students, there will be elements of solidarity to take into account (Fairclough, 2003). Where power manifests itself in the hierarchy, solidarity says something about social distance. Solidarity in the relation between teacher and students can, for instance, be how the teacher and students talk together and how the teacher cares for the students by not giving too difficult tasks and ensuring the students' wellbeing by organizing groups in which the students feel comfortable. Power can manifest itself in different ways – e.g., how much time the teacher allots students to finish their inquiry. Another aspect of power and solidarity is difference. Difference is a generative force in communication (Kress, 2010). In the classroom, difference needs to be made explicit. There is difference between a science view of a phenomenon and the everyday view, and there is difference between students' previous understanding of the phenomenon and the new way of seeing it (Ogborn et al., 1996). When doing practical work and inquiry, different methods might be used and there will be different results. To address these differences is part of shaping the students' subject matter understanding and thus an aspect of the power relations in the classroom. When addressing differences, the teacher will challenge students or students will challenge peers. Challenge refers to the practice of arguing and persuading about scientific issues (Veel, 2000).

Moreover, the challenge might be seen as empowering students. They are to question and assess the subject matter, procedures and methods. In other words, students relate critically to subject matter, procedure and methods. In school there is a potential element of 'empowering' students, they are to be proficient in what they are doing. This can mean a more or less explicit approach to give students responsibility and hand over the 'right to use' science entities, procedure and methods.

### 5.5.3. Rhetorical framing - summing up

Rhetorical framing is an analytical construct that defines something as the practice of practical work and inquiry – and something not. As the illustration below attempts to illustrate, the practice is driven by the participants' interests and expectations. The rhetorical framing relies upon interpretation and (sometimes tacit) expressions of competence aims, time, physical surroundings, resources and established norms. The product of the process of rhetorical framing – the frame, is seen as semi-stable, as it might be changed according to the participants' interests.

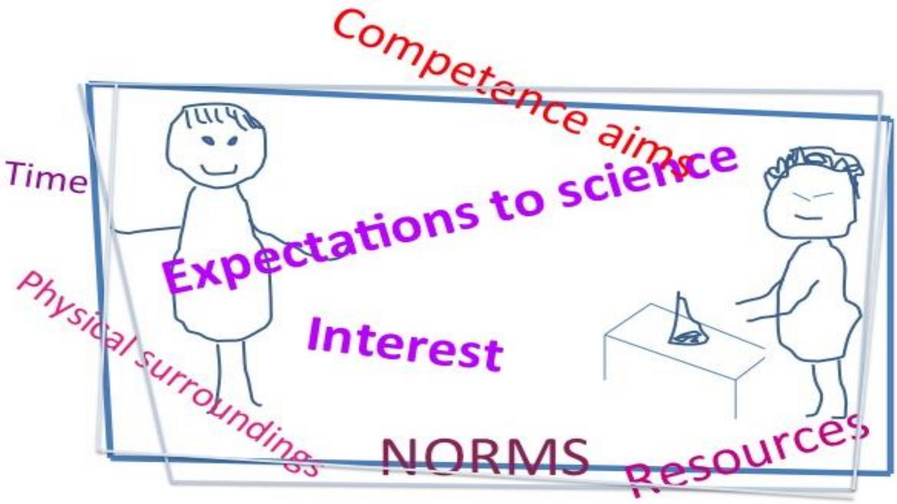



Figure 1 Rhetorical framing

Norms are seen as the most prominent part of the process of rhetorical framing. The norms are tacit and need to be inferred from the teacher and students' semiotic actions. The norms constitute a practice that is taken for granted ('we just do it like this') and the norms direct the practice as it should be (this is 'right' and 'proper'). Analytically the norms are divided in two – regulative and instructional. Regulative norms deal with behaviour, organizing and structuring of practical work and inquiry. Instructional norms deal with subject matter (methods, knowledge and 'science language'). Instructional norms thus give a stance toward epistemology and ontology of science.

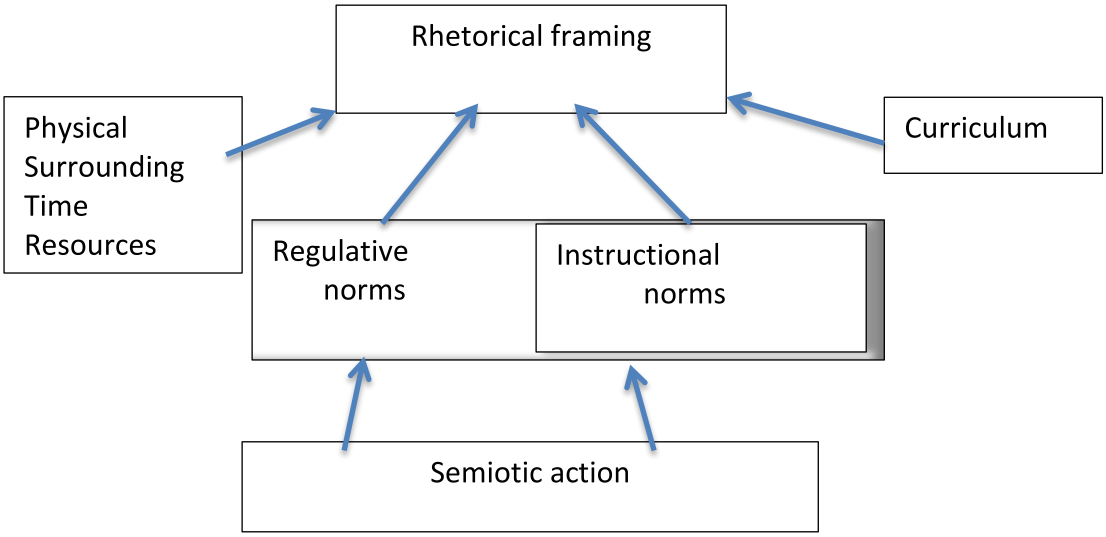



Figure 2 Inference of rhetorical framing (schematic illustration)

The arrows indicate inference in the analysis of the data in the three cases.

As part of the rhetorical framing, there will be power and resistance as a part of the shaping of the students' attitudes and subject matter knowledge. Part of shaping is to challenge the students and subject matter, e.g., by allowing for subject matter differences. The teacher, as main rhetor, exercises power, by e.g., assessing what is 'good' and 'proper'. Students might resist in several ways, e.g., by inattention or rejection of the teacher's standards. There is also solidarity in the relation between the teacher and students, e.g., in the form of teacher involving students in decisions.

As time goes throughout the school year, the framing becomes more fixed because the norms expressed through semiotic actions which frame practical work and inquiry become 'the normal'. When norms are relatively stable, this has an impact on how the teacher plans and conducts practical work and inquiry and how students carry it out.

Because the framing cannot be observed directly, it has to be inferred from semiotic actions. Thus, it is of great importance to have analytical methods and features that make it possible to infer the frame so there is a reasonable fit with the practice. This is what the rest of the chapter is about. However, of course, there will always be a discrepancy between the interpretation and the social practice itself.

## 5.6. Multimodal discourse analysis

My position is that norms and rhetorical framing are to be inferred from the 'signified' (meaning) – as well as the 'signifier' (form). The semiotic actions have both form and meaning. What the participants do (speech as well as physical action) is part of their semiotic work. The semiotic actions are multimodal where the different modes are intertwined. Norms and semiotic work constitute each other, norms will impact what is seen as appropriate and apt semiotic actions in the situation - and *what* and *how* we communicate will over time give norms for how subject matter should be dealt with. It is thus a need to have a way of analysing the empirical material that allows for both looking into action as well as that which is verbalized.

I label the method for analysis 'multimodal discourse analysis'. This is a fusion of multimodal social semiotic and critical discourse analysis. Multimodal discourse analysis is a term that has been used by several authors, see e.g., Iedema (2003) or Royce (2007). However, these authors have analysed printed texts where there is a combination of modes (writing, images, and graphs). However, they have not addressed physical action in these writings.

Critical discourse analysis is established as a method for identifying ideology in language (Alvesson & Sköldberg, 1994), but do (to my knowledge) not look into physical action. In this thesis, norms are seen as operationalized ideology and thus critical discourse analysis can be a tool to elicit the norms from speech and writing. The approach to critical discourse analysis used in this thesis is based upon the writings of Norman Fairclough. His approach to discourse analyses leans on the works of Halliday, and can thus be said to have a social semiotic view on communication.

On the other hand, multimodal social semiotic has its strength in looking into resources used in semiotic action including physical action (Kress & van Leeuwen, 2001; Norris, 2004; van Leeuwen, 2008). This approach to analysis of communication thus emphasizes the *how* of communication (van Leeuwen, 2005). Multimodal social semiotics takes an interest in ideology conveyed through the resources for presentation (Kress et al., 2001; Kress, 2010).

Both multimodal social semiotics and critical discourse analyses have a 'starting point' in the same 'root' of social semiotics and they are thus seen as compatible. For instance, both approaches use Halliday's metafunctions as a way of structuring communication. Multimodal social semiotic and critical discourse analyses are also compatible in the form that both have a perspective of communication as social practice and that communicative interpretations are not a blueprint of the utterance (Fairclough, 2003; Kress, 2010). In both approaches to communication, there is a view that we shape and are being shaped through communication. This implies that teacher and students shape their views of science through actions and speech.

Multimodal analysis is labour intensive because of the multiple modes. This often leads to a micro-ethnographic approach (Snell, 2011). In micro-ethnographic, emphasis is placed on very detailed analysis of short intervals of semiotic actions (see e.g., Norris (2004)). Micro-ethnographic leaves little room to explore the rhetorical framing of practical work and inquiry in the science classroom, as these are practices that unfold over time. To achieve the possibility to do 'meso-level' analysis, there has to be analysis of longer stretches of communication. The consequence of this is that the analysis cannot be very fine-grained. There is a constant struggle between presenting semiotic actions over time and diving into moments of significant importance.

The analysis in this thesis follows a discourse analysis model as described in Fairclough (2001). It is important to not only describe and interpret communication but also to try to explain it in view of the social conditions – the context. This is a three-step analysis:

1. Text description - including the formal properties of the text
2. Text interpretation
3. Explanation of what is going on in view of context

The terms text and context need some explication before proceeding to description, interpretation and explanation.

I will apply a notion of the term 'text', which differs from everyday use of this word. A text is a sequence of semiotic actions whether these are physical action (with props), speech, or (producing) a written text. "*Communication – whatever mode – always happens as text.*" (Kress, 2003, p.47).

Texts can be interpreted as representations of social practices, although it is important to stress that the representation is not equal to the social practice. When making the (research) texts that are the basis for analysis, several decisions are made during the process of construing the text, e.g., what to video record (section 2.3.2) and how to transduct the film into transcript (section 5.8.1). The text is thus a recontextualization of a social practice ( van Leeuwen, 2008). This means that the text is moved away from where it originally emerged into a new context – the context of social science. Further, as the text is a re-representation of semiotic actions, it implies that the start and endpoint of a text may be relatively open. The text's start and end points correspond to case boundaries in section 4.5.2.

Classroom practice is situated and thus bound to context. The participants in the classroom operate within a context which provide the background that enables them to understand what is going on (van Oers, 1998). In this thesis, the context presented is my interpretation of the 'real' context. By choosing those aspects of the practice I find helpful to describe and explain practical work and inquiry, I choose to leave out those aspect I find less salient. The context has to be inferred and thus the context influences research perspectives (Flyvbjerg, 2001, 2006). This can be taken one step further: Knowledge in the social domain is context-dependent (Flyvbjerg, 2001). There is also another reason for emphasizing context. When I read educational literature, it seems so often to be prescriptive. It often 'blames' the teachers or students for that which is 'wrong'. When context is more prominent, it might prevent a search for 'easy solutions' as the classroom practice becomes more complex and one understands that teachers and students have to make many deliberations all the time.

Moreover, the context presented in this thesis constraints the researcher's interpretation of classroom practice but it also provides a possibility to understand the practice as part of a larger picture (van Oers, 1998). There are several ways of defining the ‘elements’ that constitute the context (ibid.). The context for the cases can be seen as the background from which the practical work and inquiry emerge. The close context of the case varies with the cases, but is typically the planning of the practical work (teacher and researcher), what happened the day of the practical work before and after, as well as evaluations between the teacher and researcher. The larger context is what happened in the practice over the year as well as teacher and students verbalizing the practice (interview and conversations). In addition, there is literature on Norwegian school science and about being young in contemporary Norway. This larger context was presented in chapter 3. The larger context will primarily be used in the final discussion where the focus is to explain the practice.

I see text description as interpretation as well, thus there will be no strict division between descriptions and interpretations in the results chapters. The fluid transition between descriptions and interpretations is according to the ‘fact’ that any observation, and thus description, is from a certain point of view (Flyvbjerg, 2001; Gobo, 2008). One chooses what to observe and the language used to describe these observations will never be objective. Observations will be inscribed into a culture as the language of describing is itself a social practice (van Leeuwen, 2005; 2008).

A major part of text interpretation in this thesis is inferring norms and rhetorical framing. The interpretations of norms and rhetorical framing will be made in light of the close context of the case (what happened just before or after the practical work/inquiry) in each of the empirical chapters. However, these norms and rhetorical framing have a provisional status as they are bound to the case. In chapter 9, there will be a cross-case interpretation of norms and rhetorical framing. If the provisional norms from each case are consistent across all three cases, it is more likely this is a stable norm. In short, it adds confidence to the findings (see section 4.5).

The analytical strategy can be summarized in the following illustration:

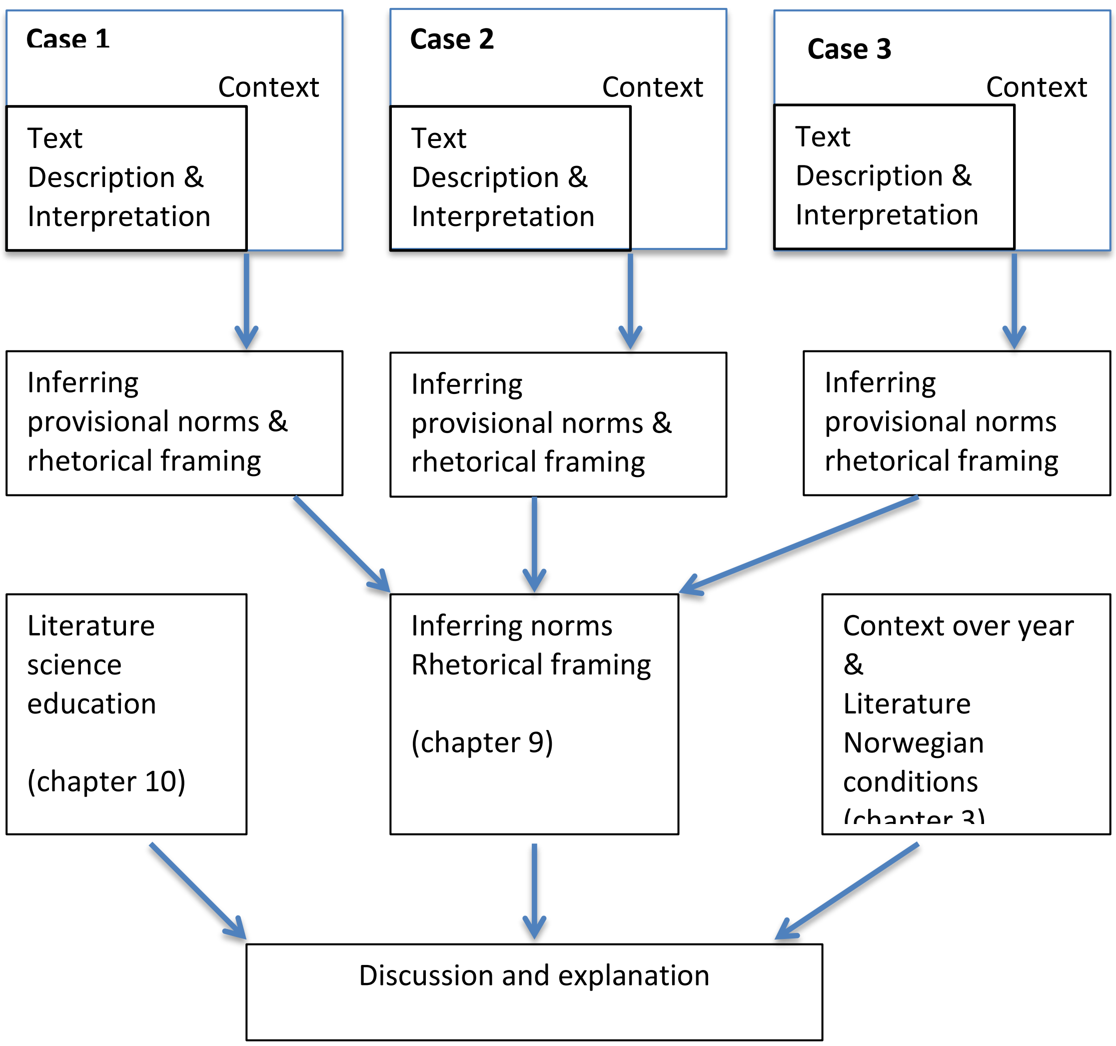



Figure 3: Overview of analytical strategy

As we will see in the coming chapters, the outcome of the close-up analysis provides results that deviate from what literature sees as the 'ideal' science teaching and learning. The detailed analysis is necessary to be able to scrutinize the practice of practical work and inquiry. For a long period of time problems with practical work and inquiry have been reported, there is (in my view) a need to go into a detailed analysis of communication – and make a critique of practice.

> A critique does not consist in saying that things aren't good the way they are. It consists in seeing on what type of assumptions, of familiar notions, of established, unexamined ways of thinking the accepted practices are based. (Foucault, 1994a, p. 456)

To discuss and thus make a critique of the practice of practical and inquiry, it is necessary to present a literature review of what science inquiry and practical work in science is and should be. The starting point of the literature review is the objectives and aims in the curriculum. How might the curriculum be interpreted from a 'science education for all' perspective? In addition, how does this curriculum (interpretation) correspond to the practice? Is it possible for the practice to achieve the objectives and aims in the curriculum to a reasonable degree? If not – why? These are the questions that drive the final discussion in chapter 11.

The text's features for describing, interpreting and inference of norms and rhetorical framing are the theme of the next section, and then a section on how the multimodal discourse analysis was carried out in practice.

## 5.7. Text features to describe and interpret rhetorical framing

In section 5.5, aspects of rhetorical framing of practical work and inquiry are defined, largely based upon the terms framing (Selander & Kress, 2010) and rhetoric (Kress, 2010). These are curriculum, time, physical space, resources and norms. Resources will be dealt with in each case both as part of the communication (e.g., how entities are expressed through different modes) and separately in a discussion on how various artefacts are used in the case. Curriculum is described in chapter 3. The competence aims connected to the subject matter in practical work and inquiry are presented at the start of each case, chapters 6-8 and what they might entail. The curriculum will be dealt with further in chapter 10 where the science curriculum provides the starting point for the literature review.

### 5.7.1. Time and space

Time is a means for controlling and regulating behaviour. The teacher regulates the students' behaviour through giving signals to start, stop and by giving students time to respond. This is what van Leeuwen (2008) calls time summons.

> When a time summons is personalized, it is given by someone who has, in the given context, the right to authoritatively time the activities of another participant or type of participant. This right to time has always been a sign of absolute power. (ibid. p. 76)

During a teacher's introduction, there will be (and have to be?) time summons in the transition between activities that occurs in whole class and group activities. The time summons for ending an activity might be explicitly given to all students or it might be given directly to each group as they are (in the teacher or students' opinion) finished. When teacher asks questions there is a different type of time summons, the teacher *gives* the student an amount of time to answer. For a further elaboration, see section 5.7.2.2. The experience of time and duration is subjective. The teacher will (most likely) experience the time given as different (and longer) than the time the students receive (van Leeuwen, 2008). However, for students, it is important that they as learners have time to make meaning of what they are doing.

Schooldays are divided into timeslots. There are regular breaks and sometimes breaks indicate shifts in location, when students and the teacher have to go to another room. This institutionalized time and space have implications for how both teacher and students relate to the subject matter and each other. The introduction must be done before the break, and the students' inquiry must be finished in time for lunch and so on. There is thus external pressure on all participants.

Power relation is also prevalent in how the space is constructed and used. This can be students' seating arrangements or what postures the teacher allows (Jewitt, 2006) and the position of the teacher in the room (van Leeuwen, 2008). As part of the context, the space of the classroom itself is important, whether it is light, has space between the desks, gives a 'friendly atmosphere' or not, all of these things have bearings on the communication, if indirectly. The layout of equipment has a more directly impact on the communication in practical work and inquiry. When the teacher prepares for practical work, she has to decide where to put the equipment, the props students are to use. Shall she give it directly to the groups, or shall she place it on the teacher's desk in front or at another table. If the equipment is placed at a separate table or the teacher's desk this makes it necessary for the students to walk about the room. The teacher also has to decide whether the practical work is to take place at the students' desk or does it need to be carried out in the ventilation cupboard because of health and safety reasons. So, during practical work and inquiry, students have greater possibility to move around the room. They walk to get equipment, to wash it afterwards, to talk to some other student about something. In theoretical inquiries, there is a possibility for students to walk to the library or perhaps work outside the classroom. The teacher also moves around the room to guide students, how often she 'stops by' and what she does indicates some aspects of her relation to the students.

### 5.7.2. Text features to elicit norms

In this section, I will give an account for how I infer the norms from *what* is said and done in the classroom and *how* it is said and done. I will thus include the use of resources for making meaning. With a starting point in the texts, it is possible to make assumptions about norms and infer rhetorical framing of practical work and inquiry in this class. It is important to acknowledge that interpretation of norms is not the 'Truth', as other interpretations are possible. The purpose of the analysis is to make the assumptions as probable as possible. But it is important to bear in mind that rhetorical framing are not static. Rhetorical framing is situated and may change over time.

I choose to structure the features according to Halliday's metafunctions of language.

- The ideational metafunction expresses what is going on
- The interpersonal metafunction expresses how one relates to others
- The textual metafunction expresses textual cohesion

van Leeuwen (2005) writes

> Halliday stresses that language always fulfils these three functions simultaneously, and that there is no particular hierarchy among them – all three are equally important. (p. 77)

This means that interpretations of semiotic action divided into the metafunctions must be related to each other.

The ideational metafunction deals with subject matter, the content of communication. "*People construct representations of 'what goes on in the world' and their experience of the world through the ideational resources of a mode*." (Jewitt, 2006, p. 18). This is how we express our understanding of something. The ideational metafunction can provide participants' semiotic action regarding processes and entities, i.e. what they see as apt to express in these situations.

The interpersonal function deals with our relation with others.

> While construing, language is always also enacting: enacting our personal and social relationships with the other people around us. ... this is language as action. (Halliday & Matthiessen, 2004, p. 29-30).

This means that when we are communicating, the words we choose to say and our 'body language' give indications of how we relate to others. Our aim in communication is to relate to others, and we use modes such speech and writing, but also gaze or gesture (Norris, 2004).

The third metafunction, the textual, has

> an enabling or facilitating function, since both the others – construing experience and enacting interpersonal relations – depend on being able to build up sequences of discourse, organizing the discursive flow and creating cohesion and continuity as it moves along. (Halliday & Matthiessen, 2004, p. 30)

The textual metafunction deals with how we use resources as we see (most) fitting for conveying a message, and how we link together the text and how we link it to other texts.

According to van Leeuwen (2005), there are other notions of functions of language that also take into account aesthetic and other social elements of language, see e.g., Gee (2005). Although Halliday's metafunctions have been (and still are) widely used.

> But they have also been critiqued for being too producer-oriented and assuming that the act of interpretation is structurally determined, and for not allowing space for expressiveness and creativity. (van Leeuwen, 2005, p. 79)

Perhaps Halliday's division in three metafunctions is 'narrow' and misses some important aspects of language, but in this thesis I see Halliday as sufficient as it is subject matter and relation teacher-students and how these are expressed that are my focus. Emotive aspects of practical work and inquiry are backgrounded. Another reason for choosing Halliday as a way of structuring analysis is that this is a framework much used in critical discourse analysis (van Leeuwen, 2005).

The figure of how norms are inferred from semiotic actions can thus be expanded to

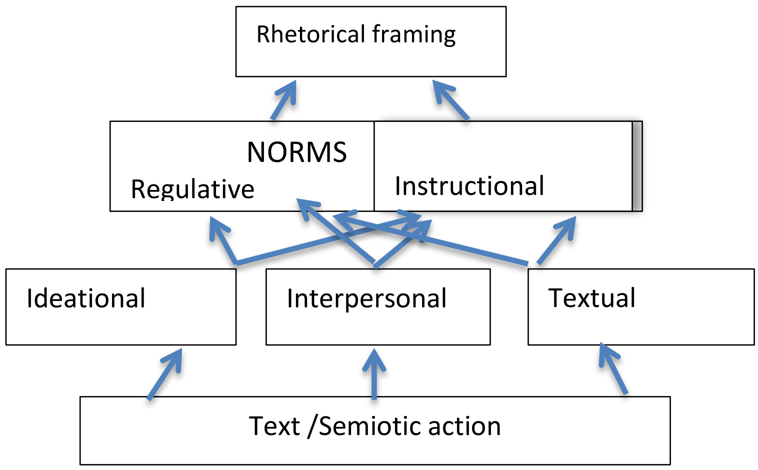



Figure 4 Inference of norms and rhetorical framing - expanded

#### *5.7.2.1. Ideational metafunction – text features*

The teacher wishes to support the students' activity when she is making the introduction to practical work and inquiry. The activities can be to manipulate objects, do observations and explain by using words. The teacher's introduction it is about supporting actions by structuring and highlighting what is seen as important. She is presenting the 'wished for actions'. Students are choosing how they will relate to the teacher's introduction. They adapt and transform 'the wished for actions' to what they see as apt in the situation. All the participants thus construe by language and action what is (supposed to be) going on during practical work/inquiry.

I look at the level of clause in the participants' use of spoken language. The clause can be structured in three main elements; processes, participants and circumstances (Halliday & Matthiessen, 2004). I will concentrate on processes and participants. Processes are realized through the use of verbs and the participants in clauses can be pronouns or entities.

I use Halliday and Matthiessen's (2004) classification system for transitivity processes. They divide processes into:

- Material – when someone is doing or creating something or something is happening
- Existential - when something exists
- Relational – when something has an attribute or having identity or symbolizing something
- Verbal – referring to somebody expressing themselves

- Mental processes such as thinking, feeling or observing (seeing)
- Behavioural

There is a gradual transition between the types of processes, and the clauses need thus to interpret the process in light of the situation in which it is uttered. I will not subdivide these processes further, e.g., by looking into transitive and intransitive material processes.

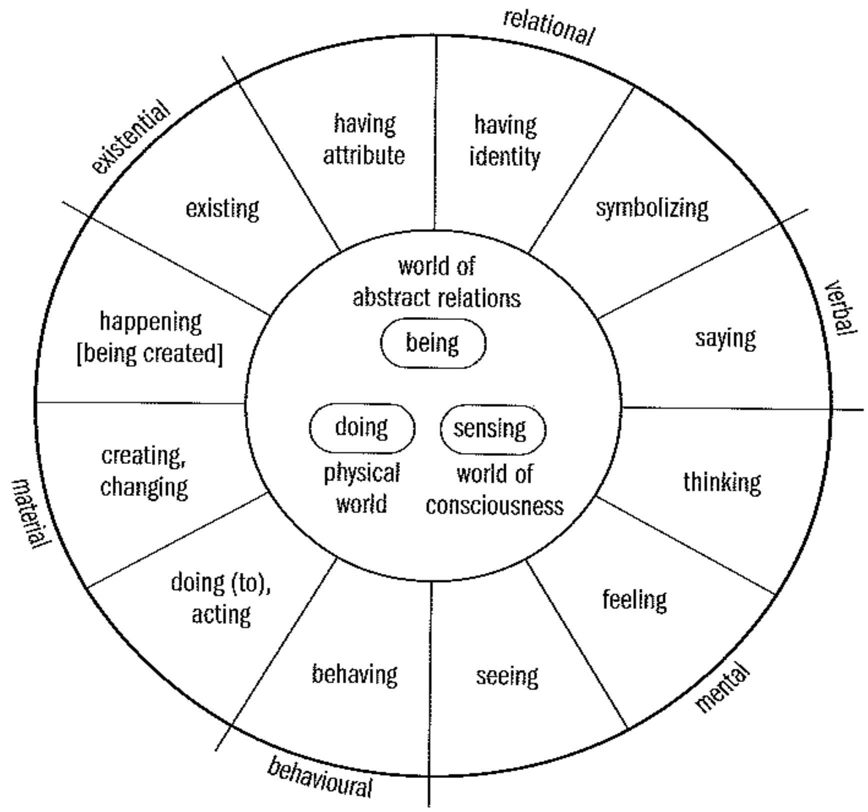



**Figure 5: Transitivity processes, from Halliday and Mathiessen (2004, p. 172)**

The participants in a clause are simplified to entities and pronouns. How the teacher expresses entities influences what is seen as important subject matter and how it is to be expressed. The entities are those artefacts/words that are to support students in their doing and meaning-making. In other words, the words and props the students are to use themselves. For example, if the teacher explains relations between entities as words in combination with artefacts/drawings, this may help students to obtain a firmer grip on what the entity means and then it might be easier to use during the practical work/inquiry and post-work. The teacher also acts as a model for what level of precision there is to be expected, the apt expressions for the phenomenon. By coding for the different entities, I can follow these entities throughout the text, and see how they are presented in different stages of the introduction, and how (and if) they are used by the students.

I look into how the teacher, in her introduction uses pronouns (I do not look into the students' use of pronouns). The pronoun will say something about who has the responsibility for doing what. Does the responsibility belong to me, you or us? The pronoun 'we' is often used by teachers as a way of expressing solidarity with students (Christie, 2005). It is thus interesting to see how the teacher shifts between the personal pronouns; I, you (singular)[8], you (plural) and we.

So, how is the analysis carried out? Let us begin with two examples:

1 Ellen said: ”*Then, I get lower pressure inside here*”

| Subject | process (being created) | entity |
|---|---|---|
| I | get | lower pressure |

Simultaneously she does:

2 The same message is conveyed through actions where teacher are supporting her explanations by using props (mode of action).

| Subject | process (material) | entity |
|---|---|---|
| Teacher | pulls | the piston |

(as she holds her finger over the air inlet and thus creates lower pressure)

What is going on? The purpose of examples 1 and 2 in combination is to establish a relationship between what is being created when you pull the piston and the entity 'lower pressure'. In example 1, this is verbalized with 'get' – lower pressure is being created. In example 2, pulling the piston (mode of action) is supporting her statement by showing how this is done. When students are interpreting Ellen's semiotic action they must, however, rely on that Ellen is telling the truth – there is actually lower pressure inside the syringe. But then, what is 'lower pressure'? How did the students carry out 'pulling the piston' and did they verbalize the connection with 'lower pressure'? Thus, there is a need to combine modes of action and speech in analysis as they support each other in the teacher and students' semiotic actions. 'Lower pressure' is one of the key ideas in this experiment. This means that it is important to see how this (and other) entities are used throughout the practical to infer the teacher and students' norms for expressing 'the language of science'. Is it important in this practice to use precise scientific terms? It is important in this thesis to see how entities are connected with processes (verbs). For instance, if the entity is observed it will result in a different impact on a stance toward epistemology than if the entity just happens (when some action is carried out).

It is my interest to investigate how the teacher expresses subject matter and methods with the implications it has for the students' semiotic work. The processes

[8] Norwegian distinguishes between you in singular form 'du' and you in plural form 'dere'.

of practical work and inquiry is about doing something on/in the physical world (material action), but it is also about observation and sensing as well as relating entities to each other (also creating abstract relations). It is reasonable that a procedure is based upon material processes (such as do, make etc.) (Halliday & Matthiessen, 2004). However, if there is emphasis on the material processes only, important aspects of supporting students in their practical work/inquiry will be lost. This means that the transitivity processes (verb) say something of what is seen as apt ways of relating to the subject matter.

Another example from the teacher's introduction is given below. Here she addresses task management.

> *Then I propose that you take notes on your pc or on paper*

Propose is an interesting word because in a school context it can be interpreted in several ways. First, it is possible to interpret it as: I say/advise you and you may do as you see fit. Second, it is possible to interpret it as: I say/advise you and you *ought* to take notes. Formally, both propose and write are verbal processes, but at the same time, this might also be seen as the teacher initiating a material process, as there is something to be done (take notes). However, both processes were coded as verbal processes. This example also shows something else – the use of personal pronouns. Ellen refers to herself as 'I' and to the students as 'you' (plural). However, very often, she uses the pronoun we, sometimes contrary to what is going to happen/happening, e.g., Ellen is standing by the board – writing a table:

> *let's see if we manage to get the alphabet in here (table)*

It is Ellen who is constructing the table or rather she is copying it from a task sheet. The students have no idea what this is so they have no possibility 'to get the alphabet in here' - they can only copy. So at first this seems to be an 'illogical' use of the pronoun 'we', but in class it can be an indicator of solidarity.

#### *5.7.2.2. Interpersonal metafunction – text features*

In the classroom during practical work and inquiries, spoken language obviously plays a central role in creating relation between teacher and students – and to the subject matter. Language is used by the teacher amongst other things to instruct students in what and how to do, provide guidelines for the outcome (e.g., report) and to pose questions to students. Students ask questions of the teacher, and they talk during the inquiry and their post-inquiry work – this 'talk' will divulge something about the students' relation to subject matter, the teacher and each other. According to Fairclough (2003), there are two major types of exchanges when people are talking. Talk is about the exchange of information and activity exchange. For instance, during the teacher's introduction she will give students information, but she will also give students instructions on what to do – demanding some activity. Here I adapt a slightly modified version of Fairclough's (2001; 2003) speech functions as a tool to describe the classroom talk. Fairclough gives five different speech functions; demand, offer, question, statement and acknowledgement. ”*These generalized speech functions could be elaborated in terms of many different ’speech acts’*.” (2003, p. 108). As I am not interested in a very detailed description of, e.g., what type of demands are made, I find it useful to apply broad categories.

Speech functions are context dependent. They have to be read as part of context. In school there are ’ways of talking’ that deviate somewhat from talk elsewhere, e.g., a question might not be a search for information, it can be a teacher checking whether a student ’knows’. In addition, the teacher has a right to decide what the students are going to do. This makes it possible to make quite strong demands without being impolite.

> But determining the speech function of a clause often requires taking account of social contextual factors. ( Fairclough, 2003, p. 118)
>
> The relationship between grammatical mood and speech function is a tendential one rather than a matter of simple correspondence. (Fairclough, 2003, p. 117)

When interpreting what type of speech function with which we are dealing, it is thus important to read the utterance in context of the other utterances. However, in addition, gestures and tone of voice adds information to that which is spoken. Communication is more complex than just the spoken words.

*Statements* Fairclough (2003) divides into three; statement of facts which deals with what is in the world; Hypothesis or predictions, i.e., that which might happen; and evaluations which deals with ’judgement’ of someone or something. There is no difinitive difference between factual statements and evaluations, as factual statements often rely upon (tacit) assumptions of what is seen as valuable (Fairclough, 2003). In addition, I find it useful to distinguish between degrees of certainty in a factual statement, whether it is absolutely true or not. Subject matter in science can be stated as absolute (true) facts or it might be given as tentative knowledge. The ‘degree of true’ will also relate to how well the body of knowledge is established.

The examples below are from Ellen’s introduction of heat pump – boiling under low pressure and condensation:
Factual:

> *When you make a reduced pressure inside here then the liquid will boil at lower pressure* (absolute true)

Evaluation:

> *One (of the liquids) is much easier to bring to boil*

Hypothetical:

> *You will probably not bring it to boil at low temperature*

*Demands* are often in the imperative mood (Hodge & Kress, 1993). Here I follow Fairclough (2003) and take a slightly different view. In the classroom, when a teacher says ’you shall do’, it is de facto an order/demand even if it is not in the imperative form. An utterance like ’you might (wish to) do’ allows a degree of student choice, but also here the teacher might be seen as the one who knows best and students will possibly want to do what they interpret as the teacher’s (implicit) position. I divide demands into weak and strong (Hodge & Kress, 1993). A strong demand, e.g., you shall do provides no real option for students’ choice. They might of course, show resistance. In many instances there are good reasons for a ’strong guiding’ of students’ activity, such as health and safety or that the inquiry will not work if the students do not follow the exact procedure. A weak demand, e.g., ’then you do’ can be seen as a requirement, but it is not so strongly put forward.

The examples below are from Ellen’s introduction of heat pump – boiling under low pressure and condensation.
Strong demand:

*We must have higher temperature here*
*This you must write down in a table*

Weak demand:

*Remember that you have to note down the temperature*

The combination of the pronoun ‘we’ and the teacher’s demand for students’ action might be seen as a way of weakening the demand. However, it is coded as a strong demand because it is a call for the students’ *action*, Ellen is not going to do this. The use of we can thus act both as a way of expressing solidarity but it can also be seen as blurring of responsibility. The weak demand above is lessened by the words ‘remember’ and ‘have to’. It is not ‘you shall write’ – which would have been a strong version of this demand.

*Questions* often play different roles in communication depending upon who is posing the question. When a student asks a question, it is (almost) always about seeking information. When a teacher poses a question, it is usually to test students’ understanding. The teacher-initiated questions usually form a sequence initiation, response and evaluation (IRE) or initiation, response and feed-back (IRF..RF) sequences (Mortimer & Scott, 2003). Often teachers tend to ask questions that require a short factual response from the students – the typical IRE sequence (Lemke, 1990). These types of questions have of course an important place in education as they may highlight what is important and help students remember important facts. That is to say, so long as these questions are not the only types of questions given. Type of questions has both a bearing on the students’ judgement of what is seen as salient in science and is a way of relating. To put it a bit bluntly, does the teacher regard the student as the person who shall remember facts or a person that can compile information and argue for a claim/statement, i.e., make connections? Questions can thus act as a way of controlling behaviour.

Fairclough (2003) divides questions into two categories. One type of question can be answered by a simple yes or no or a single word. Another type of question is that which requires an elaborated response. The latter are typically questions that start with wh.. (why, when, where, what and how). When the teacher poses a question, it is within her power to decide how long she wants to wait for an answer. It is also the teacher who usually decides who is 'allowed' to answer.

Short response question:

*Is this okay – do you understand?*

Elaborated response question:

*What happens then?*

However, a student may choose to give a very short response also to a wh-question, but it is unlikely anyone would answer with yes or no. I have coded wh-questions, which require one word answer (fact), as a short response question. This is because giving facts is a very different way of relating to the subject matter than, e.g., giving explications or longer descriptions.

*Offers* are rarely heard in classroom speech, but there is (as I see it) a sub-group of offers that are more frequent: choices. Sometimes the teacher allows students a choice between different options. It then becomes the student's responsibility to make the choice.

The coding of speech functions can be summarized in the following table

| Speech function | Sub-groups | Additional coding |
|---|---|---|
| Statements | Factual | Certain |
| | | Uncertain |
| | Evaluation | |
| | Hypothetical | |
| Demands | Strong | |
| | Weak | |
| Questions | Short response (yes, no fact) | Response - Response time |
| | Long response | Response - Response time |
| Offers/give choice | | |

**Table 3: Overview of coding speech functions**

As a short comment on grammatical mood, Hodge and Kress (1993) provide examples of how the spoken language can act as a marker of degree of 'closeness' or formality. In contemporary Norwegian, there is little use of 'formal phrases' and a student would rather ask 'can I get a postponement of this assignment' (or just deliver it when it suits the student) rather than ask politely 'could I please get a postponement?' One of the other traits of contemporary Norwegian, is that everybody calls everybody else by their first name. However, this is not to say that there is total 'equality' between teacher and students. Authority or position of the teacher is not so much given as it is negotiated. In this analysis, grammatical mood is not addressed.

#### *5.7.2.3. Textual metafunction – text features*

The textual metafunction acts as a vehicle for transporting the other two metafunctions, so it always plays a part in communication. The textual metafunction deals with the internal and external cohesion of the text, how it connects to itself and to the texts around it. It thus says something about what kind of connectors the rhetor sees as appropriate. For example, if there are references to texts outside or implicit connections are used. In this thesis, I will look into two aspects of the textual metafunction; modes and cohesion.

*Mode*

When the teacher is presenting the practical work/inquiry or the students carry out their practical work/inquiry, they use different modes simultaneously. They choose those resources they see as most apt in the situation from those available. Expressions will have different connotation depending upon mode: telling what to do vs. showing what to do is not identical, see also section 5.2.3 for modal affordance. The interplay of modes (speech, action, drawings, writing, hand movement) is important to vehicle science content (Kress et al., 2001). Choice of resource for making meaning is subject to social evaluation (Kress, 2010). The teacher will thus set the ground for what resources to use and how to use them. The students will adapt to this, but they may also express their understanding in other ways compared to teacher.

Here I am especially interested in how different entities are expressed in different modes and how entities are connected to each other. The entities the teacher presents in her introduction are those with which the students are to think when they make meaning of the practical work/inquiry (Ogborn et al., 1996). I thus see a distinction between resources to think with vs. think about (phenomena). To do this, I use 'entity – chains', to be able to identify how the different entities are expressed (in which mode) over time.

*Text cohesion*

To see how clauses are linked together I will look into relations between them. This is because in science (and probably most other school subjects), it is important to give reasons, causal explanations. The teacher acts as a model for the students' spoken language. Wellington and Osborne (2001) claim that many students (secondary school) have problems with logical connectors.

Fairclough (2003, p. 89) identifies as relations between clauses:

- Causal (reason, consequence, purpose: because, so, then, consequently.. )
- Contrastive/concessive (but, anyway, on the other side..)
- Conditional (if-then)
- Temporal (when, next, then, first …)
- Additive (and, or, ..)
- Elaboration (exemplification, rewording)

Causal, contrastive and conditional are widely used in science explanations and argumentation, while temporal and additive connectors are used frequently in descriptions.

### 5.7.3. Summing up text features to elicit norms

I have given above the coding framework that is used to elicit norms from the text. The texts are coded in the three metafunctions:

Ideational – what is goes on in the world. This has three aspects:

- Transitivity processes (what type of verb is used)
- Entities (what entities are used in which mode and how are entities connected)
- Pronouns (who is going to do)

Interpersonal – how are relations to students expressed

- Speech functions (statements, demands, questions)

Textual – how text is connected to itself and other texts:

- Mode and means
- Textual cohesion

The three metafunctions jointly construe meaning. Norms will however not be explicitly expressed. To infer norms from the text requires a search for patterns in the participants' semiotic actions. That which is the usual way for expressing will say something about what the participants see as apt and appropriate under the circumstances.

The first step of generating patterns is to combine speech functions, transitivity processes and pronouns. For example, how the teacher's strong demands are coupled with material transitivity process and actor (e.g., 'You shall do…'). To seek patterns I count frequencies of different combinations of speech functions, transitivity processes and pronouns. When a 'you shall do' pattern is established, I have searched how this pattern is occurring in combination with text cohesions. Is 'you shall do' followed by '*and then* you do' or '*because*'? These two different cohesions lead to very different epistemological bearings. Text cohesion is part of how procedure and methods are argued. Are there given reasons (e.g., because) or is the procedure given strictly sequential, which adds one element of procedure to another? These choices made by the teacher in her introduction create some expectations among students of what a (school) scientific procedure is.

Then I explore how entities are expressed. How the entities are used (e.g., level of accuracy) will provide information about how the teacher and students relate to scientific knowledge and the 'language of science'. Is it important to use the 'correct' words? Does action support verbalized entities or does the action contradict that which is spoken? With the addition of text cohesion, it is possible to identify if this knowledge is just presented or if it is reasoned. In combination with speech functions, one might say something about if the science entities are questioned or are they presented as true facts. Transitivity processes in combination speech functions add to this picture. For example, are entities to be observed (mental process where the observer is actively construing) or does the entity happen (material process unconcerned with the persons involved)?

As stated earlier it is important to see what is not present in the texts. Are there speech functions or transitivity processes that are rarely or not used? The absence of processes, entities, cohesion or speech functions say something about that which is *not* important, *not* apt in the circumstances. This 'absence' in combination with what is present in the text can strengthen claims for norms, as the choices made will result in political or ideological consequences.

However, I have to admit that the analytical process has not been as tidy as the description above. To infer norms has been far more than just counting frequencies. Most of all it has been about connecting parts of text to the whole (context of the day) as well as to assess (based on the field experience) what is seen as 'good' and 'proper' in this class. This means that I am drawing on the whole of my field experience when inferring norms cf. the ethnographic approach to fieldwork (section 2.3) - some of this experience is (still) tacit.

## 5.8. Practical analysis

The analytical process is an on-going process during a research project, from start to finish. During fieldwork, I had to make analytical decisions, e.g., of what to video record and what was important to talk to Ellen about. As the research aim and questions have changed since the fieldwork at Hill, this has had some implications for the practical analysis. For instance, I wish I had more footage of the teacher's introduction on the 'Budding researcher day'. However, during fieldwork, I did not think that day would become significant in my work, because so many of 'my' students were absent. The analytical process has continued by finding a framework and ways of interpretation that make it possible to answer the research questions, and to the final presentation of the material for the reader. The entire process has thus involved many choices, some deliberate and some perhaps more based on 'hunch'. In this section and the two next sections, I will try to make explicit the choices that were made after fieldwork.

### 5.8.1. Transcriptions and translations

Transcriptions of whichever mode, are a reduction of material (Flewitt, Hampel, Hauck, & Lancaster, 2009). It is a transduction process in which "*analytical insights can be gained and certain details are lost.*" (Bezemer & Mavers, 2011, p. 196). So, 'accuracy' of a transcription does not so much depend upon the degree of closeness to reality as to what degree it facilitates a professional vision (ibid.). Transcription is thus semiotic work done by the researcher as it involves agency in the form that I had to interpret, make selections and choices. Transcription is thus a recontextualizing in the sense that the activities that are transcribed are placed into a new social context – the context of academic writing (ibid.).

Transcription of multimodal data requires solving several problems. What is considered important data? How to ensure good quality in the resulting transcriptions? There is more empirical material than is possible to transcribe. My solution to this is to divide the material into what is considered be material for the texts and contexts. The empirical material that would be inferred into the context is mostly roughly transcribed. Roughly transcribed means that only those parts that are considered to have direct influence on the case are accurately transcribed, the rest is written in the form of short résumés. Those parts of the data files that are to form the text (i.e., input to the text analysis) are thoroughly transcribed. This meant that first step of transcription has been to get an overview and make a division of text - context. The next step was transcribing one of the modes (action or speech). After this first transcription, the other mode was transcribed. I did several revisions to ensure accuracy. The revision involved watching the video without sound to see if there were actions that were missed, and listening to the audio (without watching) to ensure accuracy in transcription of speech as well as watching *and* listening to ensure that action and speech were synchronized in transcriptions. Watching the video was in real time. I did not use a frame-by-frame transcription. The real-time decision can be argued for by claiming that it provided sufficient level of details.

Then there is the problem of how action and handling of artefacts are to be presented (Flewitt et al., 2009). There are different styles of how to transcribe and present multimodal data (Bezemer & Mavers, 2011; Flewitt et al., 2009). These will of course depend upon analytical framework and research questions. For my research questions, I identified action (handling props and hand movement that supported speech) and speech as important and to some extent writing and time. I chose to represent action and handling of props by verbal descriptions, not images. This decision was partly practical. It was easier (i.e., faster) to represent actions verbally and I considered it provided sufficient quality. The other reason for this decision was that I did not want there to be footage of the participants in the thesis to ensure anonymity (see also section 5.10).

Transcription of speech also involves making choices. Oral language is different from written language in many respects (pacing, tone, pitch and volume) (Kress, 2003). There is thus a transduction from oral to written language. Kvale (1996) points out that the researcher has to decide whether the transcript should be close to oral language or transformed into a more correct written language. I have chosen to stay rather close to oral language, with some modifications. I have not transcribed, e.g., harks or sighs. Dialect words are given a written form according to the Norwegian dictionary, but the sentence structure is left unchanged. As oral language looks ’simple’ when printed (perhaps even more so in a written academic text), this results in an ethical dilemma. Should I be close to the data and thus represent the participants as what might be seen as unsophisticated language users, or should I present data where the participants ’look better’ in the written text? I have chosen to stay close to their actual utterances in the transcriptions. The primary reason for this decision is that the purpose of the analysis is to dive into their speech (and action), which means that sentence structure has to be as accurate as possible, as well as the participants’ choice of words.

My transcripts are written in Norwegian, in a tabular form where time goes 'downwards'. The modes of action and speech are separated, where action is put to the left in the table. In addition, I am faced with yet another significant problem. It is concerning translation from Norwegian to English. There is not one-to-one mapping between these languages. Because I am not a native speaker of English, I found it difficult to translate meaning – and the right level of precision of the participants meaning. In particular students who are not very accurate in their use of scientific terms (– they are learning!) were hard to translate. To ensure quality in translations, I used a professional translator to control the translations presented in the thesis.

### 5.8.2. Coding and tools for coding

Codes are category labels. They help to identify and structure the material (Miles & Huberman, 1994). Coding of multimodal data is a cumbersome process as coding involves labelling both physical action and speech. When the goal is to analyse large material, an open scheme for coding is difficult to apply as the material can be interpreted in many ways (Miles & Huberman, 1994). Therefore, it is advised to start the analysis with a strong theoretical framework and good research questions (Derry et al., 2010). So, I have started out with an analytical framework that I have used as a 'grid' on the data. This process has been repeated, where the coding has led to refining the framework and research questions and thus to new or elaborated codes. This can be seen as an iterative process where theory and data, including context, inform each other.

The codes I use are somewhat semi-descriptive, as they are close to data but theoretically driven (and named). *"(D)escriptive codes; they entail little interpretation. Rather, you are attributing a class of phenomena to a segment of text.*" (Miles & Huberman, 1994, p. 57).

Coding was done on transcriptions with the video running simultaneously. This was to ensure that pauses, volume, pitch, etc. were part of my interpretations. This was important, as I had not transcribed pitch, volume and intonation. It was difficult to code directly on the video material because of the fine-grained framework described in section 5.7.2. The program for analysis (ATLAS) did not make it possible for me to mark the start and end points of codes with the level of accuracy I desired. This meant that I coded on the transcripts. Moreover, ATLAS made a 'mess' of my transcriptions (which were on a tabular form) as ATLAS did not keep the visual connection between the columns for action and speech. In addition, there are many codes, some also overlapping (e.g., speech functions and transitivity processes). This made coding in ATLAS look more like chaos in colour. In the end, I chose to code on paper with the use of coloured pencils for transitivity processes and cohesion. Speech functions were labelled for each utterance (e.g., D-s = strong demand). Coding on the printout of transcripts also made it easy to connect action and speech and to see a part in connection with the whole. This is probably a very old-fashioned way of coding, but it allowed me to see each utterance and action in connection with the rest of the text, which was an overview I lost in ATLAS. The problem of coding on printed transcripts is, however, that it is more difficult to count elements in each code – and to merge codes. Another problem is that every time I changed the framework I had to start new. So, coding on printouts of transcripts are easier to do and to make connections within the text, but more difficult to summarize.

The coding was done in several steps. I divided the teacher's text into regulative and instructional. Then I coded each of these separately. The students' text was coded after the coding of teacher's text. This was done to see how students 'responded' to the teacher's introduction. The students' text was only coded regarding the instructional aspect of communication. This meant that I have only to a small extent seen how they, e.g., regulate each other's behaviour. The final coding of the cases was done close in time to ensure as equal a coding practice as possible.

## 5.9. Analysis and ethics

Researching teaching and learning with a focus on action and speech have involved some ethical considerations. Communication, teaching and learning are very 'personal', and are closely connected to who we are and how we perceive ourselves. Video 'gives away' more than audio recordings, as one can see facial expressions, posture and hand movement. Multimodal discourse analysis scrutinizes action and speech. The analysis of text is thus 'enlarging' small unities before seeing these in connection to the whole. I have experienced that a multimodal discourse analysis is a very 'close up' analysis; few things are too small to look into and to write about. This raises a number of dilemmas or problems.

Surprisingly little is written about multimodal analysis and ethics. There is a great amount of literature concerning ethical approval of projects in advance, the importance of obtaining participants' consent and ethics during fieldwork. The approach to research ethics is often 'technical', but never the less important and was dealt with in section 2.5. However, literature concerning ethical dilemmas and choices during analysis and presentation of results is sparse.

First, I want to draw attention to the video footage as a starting point for analysis. As my focus is on science inquiries and nature of science, this means there is not much interest in the participants' feelings (or lack of such). Video footage also shows the little imperfections which we all have. It is, however, necessary to describe these 'imperfections' when I believe they are important for interpretation. Moreover, teaching and learning often involve pragmatic choices that perhaps cannot be described as 'best practice'. This means during analysis I often had to check myself and my attitudes toward the 'imperfect' – or as it also might be called: 'real life'. Hindsight is easy. It has thus been important for me to try to provide truthful descriptions, to do the participants justice. In developing an inquiring attitude during data analysis, I have tried to avoid prejudging the practice. However, I have to admit this has not been easy for a problem oriented – and normative – researcher/teacher.

During the analysis, I was astounded to notice that I no longer thought about the participants (Ellen, Beatrice, Fiona, Ingrid, Sheila and Peter) as real persons. They had become 'semiotic actions'. By dividing the socially construed texts into small data bits, did it dehumanize the participants? I did not think of them by real names or as ordinary and nice persons during analysis, they have become fragments of texts. To remedy this problem, I regularly think of them as real persons.

As this project has been evolving over many years, the perspectives I brought with me into the field are different from those I have when analysing data. However, it must be said that the aim is much the same: science for all students – also for those not very interested in (school) science. During the last year of collaboration, Ellen and I agreed to focus on 'semiotic resources'/'semiotic objects' as a way of dealing with the subject matter. The perspective of rhetorical framing, which I now find very useful, was not present during the collaboration with Ellen. As this has been brought in after our collaboration ended, I did not talk to her about the framing of communication. Therefore, I cannot claim that she was 'warned' and thereby had the opportunity to reject participation in the project or change the course (of the project). As I was invited into the classroom by Ellen, this is a significant problem of an interesting research focus versus standing by the in advanced agreed-to focus. To remedy this, I have had some conversations with Ellen to inform her of my findings and asked for her comments. However, Ellen has had no direct influence over what is presented in this thesis. I have not seen it as possible to obtain comments from the students as they have finished at Hill by now.

## 5.10. Writing out the analysis

The material presented in this thesis is excerpts of a much richer data material, though not all can be shown. It is important to show how the excerpts relate to each other and to the context. This is the reason why I, in presentation of the cases, will allot a large amount of space to describe context. The interpretation of part vs. whole (i.e., text vs. context) is important as the details are often difficult to understand without a thorough description of context. The context is part of the explanation of the texts (Fairclough, 2001). On the whole, this is the reason why I chose to write a monograph and not journal articles, because I saw early on that the context would be important and that it required more thorough descriptions than that which is allowed in an article. The context is especially important for understanding the teacher's choice of actions. In our school tradition, we see a teacher as a person who 'knows' and 'does the right things'. Ellen is a 'good teacher' – but her practice is not always at its best (my teaching practice is also not always at its best either, so I firmly believe this is 'normal'). Practical work and inquiries are complex and there are many choices to be made (Barnett & Hodson, 2001) and Ellen has to make choices from what she believes is best given the situation. Thus, the aim of the presentation the empirical material is to provide descriptions and interpretations that are reliable and make sense within this situated practice.

Writing out the cases involves yet another problem, which is concerning the right to interpret and put labels on that that is occurring. There is significant power in labelling and the academic style of writing extends the gap between social action and the final writing (Hodge & Kress, 1993). Although I am open to that, there could have been a wide range of other interpretations, as these interpretations are based upon my interests (Kress, 2010). There is something definite about written texts, which makes me a bit uneasy. To remedy this uneasiness, I have tried to wield this power to the best of my ability and have tried to find different interpretations.

In discourse analysis, it is customary to provide long excerpts of text and then an interpretation and connection to context (Neumann, 2001). I have chosen not to do so. Normally, the excerpts will be quite short and grouped together after what they are dealing with. The reason for this is based upon the following argument. If there are long excerpts, they will be dealing with different sorts of content, e.g., some steps of procedure, elements of regulating behaviour and connecting procedure with subject matter. This means that interpretations will be distanced in space (or pages) from the excerpts. By choosing to give short excerpts, the excerpts can be grouped thematically (e.g., those relating regulating to students' behaviour) and the interpretation is closer in space (page), which hopefully also provides some benefits to the reader. It becomes easier for the reader to see how I interpret the excerpts and this leads the reader to more easily form other interpretations – perhaps to contest mine. Interpretations are important and semiotic actions have several possible interpretations. This is the reason why I choose to give different interpretations where I can – and would be glad if the reader forms alternative interpretations. In the presentation of the results of text analysis, there is always given time on the excerpts. This means that the reader has the possibility to reconstruct the text. Time is not given to excerpts from context but these excerpts are ordered chronologically.

Some (e.g. Norris (2004)) choose to use footage as the primary mode for presentation of action. This has, though, some ethical implications as the subjects are easily recognizable (Bezemer & Mavers, 2011). As I do not want the participants to be recognized, footage is not an option in my transcriptions of action. I have chosen to represent action in writing and not, e.g., drawings because of convenience. Drawings are 'closer' to video footage than writing, but in such a large material drawings would be extremely time consuming. The mode of action is included in the excerpts when it adds vital information. Otherwise actions are primarily presented as summaries before or after the excerpt. This is a pragmatic choice as including all action will require more space.

*The structure of the empirical chapters is as follows:*
Each of the cases begins with an overview of the material that is used to write out context and text. Next follows a short description of the subject matter, including competence aim from the national curriculum. The description of subject matter is not a direct résumé of Ellen's presentation, but my re-representation of it.

Because it is important to see the texts in relation to context the third section of each case is a presentation of the close context. The close context will of course vary between the cases, as these three science days were different in topic and structure. The context includes Ellen and me planning the day, a résumé of other activities, post-practical work and Ellen and my evaluation of the day.

The fourth section provides an overview of the case – and what the practical work/inquiry entailed. After a short presentation, this section is divided into regulative and instructional. The regulative domain of classroom communication is dealing with behaviour, task structure and organization. From the combination of context, text description and interpretation, I will infer provisional regulative norms. The presentation of the instructional domain of communication follows the same structure as the regulative, but here the text deals with procedure and methods, the 'language of science and scientific knowledge. I will infer provisional instructional norms.

Each of the case chapters ends with combining regulative and instructional norms with other aspects of framing, such as physical location and curricula aims. From this, I infer the rhetorical framing of the practical work/inquiry.

### 5.11. Summing up the analytical toolkit

In this chapter, I have provided a social semiotic view of communication as a starting point for interpretation of communication in the science classroom. This view entails that the participants have *interest* and *expectations* and that they construe meaning together by expressing themselves and interpreting the others. The meaning construed has both a 'what' (signified) and a 'how' (signifier) component. The *resources* for communication (how – signifier) influence the meaning expressed and the participants use the resources they see most fitting for the purpose of expressing themselves. The expressions of meaning, or what I prefer to call *semiotic actions,* can thus be distributed over several *modes*. The students and teacher's semiotic actions can express themselves in another mode (transduction) than the original message (*transduction*), or they can use the same mode as the original message (*transformation*). Either way, they have a *choice* of what and how to express.

I see communication through a rhetorical perspective where *rhetoric* deals with the deliberations of what and how to present. As a part of this rhetorical perspective, there is *power* as the communication (actively) shapes the participants. Power is part of the relation between the teacher and students, and the teacher as the *main rhetor* sets the agenda. Where there is power, there will be *resistance* but also *solidarity* between the students and between the students and teacher. There will be a difference between the students' experiences and subject matter. There are also differences between assessments of results as well as approach to methods. To address *difference* is thus part of shaping students' view of science and *challenging* students' meaning-making is vital in this respect. Another aspect of power is *time summons*, these can be institutionalized or personal (e.g., teacher calls for attention or decides response time to a question). *Physical space, curriculum and resources* also play a part in shaping the participants' semiotic actions.

School has the purpose of conveying science to students. What view of science is taken in the situated practice does not necessarily correspond with the national curriculum, as there is not a one-to-one mapping because there has to be *interpretation of the curriculum*, subject matter as well as the participants' interest and expectations.

*Rhetoric framing* is seen as an analytical device impacted by *norms* toward science (*instructional*) and *norms* toward social and task structuring aspects (*regulative*), in addition to *physical space*, *time*, *resources and curriculum*. This framing marks the boundary between what is seen as appropriate ways of relating to practical work and inquiry – and what are not.  The framing is an on-going process that shapes the participants cf. a social semiotic view of communication and thus the frame (the product of the process) will not be static.

Norms are seen as perhaps the most important influence on the process of framing, as they are generated over time according to the participants' interests and expectations. Norms (as well as rhetorical framing) are not directly observable, and must thus be inferred. To infer the norms, I divide the texts for analysis into Halliday's three metafunctions (ideational, interpersonal and textual). In the ideational metafunction, text features are; *transitivity processes* (verbs) which say if it is a material, existential, relational, verbal, mental or behavioural process. In addition, I look into *entities* and how they are related and *personal pronouns*. The processes, entities and pronouns provide information on what is going on, how practical work and inquiry is expressed. In the interpersonal metafunction, I look into *speech functions (statements, questions, choices given and demands*). The speech functions give an impression of how the participants relate to each other and subject matter. The textual metafunction is analysed with respect to *modes* and *cohesion*.

The method for analysis is labelled *multimodal discourse analysis* and draws on both perspectives from critical discourse and multimodal social semiotic analysis. Key points in the analysis are to combine what and how in the participants' semiotic actions. Another key element is to interpret the semiotic actions in view of the context. From coding of the text features, there is emerging patterns of frequent combinations of speech functions, transitivity processes and pronouns. Entities, modes and cohesion provide patterns in how subject matter is expressed. In addition, there are some things that are not expressed (and thus not seen important). This creates a possibility to argue for existence of particular norms in each case. In the cross-case discussion (chapter 9), the overarching norms are inferred as well as some general traits of rhetorical framing of practical work and inquiry.

The analysis was practically carried out by multimodal transcription of the video material, the transcripts were then coded for the text features before inferring norms and rhetorical framing.

# 6. HEAT PUMP – FIRST CASE

This chapter is a description and interpretation of practical work connected to the explanation of a heat pump. The chapter is structured by first giving a description of the data material used to construct the case and the boundary between text and context. The second section is a short presentation of the subject matter, the heat pump, and how it is related to competence aims in the curriculum. The third section is a presentation of context, i.e., what happened the day of the practical work and the next science day when Ellen summarized the practical work and explained the heat pump. The fourth section is the text analysis. This section is divided into two parts; regulative and instructional. Each part provides a description and interpretation of the teacher as well as the students' semiotic actions, and provisional norms are inferred. In the final section, the rhetorical framing is inferred.

## 6.1. Case material and boundary

The practical work was carried out on March 9th. Ellen gave an explanation and the students worked with a (new) report on March 16th.

The data materials for this case are as follows:

| | Material - duration | Transcription |
|---|---|---|
| Context | Field notes March 9th and 16th | |
| | Audio Ellen and Gerd planning in February. Approx. 1 hour | Roughly transcribed (other parts of content such as solar cell not transcribed) |
| | Audio Ellen and Gerd planning week before the practical work. Approx. 1 hour | Roughly transcribed (other parts of content such as solar cell not transcribed) |
| | Audio Ellen and Gerd planning week after the practical work – but before Ellen's explanation. Approx. 1 hour | Roughly transcribed (other parts of content such as solar cell not transcribed) |
| | Audio Ellen and Gerd evaluation after the practical work – but before Ellen's explanation. Approx. 8 min. | Roughly transcribed |
| | Video Ellen explaining heat pump – and practical work March 16th. Approx.. 30 min. | Transcribed: speech board |
| | Audio Ellen and Gerd evaluation after the explanation March 16th. Approx. 53 min. | Roughly transcribed |
| | Audio group of students writing report March 9th. Approx. 50 min. | Roughly transcribed (much background noise). |
| Text | Video Ellen's introduction. Approx. 30 min. | Multimodal: action, board (writing/drawing), speech |
| | Video group of students doing. Approx. 25 min. | Multimodal: action, speech |

Table 4: Data material for heat pump case

The planning sessions are a part of the context as this planning left its imprint on what happened during the practical activities. Some statements from our planning are however presented in section 3.5.3. The evaluation provides yet another input for how Ellen expressed this practical work.

On the beginning of March 9th, the students completed a task on batteries. The rest of this science day (six school hours), was the heat pump practical work. The last part of the day, the students worked with the report. When the group of students (Ingrid, Sheila, Beatrice and Peter) wrote the report afterwards, there was much background noise because all groups of students were talking. This means the quality of the audio is so poor that it is impossible to make it an object of detailed analysis. A detailed analysis requires that it is possible to hear exactly what is said. This is especially important as the students go a bit back and forth in constructing the report. The audio material from writing the report has thus to inform the context and cannot be seen as part of the text.

The next science day is seen as part of the context. On this day (March 16th), Ellen summarized the practical work, explained the heat pump and reformulated the task of writing the report.

There are five smaller practical work activities in this case. Ellen introduced them in one sequence, in what might be seen as an overarching structure by using driving questions. The terms used to describe and explain the activities are together the terms needed to explain the heat pump. Students carried out these practical activities afterwards, but not necessarily in the same sequence as Ellen's presentation. I choose to see these activities as one case as the overall objective is to explain the heat pump. If I had chosen to see the activities separately, this would have become a nested or embedded case. However, then it would have resulted in some problems of boundaries between the embedded cases, as they sometimes overlap, especially in students' work.

## 6.2. Heat pump; curricular aim and overview of practical activities

In the beginning of March, the topic was the heat pump as part of the theme 'Energy for the future'. The competence aim in the national curriculum states:

> The aims for the education are that the pupil shall be able to
> - explain how heat pumps function, and in which contexts heat pumps are used
>
> (Utdanningsdirektoratet, 2006)

This is one of six aims in this theme.

The students are supposed to be able to *explain* the heat pump. What is the entity or entities to be explained[9]? On a rudimentary level, one can say that heat pumps transports energy in the form of heat from one place to another. The basic principle is that heat is always transferred from a place where there is (relatively) high temperature to a place with a lower temperature. The energy transfer in the heat

[9] Explanation is a 'tricky' word, as it might mean several things. An elaboration on explanations is provided in section 10.4.2.

pump involves a medium in a closed circuit driven by a pump or compressor. There has to be some energy into the system to get some (more) energy out. The medium goes through several phase changes during its circulation in the circuit. There is boiling under low pressure – when the medium gets the energy from the energy source (e.g., the air outside). In the compressor, the steam is compressed (the medium then has high temperature as well as high pressure). The medium then reaches the point where its energy is transferred to a place with a lower temperature (e.g., the air inside the house). This results in energy loss in the medium, which condenses, and increased temperature in the surroundings (inside the house). The last step in the heat pump is a valve that reduces the pressure in the medium before the medium can start a new circuit.

The above is not a retelling of Ellen's explanation, although all terms were used when she described and explained the heat pump on the 16$^{th}$. This short introduction to the heat pump serves as a backdrop for the practical activities presented later in this chapter.

My short and rather simplistic overview of the processes in the heat pump is mainly *descriptive,* as the sub-processes are not explained. There are several vital entities in this description; medium, temperature, pressure, heat, energy, valve and compressor. The most difficult entity for students is perhaps 'heat', as it in 'everyday' language might mean 'hot' and not energy transfer. Some of these terms can be explained in at least two different ways; a micro and macro level. The description above is at a macro level, whereas a micro level description and explanation would involve molecular movement, kinetic energy, etc. Therefore, concerning the competence aim this means that students should be able to explain all processes in the description above (boiling under low pressure, compression, condensation, and pressure reduction). Alternatively, one could perhaps read the level of detail in the competence aim as: 'the main task of the pump is to transfer energy using the principle of heat'.

According to the national curriculum, the students should have worked with gasses and states also by using the particle model in years 5-7. In years 8-10 there is a competence aim related to energy, but it is 'squeezed' in between two aims dealing with motion. Thus, it is reasonable to interpret this as mechanical energy. To students (as well as other people), it is not so easy to see the connection between thermal and mechanical energy. This means that if the students did not arrive at Hill upper secondary with the 'baggage of terms' such as 'temperature', 'heat', 'energy' and 'pressure', this would be quite new to them. (I never investigated whether or not these terms were explained and used in years 5-7 for these students.) In the autumn, there was a short introduction to heat and temperature as part of the theme 'global warming', but this was never mentioned by the students or teacher during their work with the heat pump.

The heat pump, whether from air to air or ground to air, has in later years been a popular energy source in many Norwegian households. So, perhaps the heat pump was supposed to be interesting for students?

The practical activities were in the order of Ellen's introduction:

- Reduction of volume – change in temperature?
  Strongly guided 'see & feel' practical work where a syringe was used as a prop
  Presented by Ellen as no. 1
- Boiling under low pressure
  Guided experiment – comparing two different liquids, each at three different temperatures. A syringe created low pressure. Water and isopropanol were used as 'mediums'
  Presented by Ellen as no. 2
- Evaporation – change in temperature?
  Strongly guided – all groups did this 'see & feel' under Ellen's supervision. Ellen handled the data logger. There is no footage of students and Ellen doing this, because two groups did this at the same time – which prevented me from video filming cf. section 2.5.
  Presented by Ellen as no. 3
- Expansion of volume of heated liquid
  Strongly guided 'see & feel' practical activity, where a flask (Erlenmeyer type) was used. A glove finger was used as a substitute for a balloon to create a closed volume. The 'medium' was water.
  Presented by Ellen as no. 4
- Condensation – reduction of gas volume
  The opposite of the above expansion 'see & feel'. Same props were used. When the steam inside the closed volume transfers energy to outside the steam inside the flask takes less room since it condenses.
  Presented by Ellen as no. 4 – the opposite
  (The order of number 4 and its opposite was reversed in presentations two and three)

## 6.3.Close context

*Planning*

Physics was not Ellen's 'favourite' when it came to teaching, and she was not very comfortable with explaining the processes in the heat pump. We spent a great deal of time in our planning sessions talking about the physical entities and processes involved in the pump. This was a recurrent theme in three planning sessions, two of them in advance of the practical work and the last in advance of Ellen's presentation of the heat pump the next week, March 16th.

To the first of the planning sessions, I had brought with me a large syringe. We used it as a starting point to explore boiling under low pressure and to explain pressure. In this planning session, we also agreed on the other small practical activities that students were to carry out. The textbook had these or quite similar practical activities as suggestion for exploring the processes involved in the heat pump. We spent some time to throw up ideas about apt ways of representing the results. Some of the ideas were drawings of before and after instead of verbalized descriptions, and making a table for boiling under low pressure, and Ellen could then make a summary of the groups' results in a table on the board. I made a point out of that, that if there was to be a common table for the class, there had to be control of variables, that all must have same volume and use liquid with same temperature. Ellen decided that making a table would be a good way of presenting results from boiling under low pressure and she was to make a task sheet.

One of the recurring themes in relation to heat pump was how to explain, what terms to use and what level of explanation (molecular or classical thermodynamics). Ellen wondered if she should make it explicit that in these practical activities the physical concepts of heat, temperature, etc. would be used to describe and explain. Ellen said: "*But our experienced world is not totally compatible with physics. That is the problem with physics and science – you have to get over a threshold to see the connections*."

I cannot hear that we explicitly refer to the purpose of these activities other than the obvious relationship to the curriculum and Ellen's statement that she "*want to establish a bit of knowledge about the processes*".

*The day of practical work March 9th*

This was a six hour science day.
This was the first day I video-recorded in the classroom. Perhaps this influenced Ellen's teaching. This was also my 'home turf', which might perhaps have made Ellen more reluctant to go into the physical explanation of heat pump. However, when I watch the footage I do not detect any particular uncertainty on Ellen's part.

The first part of the day was in the classroom. Before starting the practical work, the students did a task on batteries where they were going to find out more about real batteries (they were given samples of different batteries). Ellen specified what to find out. The week before, the students had worked with galvanic cells, so this task was a summary of that topic. After a short break, Ellen started to present the procedure of the practical activities, see next section. The practical activities lasted most of the mid-section of the day, i.e., 90 minutes including introductions in the science lab. The students were to do the post-practical work after lunch, which took the rest of the day. After lunch there was a school concert that the students attended, so the last part of the day was somewhat shorter (approximately one hour). The students' post-practical work was to make a report from all the activities.

The four students (Sheila, Beatrice, Ingrid and Peter) were to write one report together. Ellen at first did not specify the task of writing the report. The students seemed a bit unsure about how to deal with this and they asked each other what should be included in a report. They mentioned (between themselves) hypothesis, what happened, equipment and conclusion. Some minutes later Ellen came to their desk and clarified:

| | |
|---|---|
| Ellen: Nå skal vi se på hva som skal være med i rapporten. For det første så skal det være en hypotese om hva som kommer til å skje.<br>Peter: Det har vi - har vi ikke det?<br>Sheila: Ja, men vi må gjøre det litt bedre da<br>Ellen: Så vil jeg at dere skriver litt om hvordan dere gjennomfører dette forsøket – en sånn oppskrift. Og så vil jeg ha med i rapporten at dere skriver om hva som har skjedd og en forklaring<br>Peter: Ok<br>Ellen: Altså, hypotese, hvordan det gjennomføres, resultater og forklaring på resultater. | Ellen: Now we shall see what's going to be in the report. First there shall be a hypothesis about what's going to happen.<br>Peter: We've got that – haven't we?<br>Sheila: yes, but we must make it a bit better<br>Ellen: Then I want you to write about how you carry out the practical work – a recipe of such. And then I want in the report – that you write about what happened and an explanation<br>Peter: Okay<br>Ellen: So, hypothesis, how it is carried out, results and an explanation of results |

Sheila and Ingrid had written parts of the report while they were carrying out the practical work. So, all they had to do was to fill in the missing parts. The three girls constructed sentences together and helped each other remember the sequence of what they did. Peter was standing behind them talking to a friend on matters unconcerned with the report. Beatrice did request Peter to contribute. At times Peter was involved (involved himself) in the writing of the report.

When writing about their results, all was well until they started to relate the description to expected outcome of boiling under low pressure for isopropanol. They saw no/few bubbles, but isopropanol as an alcohol should boil more easily than water.

| | |
|---|---|
| Ingrid: Jo, kokepunktet – da skal egentlig alkoholen koke lettere, men vann koker lettere<br>Sheila: Hva er grunnen til at det ikke ble så veldig mye bobler?<br>Ingrid: Grunnen til det er et mysterium<br>Beatrice: Det aner jeg<br>Ingrid: Vi fant ikke ut grunnen – det ble et mysterium<br>Sheila: Sånn, og så er det forsøk tre vi ikke har gjort | Ingrid: Yes, the boiling point - then the alcohol really should boil more easily, but water boils more easily<br>Sheila: What is the reason there were so few bubbles?<br>Ingrid: The reason for that is a mystery<br>Beatrice: That I think<br>Ingrid: We did not find the reason – it became a mystery<br>Sheila: There, and then there is practical activity number three which we haven't done |

Sheila poses a question 'what's the reason?' when none of the others have a ready explanation for this she 'urges' the group to go on writing the rest of the report. They chose not to stay with their 'mystery', to explore it nor did they call for Ellen so she could help them with their 'mystery'. How this 'mystery' was dealt with later, see below for the next science day. Ellen had said in the introduction that they should measure temperature and volume when they explored boiling under low pressure and make a table. In the audio-recording of the students working with the report, they referred to temperature as cold, room temperature, lukewarm and warm. There are no references to measures of volume.

From a science point of view, the students had some problems constructing their explanations as the following statements show:

- Boiling under low pressure
    - "*The pressure increased – boiling point water became lower*"
    - "*It (water) boils more easily when temperature is high - and high pressure*"
- Condensation
    - "*Why does the balloon shrink when water evaporates?*"

They used the words Ellen had used in her introduction in their explanation. From a scientific point of view, it seems that the words they use are not firmly coupled to the physical entity, and their way of expressing what is happening is not aligned with the accustomed scientific way of expression. From a social semiotic point of view, they use the resources they have at hand and try these out as a part of their semiotic work of making meaning from the practical work. The following excerpt is from the students trying to explain why the balloon became sucked into the flask (condensation).

| | |
|---|---|
| Sheila: Hva er grunnen – hvorfor begynte den å gå innover?<br>Ingrid: Vanndamp har større volum – er volum rett ord?<br>Beatrice: Tetthet<br>Ingrid: Tetthet<br>Sheila: Vanndamp har større tetthet enn kaldt vann | Sheila: What's the reason – why did it turn inwards?<br>Ingrid: Steam has more volume – is volume the right word?<br>Beatrice: Density<br>Ingrid: Density<br>Sheila: Steam has more density than cold water |

Ingrid is first relating this to volume, but she does not seem sure. They then use the word 'density'. Here they used their previous experience from science and the term 'density' is relevant in this setting. It is interesting, though, that they choose a word which Ellen had not mentioned in the introduction at the expense of those entities that were used in the introduction. It is possible that they did not feel comfortable with using entities such as condensation. They were perhaps not 'at home with' phase changes and the relationship between volume of gas and volume of liquid.

A short while later, they talked to Ellen:

| | |
|---|---|
| Ellen: Har dere sett noen ting som dere ikke hadde tenkt skulle skje?<br>Sheila: Jaa, nummer fire<br>Ellen: Hva var det for noe?<br>Ingrid: Den ble trukket innover | Ellen: Have you seen anything that you did not expect to happen?<br>Sheila: Yees, number four<br>Ellen: What was it?<br>Ingrid: It turned inwards |

| | |
|---|---|
| Sheila: Hansken ble trukket innover og så sprakk den til slutt da, men det at den begynte å trykke seg innover det var<br>Ellen: Det var uvant<br>Sheila: Ja<br>Ellen: Hvorfor det?<br>Sheila: Vi trodde den skulle gå opp | Sheila: The glove got sucked inwards, and then it cracked in the end, but that it started to push inward was<br>Ellen: That was unfamiliar<br>Sheila: Yes<br>Ellen: Why?<br>Sheila: We thought it would go up |

Ellen asks a 'what' question and thus allows Sheila to point out the gap between their initial guess for what would happen and what they observed. The following 'why' question from Ellen is interpreted by Sheila as a need for elaboration on the difference between their initial hypothesis and what they observed. This was not developed further, e.g., in the form of an explanation.

The report was not handed in.

*The next science day, March 16th*

On the next science day, Ellen led the class through a description and explanation of the practical work, before she went on to explain the heat pump. Ellen asked the students questions and she wrote some points on the board.

She started by asking:

| | |
|---|---|
| Ellen: Hva er egentlig trykk dere?<br>John: Kompresjon av molekyler<br>Ellen: Mener du at de blir mindre?<br>John: Nei, det blir flere sammen<br>Ellen: Tettere sammen, ja ikke sant? | Ellen: What is pressure really?<br>John: Compression of molecules<br>Ellen: Do you mean they are getting smaller?<br>John: No, they become more together<br>Ellen: Closer together, yes right? |

In this staged explanation of pressure, Ellen challenge John. John's first statement could be interpreted as the molecules become smaller (a 'misconception' in science), his next statement is an elaboration of the first but guided by Ellen's question. After John's statement, Ellen concluded or emphasized the scientific view. Ellen elaborated on this a bit further by using the particle model (micro level) and collisions. She then related the activity 'reduction of volume – change of temperature' to bicycle pumps and the students' experiences with those.

The excerpt below is from her dialogue with the class concerning boiling under low pressure.

| | |
|---|---|
| Ellen: Greit, koking ved redusert trykk. Hvordan fikk dere til det –å koke ved redusert trykk?<br>Kevin: Vi fylte opp (sprøyta) og så dro vi<br>Ellen: Ja, da blir det redusert trykk inni | Ellen: Right, boiling under low pressure. How did you make it – to boil under reduced pressure?<br>Kevin: We filled up (the syringe) and then we pulled |

| | |
|---|---|
| her. Hva observerte dere?<br>Patricia: Når du trakk den sprøyta oppover så begynte det å boble litt – sånn at det begynte å koke.<br>Ellen: Riktig. Var det noen forskjell på om dere brukte høy eller lav temperatur?<br>Andrew: Ja<br>Ellen: Ok. Hva var forskjellen? Når kokte det lettest? Phillip?<br>Phillip: Neei<br>Ellen: Koker lettest ved høy temperatur<br>:<br>Ellen: Var det enklere å få alkoholen til å koke?<br>(noe ulike meninger blant elevene)<br>Ellen: Vi brukte en alkohol som heter isopropanol og den koker omtrent som vann. Hva kan vi lære av dette?<br>(ingen respons)<br>Ellen: Vi kan lære at når vi reduserer trykket så kan vi senke koketemperaturen – ikke sant? | Ellen: Yes, then it will be reduced pressure inside here. What did you observe?<br>Patricia: When you pulled the syringe then it started to bubble a bit – so that it started to boil<br>Ellen: Correct. Was there any difference if you used high or low temperature?<br>Andrew: Yes<br>Ellen: Okay. What was the difference? When did it boil most easily? Phillip?<br>Phillip: Nooo<br>Ellen: Boil more easily at high temperature<br>:<br>Ellen: Was it easier to get the alcohol to boil?<br>(different opinions amongst students)<br>Ellen: We used an alcohol named isopropanol and it boils approximate as water. What can we learn from this?<br>(no response)<br>Ellen: We can learn that when we reduce pressure then we can lower boiling temperature – right? |

This passage shows students answering Ellen's stepped questions. The students' answers followed immediately after the questions and their answers were in their 'own science language', i.e., there were no 'textbook answers'. Ellen's first step was a call for a description of how to do this, which Kevin answered easily (although perhaps a little inaccurately?) when describing what they did. They filled the syringe, but only five millilitres and pulled the piston while holding a finger over the air inlet. These practical elements of how to create low pressure were also emphasized in Ellen's introduction (see next section). In the next step, Ellen called for a description of their observations, a question that is answered by Patricia, they saw bubbles and Patricia elaborated on this by saying 'it started to boil'. The third step is a call for a description of differing results for different temperatures. Andrew answered 'yes' there was a difference but not what type of difference or how much difference. Therefore, Ellen elaborated on her question in two parts. The first 'what is the difference' requires a longer answer, whereas the last 'when did it boil more easily' is perhaps a question that is easier to answer, as is directly connected to the students' observations. Phillip, though, had a problem saying something about the result, perhaps he did not remember or perhaps he did not wish to answer. Here, Ellen chose to say the result herself rather than ask for another student's contribution.

The last part of the excerpt is particularly interesting, as this relates to the 'solving of the mystery' the group had when they wrote their report. Ellen's opening question "*Was it easier to get the alcohol to boil?*" – could lead the students to the scientifically right answer. However, it was not so, as there were different opinions among the students – some said yes, some no difference – and some of the students in the group I followed said clearly no. Ellen did not develop or explore this disagreement, nor tried to explain why some had not observed isopropanol boiling. To explain this, it would perhaps have been more clarifying for students if they had the opportunity to make the observation once more. Ellen chose to give a factual statement as the 'correct' answer – case closed. There were, in other words, no attempts to explore or explain the differences.

When she then proceeded to ask the students "*What we can learn from this?*" no one answered, although she waited for a response for about five seconds. This question can be seen as a reflection on learning outcome. It might interpreted more generally 'what we have learned' or it might be interpreted as 'what have we learned concerning this phenomenon'. Perhaps the students had not thought about what they had learned, or perhaps they did not think they had a 'good enough' answer to this, or perhaps Ellen's authoritative last answer was seen as *the* answer so there was no need for elaborating on it. Ellen chose not to put pressure on students to get an answer. Her answer was the physical connection between temperature, pressure and boiling.

Ellen led the class through a sequence of questions and answers, where it was established that when water boils it evaporates, and that steam or water in a gaseous state takes up much more room than liquid water, then:

| | |
|---|---|
| Ellen: Hva skjer når vi har denne full av vanndamp? (tegner kolbe på tavla) La oss si at vi har bare $H_2O$ gass inni her og så setter vi på en gummitopp her. Hva skjer da? Hva opplevde dere da?<br>John: Den synker nedover<br>Ellen: Ikke sant, her trekker det seg sammen. Hva er grunnen til det dere?<br>Christina: Dampen tar mer plass kanskje<br>Ellen: Vann tar mer..<br>Kevin: Vann tar mer plass enn den gassen som<br>Ellen: Det skjer akkurat det omvendte. Da går vann fra gassform til vann på væskeform. (påfølgende utvidelse av svar) | Ellen: What happens when we got this one full of steam? (draws a flask on the board). Let us say that we only got $H_2O$ gas inside here and then we put on a rubber top. What happens then? What did you experience?<br>John: It sinks downward<br>Ellen: Right, here it pulls together. What's the reason for this?<br>Christina: The steam takes more room perhaps<br>Ellen: Water takes more…<br>Kevin: Water take more room than the gas that<br>Ellen: What happens is exactly the opposite. Then water in the gas state goes (over) to water in liquid state (elaborated) |

John described what happened as he referred to the glove finger acting as a balloon 'sinking' into the flask. This was a memorable moment for all students (I believe) and thus easy to recall. What happened in this activity was unexpected for most of the students. When it came to explaining, it was more difficult. Christina started out continuing what was said a moment ago that 'steam takes more room' than water, but did not say that the water condensed. Ellen's response is perhaps a slip of the tongue "*water takes more...*". It is obvious that Kevin chose the opposite alternative – that water takes more room than steam. Ellen's response was clarifying the transition between the phases. Instead of building on Christina's explanation – she stated it herself.

Ellen then redefined the report to be 'a procedure' for all the different activities – with no descriptions or explanations. The purpose of this was to 'give it to the other teachers'. Students worked with this for a while.

In our evaluation, Ellen was not very satisfied with these activities in relation to what students had done and their learning outcome. She said, when referring to how the students had carried out the practical work: "*You saw last time – it was a ridiculously simple practical work – even this became too complicated*." When we looked at those reports handed in after the 16$^{th}$ (description of procedure), some students had not understood the task and had written a traditional report including attempts to explain which revealed inaccurate explanations, e.g., about pressure.

*Summary of context*

The day of the practical work with the heat pump processes, this work took most of the day with the introduction, carrying out and students writing a report with descriptions and explanations. The next science day, Ellen led a dialogic summary of the practical activities as well as provided an explanation of the heat pump.

When Ellen had a summarized of the practical work, she used typically an initiation, response and feedback strategy (IRF). The feedback is primarily Ellen elaborating on or rephrasing the students' responses. In this dialogue Ellen always related to individual students, as there was, for instance, no group responses or think-pair-share to get more or other contributions. The students' responses were prompt or if not Ellen provided the answer.

In the summary, scientifically wrong answers were ignored, so was differing results. Students were lead to the 'right' answer without exploring the 'wrong' ones. The consequence of this might be that Sheila, Beatrice, Ingrid and Peter did not understand why their isopropanol did not boil. However, when the students had Ellen for themselves on the day of the practical work and Ellen asked them: "*Have you seen anything that you did not expect to happen?*" none of them chose to talk about the mystery or what might be seen as challenging for them to explain. They (Sheila) chose to talk about the fascinating event of the 'balloon'. They could have chosen to say that they did not see isopropanol boiling.

When the students were writing their report the day of the activities, they used only one computer. In a group of four students, this means that it is difficult for all to contribute. In addition, Ingrid, Sheila and Beatrice were used to working together, whereas Peter was new to the group. Peter let the girls take much of the responsibility for the task.  The students clearly tried out the scientific words to use in their descriptions and explanations. After Ellen's summary they would perhaps have had some input on how to improve their explanations, however the 'report' was then reformulated to writing a procedure.

Next follows the analysis of the text, i.e., the heat pump activities.

## 6.4.Practical work related to heat pump

Ellen started the introduction to the practical work with an appetizer: "*Are there any strong students here*?" she asked the class. One of the girls (Sara) was suggested by some other students and Sara came forward. "*This is a syringe, right*" Ellen said, and continued, "*We are to use syringe today*". This led to students cheering and clapping. Ellen held over the syringe's air inlet (to create an approximate vacuum) while Sara pulled the piston. The rest of the class contributed with encouraging calls such as "*Come on, Sara*". There was a loud 'plop' as the piston left the syringe. Ellen called for silence and said: "*Notice that Sara had to use her whole body here*". She elaborated on this by saying that it was heavy to pull – so there was a need for cooperation.

Ellen chose to say nothing about the heat pump – its purpose or function – before she started to introduce the practical work. However, she did relate these activities to the subject matter in a more general manner later in the introduction (see below). She chose to introduce all five different practical activities in one sequence. In our evaluation, I never asked Ellen why she chose to introduce all activities before the students started to do them. This approach could perhaps be a bit difficult for students who often forgot. For each of the activities, she asked questions such as 'what's going to happen when…' These questions were not meant to be answered by students in the introduction, but can be seen as a way of supporting the students' 'hypothesis' or as triggers for curiosity.

The procedures were repeated three times in the introductions. The first time in the classroom where Ellen talked, she used some of the props and wrote on the board. After a break, the class relocated to the science lab and Ellen gave a short 'reminder' of all five procedures lasting 3-4 minutes. Students started to do the practical activities, but after a few minutes, Ellen chose to go through all the procedures once more so she called for their attention. There were practically no contributions from students during these introductions.

When she went through the procedures, there were some students not paying attention, and there were students talking during Ellen's introduction. She had to call for silence several times during the first minutes of her introduction.

There were four students in the group this day, Sheila, Beatrice, Ingrid and Peter. They divided work between them, but Sheila and Ingrid were the ones taking notes on their computers.
The students did the practical activities in the following order:

- Reduction of volume – change in temperature?
- Expansion of volume of heated liquid in closed volume
- Condensation – reduction of volume for a cooling liquid/gas
- Boiling under low pressure
- Evaporation – change in temperature?

The rest of this section is divided into regulative and instructional parts of the introduction. The border between the regulative and the instructional will be somewhat fluid, and it would thus be possible to divide the text differently.

### 6.4.1. Regulative

The regulative part of communication deals with the structure and organization of the task. The first part provides a description and interpretation of the text. In the second part, I infer what seems to be the norms based upon the descriptions and interpretation.

#### *6.4.1.1. Text description and interpretation*

In this section, there are some points to draw attention to; behaviour, division of groups – and group size, the goal and purpose of activity, the order of the activities, task manageability, taking notes and dealing with student-initiated questions and comments. First, I provide a short overview of the text.

In the introductions, Ellen uses the pronoun 'we' often. There are three different uses of 'we' in the regulative part of the text. She sometimes used 'we' where she just as well could have said 'you', e.g., 'we are going to', i.e., 'you are going to do'. In using 'we', she makes a bond of solidarity between her and the students, but perhaps the use of 'we' leads to a blurring of responsibility. Who are to do this? Almost just as often, is 'we' when she is talking about both her and students. There are a few uses of 'we' when she just as well could have said 'I', e.g., "*when we are holding here*" and she is doing the holding herself. Ellen also uses 'I' usually in combination with 'think' or 'want you to'. However, as part of regulating students and tasks Ellen also uses you (singular and plural), see below for example in regulating behaviour. When Ellen is regulating the students' behaviour, the speech functions are mainly questions, but when she relates to the task structure, they are mainly statements or demands. There is a range of different transitivity processes.

*Regulating behaviour*

After the 'appetizer' where students were cheering and clapping, it seemed as if they did not calm down. There was loud talk while Ellen started to present. Ellen waited for silence and said 'hush' several times which led to relative quiet for a short while.

In the next excerpt, it is difficult to hear Ellen's statement because of students talking – this is indicated with (??).

| | | |
|---|---|---|
| 01:32 | Før vi fortsetter (??) så vil jeg ha oppmerksomheten her.<br>Elev (halvhøyt): Jajaja (ler) | Before we continue (??) I want your attention.<br>Student (half loud): Yeah, yeah, yeah (laughs) |

After this, it was more or less quiet for a short while. However, the students 'forgot' themselves and started talking loudly again. Then:

| | | |
|---|---|---|
| 04:02 | Ellen: Jane kan du fortelle meg hva, altså, når du er det du snakker der du ikke skal snakke?<br>Patricia: Er det nå plutselig<br>E (avbryter): Jane skal fortelle meg det | Ellen: Jane, can you tell me what, then, when you are talking where you shall not talk?<br><br>Patricia: Is it now suddenly<br>Ellen (interrupts): Jane shall tell me |

By singling out Jane as a 'target' of unwanted attention, Ellen did something she usually did not do. She usually addressed the whole class when it came to matters of classroom order. Jane was definitely not the only student talking, but she did often talk when Ellen was presenting something and she did not always talk in a hushed voice. It seems that Patricia was contesting that Ellen singled out Jane, but perhaps she did not see the students' talk as something Ellen ought to put so much significance into. When Ellen interrupted Patricia, her voice was stern. After Jane had stated that she should not speak when the teacher was speaking, Ellen addressed the rest of the class:

| | | |
|---|---|---|
| 04:43 | Ellen: Og dere andre?<br>John: Vi holder kjeften igjen<br>Ellen: Det er greit, hvor lenge holder dere kjeft?<br>David: Ti sekunder<br>John: Det kommer helt an på<br>Ellen: Det kommer helt an på | Ellen: And the rest of you?<br>John: We keep our mouths shut<br>Ellen: Right, how long do you keep your mouths shut?<br>David: Ten seconds<br>John: It depends<br>Ellen: It depends |

In the last excerpt, the students' voices are almost cheerful whereas Ellen's voice is level. These three excerpts show that the class was not easily rebuked. Throughout the whole sequence, the students have a half-joking attitude towards Ellen's attempt to get their attention and relative quiet when she presented. The students' answer in the first and the third excerpts show this. Shutting up for 10 seconds is not a very long time. The second to last statement, "*it depends*", gives some room for speculation. Depends on what? That the introduction Ellen is going to give is easy to follow so they do not lose their concentration, that it is entertaining or that they understand what and why they are going to do this? Throughout the entire sequence of regulating behaviour Ellen did not raise her voice, although her voice at one moment was stern. She poses questions to the students as to their behaviour and classroom order, she is, e.g., not making any demands. Moreover, there is a clear division between 'I' and 'you'. Ellen does not use 'we' in the passages when she is talking about behaviour. These excerpts might be interpreted as a negotiation or a power struggle between Ellen and the class about who is to decide what level of quietness is required.

*Organizing the task: Dividing students into groups*

The students were divided into groups by how they sat, i.e., by 'friendship'. There were only five syringes, which meant that the groups became quite large. When groups are large, there is a risk that some of the students might withdraw from the activity and become passive members of the group. Ellen did not explicitly divide labour between students, so they did this themselves in an ad hoc manner. The group in the video-recording, e.g., agreed that one of them (Sheila) was to write while they did their practical activities. Ellen had not made it explicit that the report was to be a group report. By dividing the labour between the students, the carrying out of the practical activities would run more smoothly for the students, as not all of them needed to take notes. Sheila took the main job of taking notes, but also Ingrid took notes. Beatrice did a lot of the practical work. She asked her fellow students "*What shall I do?*" and they usually gave her an answer. Beatrice and Peter did not (I cannot see it in the video material) use their notes to unearth the next step of the procedure. This meant that Sheila and Ingrid also had the job of directing Beatrice and Peter on procedure.

In a roundabout way Peter, Beatrice and Ingrid negotiate which one of them who are to fetch water for boiling under low pressure. Ingrid was sitting by her computer with the syringe in hand, Peter and Beatrice were standing behind.

| | | |
|---|---|---|
| 41:27 | Peter til Ingrid: Du har sprøyta, har du ikke?<br>Ingrid: Da skal vi putte vann oppi – skal vi ikke<br>Beatrice til Peter: Nå skal du ta vann i den<br>Peter: Det er du som har sprøyta er det ikke det? | Peter to Ingrid: You have got the syringe, have you not?<br>I: Then we are to put water into – shall we not?<br>Beatrice to Peter: Now you shall take water into it<br>Peter: It is you who has got the syringe – is it not? |

Beatrice did try to get Peter to fetch the water. He did not – Ingrid did. Later, he and Ingrid cooperated on holding and pulling the syringe to get the liquid boiling. There were no detectable conflicts among the students concerning division of labour, and they seemed to be quite amiable towards each other.

*Structuring the task: Purpose and goal*

After the 'appetizer' Ellen started to present the procedure for all five activities. She did not make it explicit why to do this, nor was any purpose of each of the activities provided. But after the ‘appetizer’ and before the introduction of each procedure, Ellen said while holding the syringe:

| | | |
|---|---|---|
| 01:58 | Vi skal nå gjøre forsøk og grunnen til at jeg tar opp dette her er at vi skal gjøre forsøk der vi skal holde for her og dra og akkurat det kan være littegrann tungt - så dere må samarbeide | We are now to do practical work and the reason why I address this is that we are to do practical work where we are to hold for here and pull and that might be a little bit hard – so you have to cooperate |

In this excerpt, Ellen emphasized two aspects of the practical work – the practical element of pulling the piston and cooperation in relation to the practical work.

However, after she had presented all activities in the classroom she said:

| | | |
|---|---|---|
| 16:00 | Dere syns sikkert at dette virker som helt banale små forsøk, men vi skal prøve å bruke dette her til å forklare begrepet varmepumpe. Da er det en del ting når det gjelder varme (som) vi må ha sagt litt om først. Vi har et faglig fokus på dette her. Er det greit? | You surely think that these seem like completely banal practical work, but we shall try to use these to explain the concept heat pump. Then there are some things about heat (which) we need to say something about first. We have a subject matter focus on this. Right? |

This excerpt starts with a factual statement that students *surely* think this is banal or simple. The use of the word ‘surely’ indicates that Ellen interprets students in a way that this task is simple. As the introduction emphasized how to do the practical activities, it is reasonable to assume that she referred to banal or simple to do. She continued with a contrastive but, and an uncertain statement. Uncertainty is expressed through the use of ‘shall try’ – it is not ‘we shall use this to explain’. The contrastive but can be interpreted as; simple to do – hard to explain or as simple to do – might help explain the heat pump. She elaborates on this in the two next statements. By asking “Right?” in the end – it is if she ‘challenged’ the students: these are not just hands-on and mind-off activities – they are useful subject matter. On the other hand, it might be that she feared that the students did not see subject matter relevance. Regardless, one student immediately answered ‘yes’.

*Structuring the task: The order of the activities*

With five different practical activities, it can be difficult to keep track of which is which. Ellen’s way of dealing with this seemed to be strongly related to the equipment used in each. In the beginning, she stated that in two of these experiments ‘we are to use the syringe’, but not anything about the purpose or why a syringe.

When she had presented three of the activities, she had a slip of memory:

| | | |
|---|---|---|
| 12:40 | Ellen: Så skal vi ha et siste forsøk, | Ellen: Then we shall have a last practical |

| | | |
|---|---|---|
| | hva var nå det?<br>:<br>Gerd: Var det kondensering?<br>:<br>Ellen: Det var det, det var det, ja. Da vi skal bruke engangshansker | work, what was that?<br>:<br>Gerd: Was it condensation?<br>:<br>Ellen: That's it, that's it, yes. When we shall use the disposable gloves. |

The colons in between our questions indicate that Ellen answered questions from students parallel to this. Here she related what to, do not what is to be observed or explained, but what equipment to use.

When Ellen numbered the activities, there is no direct connection to the sequence of processes in the heat pump.

Ellen chose, as mentioned above, to present all five relatively small practical activities at once. This led to some confusion among the students when they carried out the activities – 'which one are we doing?'

| | | |
|---|---|---|
| 33:28 | Sheila: En var luften - er det to? - hvilken gjør vi? – er det forsøk to?<br>Peter: Jeg vet ikke, men vi hoppet over toeren – helt sikker<br>Sheila: Hvilken gjør vi – er det den?<br>Ingrid: Toeren var den jeg skrev på, så det var toeren (??) varmt vann<br>Sheila: Vet du hva, jeg skjønner ikke<br>Peter: Jeg skjønner alt (fleipe-stemme)<br>Sheila: Hvilket forsøk gjør vi nå?<br>Peter: Vi gjør treeren<br>Sheila: Tre?<br>Peter: Jeg tror det<br>Gerd: Jeg lurer på at det er fire dere faktisk gjør (ler)<br>Sheila: Ja, det er fire<br>Peter ler | Sheila: One was the air – is this two? Which one are we doing? Is it activity two?<br>Peter: I don't know but we skipped two – quite sure<br>Sheila: Which one are we doing? Is it that one?<br>Ingrid: Number two was the one I wrote on, so that was number two (??) hot water<br>Sheila: You know what, I don't understand<br>Peter: I understand everything (joke-voice)<br>Sheila: Which activity are we doing now?<br>Peter: We do number three<br>Sheila: Three?<br>Peter: I think so<br>Gerd: I think that you actually are doing number four (laughs)<br>Sheila: Yes, it is four<br>Peter laughs |

They were doing expansion of volume – and none of them related this to 'number four'. They related the activities mainly to numbers, i.e., the order that Ellen used in her first presentation. They only partly related the activities to what they are about. Sheila connects number one with 'air' and Ingrid connects number two with 'hot water'. Sheila was pushing for an answer here as she repeatedly asked 'which one'.

Ingrid is trying to eliminate, it is not number two, and they had already completed number one (compression of air – change in temperature). I intervene in their process by my uncertain statement (to take the edge off that they are mixing the activities?).

The students had other problems as well concerning what to do. They had forgotten that they should do the opposite of number four and they forgot that they should not only use water but also isopropanol, for the activity boiling under low pressure (and I reminded them).

*Structuring the task: Manageable activities and explanation*

When Ellen had finished the presentation of the practical work in the classroom, she stated that these (surely) were banal activities for the students and that the activities were to be used for explaining the heat pump later, see above. She thus indicated that these activities were simple. This is repeated after the first of the two introductions in the lab. Before Ellen ended the second introduction, she said:

| | | |
|---|---|---|
| 18:06 | Dere vet en del om det her fra før, men vi skal prøve å sette det littegrann i system<br>:<br>Ok? Det tror jeg egentlig var det jeg hadde tenkt at vi skulle gjøre – forsøkene er små og greie | You know some if this from before, but we shall try to place it a bit into system<br>:<br>Okay? That was what I had thought we should do – the practical activities are small and easy |

Ellen stated that the students had previous knowledge. Of course, students have had plenty of encounters with heat in everyday settings and also some in the context of school science, e.g., last autumn. As Ellen had not asked any subject matter questions to the students during the introduction of these activities, how did she know what students were able to recall? This is perhaps the 'motivation' of the contrastive 'but'. The contrastive cohesion indicates a shift between 'know from before' and 'create a system'. This might indicate that Ellen perceived that students' knowledge was not systematic. She also did a 'hedging' through the uncertain statement 'try to place it a bit into system' and this might indicate that a system is not possible (for us), thus, lowering the expectations for an outcome (knowledge).

The check for understanding the question 'Okay?' had practically no response time, as she continued directly stating that this is what we are to do and that the practical work (activities) are small and easy. After a few minutes of students' activity, Ellen 'blew the whistle for time-out' and a new introduction. The students' activity revealed confusion about what to do. Although perhaps each and every one of the operations within the activities were simple, the activities were not so simple for the students as Ellen had thought, or students did not remember what to do in all the different activities.

After doing the very last introduction to expansion, but before condensation, Ellen did a circular (horizontal) movement with her right arm and said:

| | | |
|---|---|---|
| 25:11 | Og dere har alle en formening om hva som skjer, ikke sant? Her har dere en del kunnskaper om dette som skjer, men dere har ikke tenkt på hva det er som faktisk skjer. | And you all have an opinion about what's going to happen – right? You got some knowledge about this, but you haven't thought about what's actually happening. |

Ellen posed some questions to help the students generate hypotheses (see section 6.4.2) and some students had tried to respond to these questions. Therefore, she had good reason to think that (at least) some of the students had some idea about what was going to happen. The response time to the short-answer question 'right?' was approximately one second. There was thus not much time to find out if they (the students) had any opinion on the matter. In the last part of this excerpt, Ellen contrasts students' knowledge and what 'actually happens'. How might this contrastive statement be interpreted? Is it concerning students' everyday knowledge vs. a more formally (verbalized) scientific explanation, or is it everyday knowledge vs. the *real* happening (the scientific) about which the students have not thought? Is what *actually* happens different from everyday knowledge? Ellen is perhaps not making a division between different ways of seeing a phenomenon, in an everyday way or a scientific way. Is the actual way of seeing the phenomena the scientific way?

Students had many activities to do. This, I think, led to a task focus that did not allow them to dwell upon what they experienced. After they had done the condensation activity, and the 'balloon' had imploded into the flask – and exploded – which all of them thought very amusing, this conversation took place:

| | | |
|---|---|---|
| 41:16 | Sheila: Da klarte vi det da, uten at vi skjønte. Ja, ja da skriver jeg – vent da<br>Beatrice: Nå skal vi ta en nytt,<br>Ingrid: Nå skal vi ta det sprøyte opplegget | Sheila: Then we made it, without understanding. Yes, yes – then I write – wait a moment<br>Beatrice: Now we shall start a new one<br>Ingrid: Now we are to do the syringe-thingy |

Sheila's opening statement is perhaps the activity in a 'nut shell'. They knew they had 'done it' since there was a result, something had happened. However, they did not understand. Sheila wanted the rest of the group to wait so she could catch up with the writing, but Ingrid and Beatrice surged on. They started to do 'boiling under low pressure' without asking the question: – why? Nor did they stop to elaborate their amusement. Their primary focus was on 'doing', see also instructional.

*Organizing the task: Taking notes*

Before starting out on the procedures, Ellen said:

| | | |
|---|---|---|
| 02:23 | Da foreslår jeg at dere noterer på pc'en det dere skal gjøre eller på ark | Then I propose that you take notes on your computer or you can do it on paper |

The uncertainty in this statement provided an opportunity for students' interpretation. The notes could be written on paper – or the computer. However, 'propose' can just as well indicate that it is up to students' decision whether or not to take notes. Some might want to rely on memory.

| | | |
|---|---|---|
| 14:00 | John: Skal vi tegne det der på paint?<br>Ellen: Altså, hva dere gjør bare så lenge dere vet hva dere skal gjøre når dere kommer ned der nede, ok? | John: Shall we draw that one in Paint?<br>Ellen: Then, what you do as long as you know what you shall do when you come down there, okay? |

"Down there" refers to the science lab. Here Ellen leaves it to the students' judgement whether or not to make drawings of the equipment. She relates this to their responsibility to assure that they know what to do when the practical activities begin. The students are thus given the responsibility to use the means they find most apt. Writing and taking notes from the practical activities will be further explored in instructional section ('the language of science').

*Comments and questions from students*

Ellen started by writing on the board: "*Experiments with heat*" (No: Eksperimenter med varme). One of the students then asked, "*What does it say? Experiments with vacuum?*" (No: eksperimenter med vakuum). Perhaps the student did connect the text on the board with the 'appetizer' and thus it became an 'obvious' interpretation to connect the experiments with vacuum. Ellen's handwriting on the board is quite good and I have a problem understanding that the word 'varme' could be read as 'vakuum'. So, was this a 'mock question' from the student? A question that was meant to put Ellen off balance? Anyway, Ellen replied "*with heat*" and no further elaboration.

There are a few questions from students during the introduction. Except for one or two, they are all concerned with copying the board, whether or not to copy, what a drawing means, and how to make the symbol for degrees. One of the students told about an experience from earlier that school year, which drowned in noise from outside. Ellen just nodded. Perhaps she did not hear, but she did not move closer to the student nor did she follow up on this comment from the student. Ellen answered all factual questions from students promptly, but in this situation, Ellen did not use the student's experience as a possibility to connect the experiment with other subject matter, or perhaps she deemed the connection irrelevant (if she heard it).

#### 6.4.1.2. *Text – context and regulative norms*

The norms are inferred from the teacher's semiotic actions and how these semiotic actions provide possibilities for students' semiotic work. What the teacher says and does provide an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as 'tacit' practices or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., a rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Organizing the task*

Ellen did not speak about how the task should be carried out in terms of division of labour or how to organize the collaboration. The procedure (see instructional) was the primary source for organizing the work. There was no further support or structures in relation to how to collaborate. Ellen did, however, mention the need to cooperate concerning carrying out one of the activities (boiling under low pressure), and she did in a general manner ask students to contribute to the report, if not there would be additional tasks. When the students were to carry out the activities and to write the report, there seemed to be some who withdrew from the task. The large group made it impractical to gather around one computer to write or round the equipment, but this was a problem for the group to solve. This can be seen as the teacher giving the students a great deal of social autonomy and the autonomy to organize collaboration.

Norm: Students are implicitly given autonomy to organize collaboration (within the structure of procedure) for how to carry out the practical work and make meaning of it.

Questions, writing and taking notes are part of how to organize the work, but are also a part of communication of subject matter. I will thus deal with this in the instructional section.

*Structuring the task*

Ellen did provide a vague purpose for the activities ("*try to use these to explain the concept of heat pump*"). This purpose was given at the end of the first introduction. This means that the procedures took precedence over the purpose, as the purpose does not guide the students' attention during the introduction. Further, the purpose is given as an uncertain statement, which might be seen as a way of reducing its impact. The day of this practical work Ellen did not made it explicit why it was important to learn about heat pumps. The purpose or reasons for why the activities were structured the way they were, was never provided (e.g., why the need for testing two different liquids in boiling under low pressure activity). There is no explicit goal for the activities. To carry out the procedure seems to be the goal. Emphasis on ‘do’ (see next section) strengthens this interpretation.

Norm: The goal is to carry out the practical activities.
Norm: Purpose is not emphasised.

Ellen did use the words simple and banal about the activities on several occasions. This together with expressing doubt (by using uncertain statement) about meaning-making of the activities creates a prevalence for managing ‘doing’ at the expense of meaning-making. There are no expressions in the introduction that there might be some difficulties, although Ellen creates a slight uncertainty about if it is possible to make meaning of the activities.

Norm: The activity shall be easy and simple to carry out.

*Behaviour teacher –student relation*
In relation to behaviour, Ellen uses questions and (uncertain) statements as speech functions. This is a stark contrast to how subject matter is dealt with. She also uses a very clear division between ‘I’ and ‘you’ that might indicate clearly identified roles and responsibilities, a division that is blurred when it comes to subject matter. Students are in a (mostly) humorous way contesting the need to be quiet and to pay attention.

Norm: Students may challenge the teacher regarding behaviour
Norm: Appropriate behaviour is (partly) negotiated

### 6.4.2. Instructional

The part of communication that is dealing with subject matter (instructional) is embedded in the regulative (structuring and organizing activities). There will thus be some overlap and it would be possible to divide the text differently. I have chosen to treat all material that directly relates to carrying out the activities as instructional.

In this section, there will be a description and interpretation of both what is found as typical during these activities as well as moments of special interest. The presentation is centred round some themes of the procedure presented in the introduction and the students ‘response’. These themes are hypothesis, observations and measurement, and inscriptions (making a table). First, there is an overview of the text.

#### *6.4.2.1. Text description and interpretation*

This overview of the text is based upon transitivity processes, actors, text cohesion and speech functions as well as entities. I will proceed to provide some examples from the activities and the students’ ‘response’ to the instruction.

*Transitivity processes, actors, speech functions and cohesion*
The most prominent of the transitivity processes in Ellen's introduction is material processes; do-processes. Do-processes occur about once for every other process. There are also many references that something is (going to) happen. There are some references to mental and relational processes, but few references to observations and verbal processes such as say and write.

When transitivity processes are linked to actors and speech functions, what is most frequently occurring is:

- Do-processes are often given as demands 'we shall' or' you shall', where 'we' occurs most often.
- Factual statements (certain) are linked attributes and relationships, e.g., "*One (of the liquids) boils more easily*." These are statements that concern the subject matter (science knowledge). There are a very few of these factual statements concerning subject matter that are uncertain.
- There are two types of questions. First, there is the question 'what happens?' This type of question refers to a material transitivity process. The next type of question is checking for understanding, such as 'right?' 'okay?' and 'do you understand what to do?'.

There is a class of utterances coded under 'do-demands'. This is when Ellen uses the pronoun 'I' combined with do-processes. The speech function is strictly speaking a statement, but within this context, it can be considered a demand as Ellen herself is not going to do the activities. She just models how the students shall do them. An example of this is: "*Then I hold over here* (syringe's air inlet) *and then I pull out* (the piston)".

Questions that function as a test of students' understanding are quite frequent. All are short response questions and can be answered by a single yes or no. Often students did not answer these questions. Sometimes the response time given to them was too short to answer verbally, i.e., when the time given was zero or one second (zero second response time means that Ellen started directly on the next utterance). Twice Ellen waited for approximately four seconds for responses, but most often just for one-two seconds. In this time, she can see if there are students nodding or shaking their heads even if they do not say anything aloud. At times students say yes – they understand. However, when questions concerning understanding are not directly on what students understand (not), the questions might become rather non-committal. The student might have a 'foggy' idea what this is about – and what to do, but as long as the student her/himself does not make the understanding explicit, it is not easy to know what one does understand. I suppose everybody knows the feeling of 'but everything seemed so simple when the teacher told it'.

There is one explicit choice given in the introduction, it is regarding temperature. The students are to choose the temperature of the liquid as they see fit. (This can be seen as a practical choice made by Ellen as it is difficult to ensure that all students used the same liquid temperature.) Implicit choices will be dealt with later. There are also some hypothetical statements – 'this might (not) happen'.

Cohesions in the text are typically additive, temporal (and then, next) as well as elaborations. There are a few contrastive (but) and conditional (if) and no real causal connectors. The closest to a causal connector is in the statement:

| | | |
|---|---|---|
| 10:37 | For det jeg nemlig vil se er at dere kan trekke ut denne her (stempel) og sannsynligvis så behøver dere ikke trekke så veldig langt ut hvis dere bruker varm væske som kald væske | Because what I want to see is that you can pull this one (piston) and most probably you do not need to pull much if you use a hot liquid as a cold liquid |

The most often occurring pronouns in the introduction are 'you' (plural) and 'we''. The pronoun 'we' is used in three different ways. The most often use of 'we' is when Ellen just as well could have said 'you'. The frequent use of the pronoun 'we' in the meaning of 'you' is perhaps typical 'teacher-language'. 'We' creates a bond of solidarity between the students and teacher, 'we are in this together', but it is strictly speaking not true. Perhaps the use of 'we' gives a blurring of the responsibility. Interestingly, the proportional use of 'we' meaning 'you' increases from the regulative part of the text, i.e., there are fewer 'real we' in the instructional text. How do these transitivity processes, and cohesions influence students doing the practical work?

In students' speech, there are three primary transitivity processes: the mental process 'think' as well as material processes do and happen. Think processes might be used by students for two purposes. It is used to state the anticipated outcome of the activities when the students made their hypothesis. The students also use think or other such words as a form of hedging. They are in this way indicating that they are not sure of what they mean. This is perhaps a manner of speaking that allows for other students' contributions.

There will of course be a lot of 'do' in students' practical work – both in speech and in action. Many do-processes are connected to the question 'what shall I/we do next?'

The excerpt below is from the activity expansion - steam in a closed volume. Beatrice is watching the flask with the glove finger (acting balloon) on top. Peter is standing on the other side of the hotplate, while Sheila and Ingrid are sitting by the desk with their back to the flask on the hotplate.

| | | | |
|---|---|---|---|
| 32:30 | B moves her fingers – indicate that the water 'moves', she touches the flask<br>S turns round, P looks | B: Det er det vannet som er under som begynner nå å<br><br>S: Noe mer? | B: It is that water which is under that starts now to<br><br>S: Anything else? |

| | | | |
|---|---|---|---|
| | down at the flask<br><br>B points at lower part of flask (the water in the flask?)<br>B touches the glove finger lightly with her index finger<br>P stands behind – pulling the syringes<br><br>S looks at hot plate – bends down to look closely at the water in the flask<br><br><br><br><br><br>B touches the glove finger | <br><br><br>B: Oi, oi den var hard<br><br><br><br><br>P: Nå har det skjedd noe her<br><br>S: Det skjer noe der, da<br>B: Det kommer nesten bobler<br>S: Det skjer ikke akkurat noe i vannet men jeg tror det skjer noe i lufta<br><br>B: Neeei?<br>S: Jeg tror det skjer noe – det bobler | <br><br><br>B: Oops, opps, it was hard<br><br><br><br><br>P: Now there has happened something here<br>S: Something happens there, then<br>B: It is almost coming bubbles<br>S: It is not exactly happening anything in the water, but I think something is happening in the air<br>B: Nooo?<br>S: I think something is happening – it bubbles |

Students observe the water in the flask, there are some bubbles in it, and they touch the glove finger and feel that it is hard. Something is clearly happening. Beatrice, Peter and Sheila talk about 'something is happening', perhaps triggered by Sheila's question "*Anything else?*" All statements above are about 'happening', except for the statement where Beatrice refers to her observation of the hardness of the glove finger. Sheila is trying to figure out where it is happening, is it the water? – it bubbles, but then the glove finger is not filled with water, it is filled with air. What is happening here? After this, they proceeded to the next practical activity. Therefore, there were no elaborations of observations or further explanations.

Sheila hedges by using the word 'think' when she tries to explain what she sees.

*Entities*

In Ellen's introduction, she uses several modes to convey her message. She speaks of course, writes some sentences at the board, makes drawings on the board, uses equipment to 'tell the story', as well as uses gestures. There are most often several modes at play at the same time. In this case, there are several entities to keep track of – and they are often related to each other. The figure below shows how an entity chain develops during time. The entities here are: glove finger (acting balloon), flask, water & steam, heat (noun or verb), boil – and expansion. Time is read downwards.

D – drawing, S – spoken words, A – action with prop, W – writing, G - gesture
The dashed lines indicate a shift between introductions. Arrows means connections in speech/action – thin arrows are elaboration.

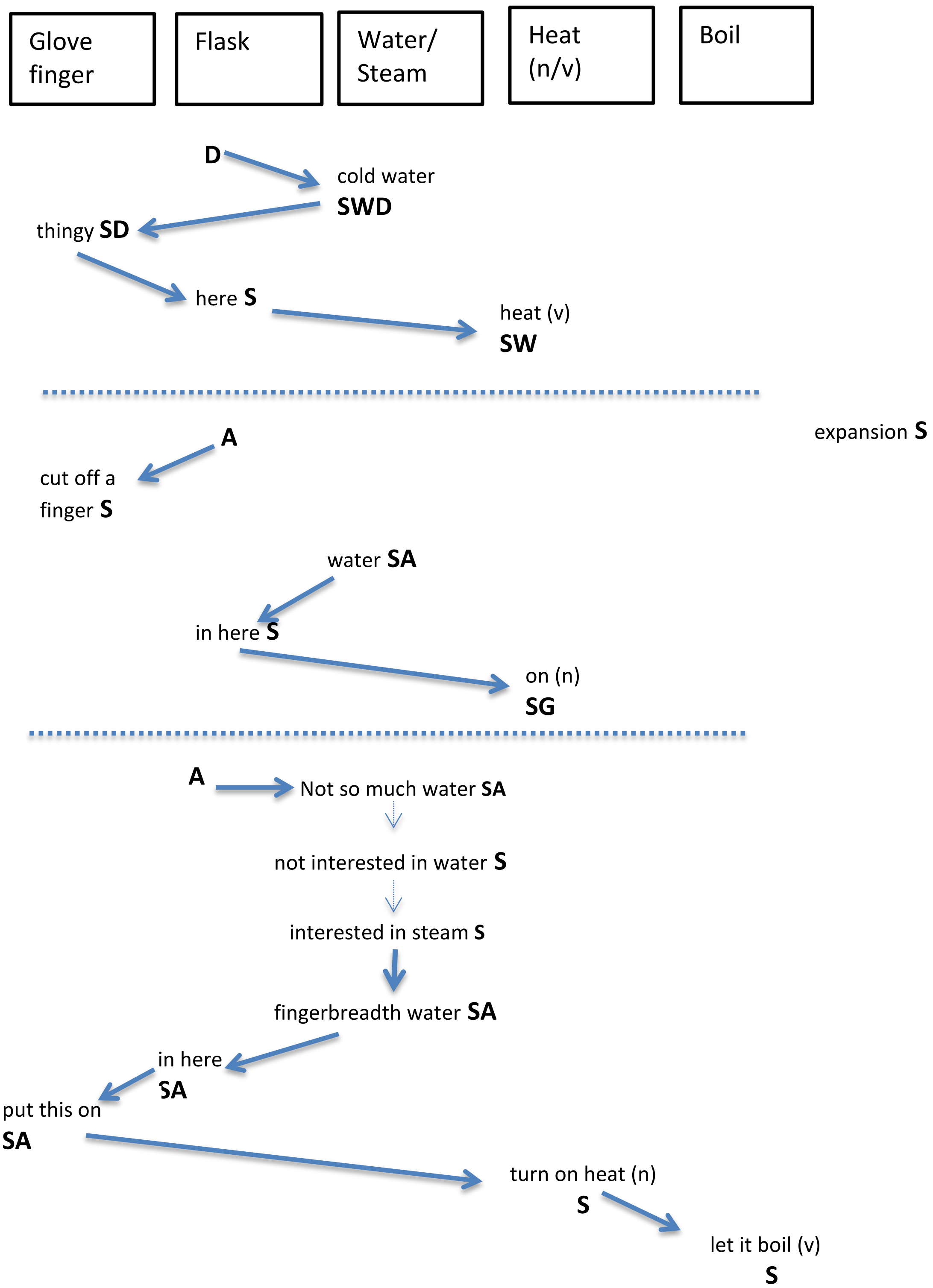



Figure 6 Entity-chain: expansion in closed volume

The figure above shows how entities are used during the three different introductions to expansion of steam within a closed volume. The first part of this introduction was conducted in the classroom and Ellen used the board to draw an Erlenmeyer flask with water inside and a glove finger on top. She then wrote 'heat up' on the board. Then she just asked, "*what happens*?" and proceeded directly to a type of conclusion. The dotted line indicates a shift to the next time she introduced the procedure for expansion, i.e., after the break in the science lab. The third time she introduced it was after she had stopped the students' activity once again to go through the procedures. In the two last introductions, Ellen relies more heavily on the props and less on drawing and writing on the board. The middle section of the figure shows that she starts with the flask in hand with a glove finger on top and she said she had cut it off the glove. She then posed the question: "*What happens when I have water in here and put it on* (the hotplate)?" In the very last introduction, she starts out with a flask borrowed from a group of students. The flask is almost full of water. Her speech, combined with holding the flask, created emphasis that there should not be so much water only a fingers breadth, which she showed by using a finger along the flask bottom.

The entity can thus be presented in any mode: drawing, writing, action with prop or speech. In speech, a substitute for the formal 'science word', e.g., 'in here' instead of 'inside the Erlenmeyer flask' or 'thingy' for 'glove finger' is often used. For the other activities, this use of substitute increased in the presentation – when Ellen used props instead of drawing. This makes the spoken language more informal, or more 'everyday'. This informal or everyday use of language is clearly visible in the use of the entity heat. In physics, heat refers to energy transfer due to difference in temperature. Ellen first uses the everyday form of 'heat it' but this verb-form can be said to be a shortening of the physical process of heat. The other two refers not to heat but to the hotplate 'put it on' and 'turn on the heat – and let boil'. Perhaps I over-interpret Ellen's 'put it on' when I link it to heat. Most likely, she meant the hot plate, but since it is not explicitly said, it is easy for students to make the connection that heat as process equals heat as hotplate.

The only entity that is not connected to any other is 'expansion'. (Expansion is a nominalization for the entire process and a typical 'science word', see section 10.4.1.) This word was said by Ellen in the beginning of her introduction in the science lab. She asked the class what other activities they were to do – and she got a response from a student (which sadly is inaudible) and Ellen's response was "expansion and condensation". These were not related to the rest of the entities, as the chain above shows – nor were they explained later.

In this case, there are many entities to keep track of. From the simple ones that are artefacts (syringe, flask etc.) to difficult physical concepts such as temperature, heat and pressure. Heat and temperature are words used in everyday language. This might make it even harder to be aware of when one is using the 'physical' word and the everyday word. In physics, these entities have interlocking definitions, i.e., the definitions depend upon each other. Ellen had no introduction to any of these entities. The only entity that was more formally explained was the syringe ("*This is a syringe*" as Ellen held it up). Some of the entities were used during the topic radiation where heat, and temperature and partly pressure were dealt with then.

However, that was in the autumn. Ellen did not refer to this topic or the explanation of the entities that were made then.

One of the entities is of special interest – because it was changed. In the introduction in the classroom, Ellen said that one of the liquids to test in the 'boiling under low pressure' activity was denatured (red) spirit. However, when she got into the storeroom in the science lab there was no denatured (red) spirit, so she had to substitute with isopropanol, which has other chemical properties, amongst others it has a higher boiling point than denatured spirit – but lower than water. See also observations below.

The excerpt of students doing and talking about what is happening in the flask and with the glove finger above is basically what the students did on the activity expansion of volume in closed volume. The entities to which the students refer are 'water' 'bubbles (in water)' 'air' and 'it' as a substitute for glove finger. They do not refer to steam, but then, Ellen had just briefly mentioned steam when she talked about this activity. This is perhaps the reason why it was so hard for Sheila to explain. The point that water turned into steam and that steam requires more space was perhaps a verbal resource that was not made sufficiently explicit for the students.

It also seems hard for students to put words to their observations, in other words it seems hard for them to transduct from the semiotic action of observation to spoken semiotic actions. This can be seen as two interrelated problems: first, what are they looking for and second, how might it be verbalized.

*Hypothesis*
When Ellen presented the procedures, she systematically asked a question after each one. For example, after she had presented the first one 'compression of air', by using the syringe she asked:

| | | |
|---|---|---|
| 05:56 | Vil det skje noen temperaturendring? Blir den kaldere, blir den varmere eller blir den ingenting? | Will there be any change in temperature? Will it become colder, will it become hotter or will it become nothing? |

First, a short comment on the 'it' in these questions. 'It' must here refer to temperature or else it makes no sense. The physicist's way of saying this would be 'will it increase, decrease or no change'. Temperature in everyday language can, on the other hand, be coupled with hot or cold.

These are two short response questions, where the second one is providing the three different alternatives for answers. Between these two questions, Ellen had a pause for about two seconds, while after the last question she went directly to saying that this was the first practical activity. By doing this, she gave support for the students' own hypothesis but she did not make it clear at this point that the students were to make their own hypothesis. Ellen said this approximately six minutes later when Ellen had been presenting activity number 3, ‘evaporation’:

| | | |
|---|---|---|
| 12:19 | Jeg stiller dere noen spørsmål. Før dere begynner på disse oppgavene så skal dere ha en hypotese på hva som skjer. Hypotesen kan være fullstendig feil – det gjør ikke noe - bare dere har tenkt gjennom – går temperaturen opp, hvorfor eventuelt går den opp | I pose some questions to you. Before you start (to do) these activities then you shall have a hypothesis about what’s happening. The hypothesis might be completely wrong – that does not matter – if only you have thought through – will the temperature increase, why does it possibly rise |

Ellen made a demand that the students were to make hypotheses before they started to do the practical work. These hypotheses can be a more or less well educated guess, as they do not need to be ‘correct’( see also section 10.5.2). However, what is a wrong hypothesis? Perhaps Ellen referred to that the students’ guesses did not need to be aligned with textbook knowledge?

By demanding that the students make hypotheses before they start Ellen indicates that she wants the students to think before they act, think about what the expected results might be. In doing so, I believe she engaged the students more than if there was just a procedure to do. Ellen signals through this demand that students are to give reason(s) for their hypothesis. Many of the questions posed to support the students hypotheses were of a type ‘what happens if..’ (see above). However, Ellen gave no reason for why the students were to make the hypotheses. This can be linked to a low emphasis on purpose.

Ellen did not provide a specific time for students to formulate hypotheses before they started the practical action of the activities. This can be linked to the norm of students’ autonomy of collaboration within task, see regulative. This group of students made the required hypotheses. Two students made hypotheses while the other started to carry out the practical work. In the beginning of the activities, Sheila and Ingrid were sitting by the computer, Beatrice was standing behind. Sheila started by posing a question: (The excerpt below can also be interpreted as an incident where students organize their task, see regulative part of text analysis.)

| | | |
|---|---|---|
| 29:45 | Sheila: Ok, hva tror vi kommer til å skje på den?<br>Beatrice: Hvordan?<br>Sheila: Hva skjer?<br>Ingrid: Jeg tror temperaturen kommer til å synke når den fordamper<br>Beatrice: Hvorfor kommer det her til å skje?<br>Sheila (skriver) : Vi – tror- den | Sheila: Okay, what do we think is going to happen in that one?<br>Beatrice: How?<br>Sheila: What happens?<br>Ingrid: I think the temperature will drop when it evaporates<br>Beatrice: Why will this happen?<br>Sheila (writes): We - think – it will drop<br>Sheila: Will drop. Will drop? |

| | | |
|---|---|---|
| | kommer til å synke-<br>Sheila: Kommer til å synke, Kommer til å synke?<br>Ingrid: Hæ, temperaturen kommer til å synke<br>Sheila: Når den fordamper?<br>Ingrid: Det synker når<br>Sheila (overtar): Når vannet fordamper<br>Ingrid: Ett eller annet, jeg aner ikke – det holder, tror jeg | Ingrid: Eh, the temperature will drop<br>Sheila: When it evaporates?<br>Ingrid: It drops when<br>Sheila (takes over): When the water evaporates<br>Ingrid: Whatever, I have no idea – it's enough I think |

'What happens' is perhaps the best way of expressing it but they could have chosen other ways of expressing this, e.g., the temperature we are to measure, will it increase or decrease? Sheila chose Ellen's words – 'what happens'. Ellen had repeated this formulation several times during the introduction so it is possible that it 'rubbed off' on the students.

Beatrice asked 'why' and thus it seemed she wanted a reason for why Ingrid said that the temperature would drop. Ingrid and Sheila did not seem to think Beatrice's contribution as relevant so they continued to formulate the hypothesis without taking notice of it. Thus, Beatrice's contribution was not important to them. Perhaps they did not see any reason why a hypothesis needs backing. Perhaps they ignored Beatrice because what she should do was to start carrying out one of the practical activities?

Ingrid's last statement "*it's enough*" is interesting. They have made a guess and they see no reason to argue for this guess. Ingrid perhaps deems it satisfactory for their use and she seems to mean the hypothesis fulfils the requirements made by Ellen.

I am not really sure to which of the activities this hypothesis 'belongs'. It could be evaporation. In that activity, the temperature will drop as evaporation requires energy (from surroundings), but in this activity there was no water – isopropanol was used. In the other activity where water evaporated, there was no need to think about temperature.

*Observations and Measurement*

As written above, Ellen did not often use transitivity processes that can be labelled as 'observe'. One of the activities is breaking this pattern. In the first activity, where the point was to reduce volume inside the syringe to compress the air, she frequently used the word 'feel'.

| | | |
|---|---|---|
| 5:11 | Den første er litt vanskelig å kjenne. Når dere har dratt luft inn i denne sprøyta her, ok, så er den full av luft. Så skal vi komprimere luften – | The first one is a bit difficult to feel. When you have pulled air into this syringe, okay, then it is full of air. Then we shall compress the air – and then |

| | | |
|---|---|---|
| | og da må dere gjøre sånn. Og dere skal prøve å kjenne at når dere har luft inni her så har den en viss energi og når dere komprimerer luften så skal dere kunne kjenne noen ting med temperaturen. Det er ikke sikkert at dere kjenner det, men dere må prøve i alle fall | you do like this. And you shall try to feel that when you have air inside here then it has a certain amount of energy and when you compress the air then you shall be able to feel something about the temperature. It is not certain you will feel it, but you have to try anyway |

This excerpt contains about one-half of all of Ellen's references to observation – in this case 'feel'. There is a slight contradiction as she opened with 'difficult to feel' but in the second to last statement she rephrases it to a certain statement 'you shall be able to feel' before she, in the last statement, made another uncertain statement 'it is not certain you feel'. Ellen is perhaps not sure of the outcome of this 'see and feel', so she allows for both possibilities – feel and not feel.

One of the statements (demand for action) might be a bit problematic "*And you shall try to feel that when you have air inside here it has a certain amount of energy*". To 'feel energy' is perhaps a phrase that is not often connected to science. The average energy of the air molecules will be related to room temperature, so touching the syringe would feel as 'hot' or 'cold' as any object in the room. However, when this statement is read together with the next – compress air – it becomes meaningful from a science point of view, i.e., work is done on the molecules.

The students were not sure whether they felt anything when they did this activity. Sheila sits with the syringe in hand and draws in air and compresses it several times.

| | | |
|---|---|---|
| 20:17 | Sheila: Hvordan skal du kjenne det?<br>Peter: Du skal kjenne om det blir varmere eller kaldere<br>Sheila: Når luften kommer ut?<br>Peter: Det er ikke lett å si om den er varmere eller kaldere<br>Sheila: Jeg vet ikke | Sheila: How are you to feel it?<br>Peter: You shall feel if it becomes hotter or colder.<br>Sheila: When the air escapes?<br>Peter: It is not easy to say if it is hotter or colder<br>Sheila: I don't know |

Sheila continued after this to explore the syringe and compression of air. She later stated that the syringe did become hotter. Beatrice did not do this 'see and feel' at all. Ingrid did it later (footage) but she did not say anything about what she found out.

The rest of this section will concentrate on the activity 'boiling under low pressure', as it was here where the most difficult observations and measurements were to be done. This was a rather complex practical activity, as it involved two different liquids each at three different temperatures. As this took five minutes to present and several pages of transcriptions, I give an overview of Ellen's introduction to this practical activity.

- Put the syringe in a liquid and draw up 5 ml liquid (Ellen models reading of 5 ml)
- Pull piston and hold over air inlet to create a reduced pressure (Ellen models and speak). Reduced pressure and the liquid boils at lower temperature (Ellen said this in slightly different versions)
- On the board: "Pull piston does the liquid boil?"
- Two different liquids - different temperatures:
    - Ethanol (denatured spirit) room temperature, 30$^{o}$C 40$^{o}$C
    - Water- more difficult to boil, 40$^{o}$C, 60$^{o}$C 80$^{o}$C (written on the board first intro)
- Make a table of results

In the last introduction, Ellen gave the students choice regarding temperature. They had to decide for themselves what temperature they should use. This was the only explicit choice Ellen gave to the students in the entirety of this practical work. However, it would be very difficult to ensure that all groups of students used exactly the same temperature.

In the first introduction, Ellen said:

| | | |
|---|---|---|
| 11:01 | Når det begynner å koke så ser dere at det dannes bobler | When it starts to boil you will see that there are bubbles emerging |

Here, Ellen helps the students with how to observe boiling. In this introduction, she also said (there is no footage of Ellen when she said this, she was standing in the middle of the room):

| | | |
|---|---|---|
| 10:56 | Så må dere se om dere klarer å lese av på skalaen her for hvor langt dere må trekke ut for å få det til å koke | Then you must see if you manage to read the scale here for how much you need to pull before it starts boiling |

In the first part of the introduction, she also said that it might not be possible to bring the liquid to boil, especially if the temperature was low.

In the last introduction Ellen did:

| | | | |
|---|---|---|---|
| 23:20 | Ellen puts left thumb over syringe air inlet. Holds the syringe in front of her – slant angle. Turns the syringe so that the air inlet is toward her face – thumb still over air inlet – and pulls the piston. She pulls all way down | Så holder jeg for, for da er det vann inni her – og så holder jeg for der<br><br>og så trekker jeg ut | Then I hold over, because then it is water inside here – and then I hold over there<br><br>and then I pull out |

In this last excerpt, the most important aspect is not what Ellen said but what she did. By pulling the piston all the way, she did not mark an (imaginary) volume where it started to boil. (There was no water in the syringe.) She pulled the piston in one movement. To find the volume where it starts to boil, one needs to find the border between boiling and not-boiling point. This means that there is pulling and pushing of the piston until one has the border value. This created some problems for the production of the table – see below.

When the students did this, they pulled all the way and the water boiled nicely. Then I reminded the students that they were to repeat this using isopropanol. They pulled – and saw 'nothing'. They heated the isopropanol even more to see if they could bring it to a boil in the syringe. Students were watching the temperature rising as isopropanol was heating in a water bath:

| | | |
|---|---|---|
| 40:05 | Sheila: er det åtti?<br>Peter: det er vel det<br>Peter: Det skal være fem sånne milliliter da – det skal bare være littegranne – sånn ja – flott<br>Sheila: Da var det åtti – da skriver jeg<br>Peter: Det skjedde ikke mye der<br>Sheila: (skrivestemme): Men det skjedde ikke noe spesielt<br>Gerd: Det boblet mye mer for vann gjorde det ikke<br>S/I/B: Ja | Sheila: Is it eighty?<br>Peter: It is so, I believe<br>Peter: It shall be five such millilitre – it shall just be a bit – there yes – great<br>Sheila: Then it was eighty – then I write<br>Peter: It didn't happen much here<br>Sheila ('writing voice'): But it didn't happen anything special<br>Gerd: It bubbled a lot more for water – didn't it?<br>S/I/B: Yes |

When they pulled their five millilitres of isopropanol into the syringe, they held a finger over the air inlet – and pulled – and they did not see 'anything special'. There were no big bubbles as was with water. They had heated isopropanol to a temperature right below its boiling point and they could not bring it to boil in the syringe. Strange? This stayed a 'mystery' for the students.

When the students started to work with 'boiling under low pressure', they had forgotten that they were supposed to measure the temperature so I reminded them of this. In the excerpt below, Sheila and Beatrice are measuring the temperature of water after they had brought it to boil in the syringe. They had thus five millilitre of water in a flask and a thermometer:

| | | | |
|---|---|---|---|
| 46:05 | B takes the thermometer halfway out of the flask shows it to S.<br>S looks sceptical (furrow her brow) | S: Tre…<br>S: Tre? | S: Three…<br>S: Three? |

| | | | |
|---|---|---|---|
| | B holds thermometer to indicate where the column ends | B: Nei, se her – under her, hvor mye er det - det der er to<br>S: To komma tre | B: No look here – under here, how much is it – it is two<br>S: Two point three |

Ellen had not modelled how to read the thermometer. She had taken for granted that the students were able to read an analog thermometer. The students seemed unsure, but the thermometer read two or three – so it had to be like this. This led to the following talk amongst the students:

| | | |
|---|---|---|
| 47:27 | Sheila: Var det tre gader i den andre?<br>Peter: Det kan ikke være tre grader – hvordan fikk dere tre grader?<br>Beatrice: Nei, det var her<br>Sheila: Jeg skjønner ikke – tretti grader<br>Peter: Tre grader var kanskje litt lite for varmt vann<br>Beatrice: Det var passe varmt da<br>Peter: I kjøleskapet ditt er det sju grader<br>Beatrice: Det vet vel ikke jeg<br>Sheila: Hva vet vi om temperatur?<br>Peter: Sju grader – varmt<br>Beatrice: Ok, det der gikk ikke så bra – tre<br>Ingrid: Trettifem grader<br>Beatrice: Nei, nei nei<br>Peter: Veldig varmt som er trettifem grader det er<br>Ingrid: Men det er blitt kaldere | Sheila: Was it three degrees in the other one?<br>Peter: It can't have been three degrees – how did you get three degrees?<br>Beatrice: No, it was here<br>Sheila: I don't understand – thirty degrees<br>Peter: Three degrees is perhaps a bit low for hot water<br>Beatrice: It was sufficiently warm<br>Peter: In the fridge there is seven degrees<br>Beatrice: I don't know that<br>Sheila: What do we know about temperature?<br>Peter: Seven degrees – hot<br>Beatrice: Okay, that didn't turn out well – three<br>Ingrid: Thirty five degrees<br>Beatrice: No, no no<br>Peter: Very hot that is thirty five degrees that is<br>Ingrid: But it has become colder |

Peter presents here a bit of everyday reasoning, which opposes the girls' reading of temperature. Three degrees are cooler than the refrigerator. Ingrid helped Beatrice and Sheila by reading the thermometer and said it was 35 degrees. Again, Peter states the 'obvious' – there is a touch of irony in his voice - that very hot water at 35 degrees is … Ingrid then said that it had become cooler. The volume of water was small and it had taken some time from when the water was in the syringe to when the temperature was measured. Ellen had not given any demand for *when* temperature was to be measured, before or after it was brought to boil in the syringe. This provided an implicit choice situation for students. This group of students measured the temperature of the water *after* it had boiled in the syringe and they measured the temperature of the isopropanol *before* they had it in the syringe. In the introduction, there was no reference or outspoken demands to the need of being systematic or to deal with uncertainty in measurement.

What is not there in both Ellen's and the students' semiotic actions is any reference to uncertainty or errors in measurements.

*Inscriptions – making a table*
The results of the 'boiling under low pressure' activity were to be presented in a table. After Ellen had presented this activity the first time, she asked "*Do you understand what to do?*" and at least one student said yes. Then Ellen said:

| | | |
|---|---|---|
| 10:34 | Og dette her må dere føre inn i tabell | This you must write in a table |

This was not further elaborated.

After the last introduction in the science lab Ellen went through the procedure once more but left it to the students' choice to decide the temperature, she said:

| | | |
|---|---|---|
| 24:16 | Husk at dere skal notere temperatur, hvor mange milliliter dere trekker ut. | Remember that you shall take notes of temperature, how many millilitres you pull out |

This was not further elaborated upon, nor was any specific reference to the table provided. The students did not often use tables in science and I am not sure of their skills in making science-tables. Did the students make a table? Probably not, as they did not have any numbers to write in it. However, at this point I cannot be sure, as they did not hand in the report after the practical work.

When making a table in science it is important to identify the variables that are to go into it. In this activity, there were two independent variables – the two liquids – and for each of the liquids three independent variables – the temperatures and the corresponding dependent variable the volume where it started to boil. A prefabricated table may have structured this for students. The word 'variable' was not mentioned.

#### 6.4.2.2. Text – context and instructional norms

The norms are inferred from the teacher's semiotic actions and how these semiotic actions provide possibilities for students' semiotic work. What the teacher says and does, gives an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as the 'tacit' practice or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Procedure, methods and carrying out practical work*
In the introduction, there is a clear emphasis on how to do. Procedure = Do! and then Science Happened! The two transitivity processes 'do' and 'happen' provide a view of science as something that happens when you follow a procedure, and not as a way of seeing natural phenomena. The outcome of the doing is referred to as 'happen', seldom as 'observe'. Happen is independent of the observer ('it happens') whereas 'observe' most often is connected to the pronoun 'you' (plural) and at some instances 'we'. 'Observe' requires an active observer. There are few verbal or mental transitivity processes in the introduction. The occurring mental and verbal processes are used just as often together with the pronoun 'you' (plural) as 'we' or 'I'. This weight on action and 'happen' is also prevalent in the students' dealing with the activities. I will claim that the 'do!' is strengthened by the choice of introducing and carrying out five activities in a row. For students it becomes important to finish them all within time, i.e., little time to ponder.

Norm: Practical work emphasizes doing.
Norm: Results will show themselves (happen) when procedure is followed.

There are many demands for specific actions in Ellen's introduction, e.g., 'you shall' or 'we shall'. Students are given only one explicit choice (temperature of liquid). There are implicit choices, as there are some unresolved tensions in Ellen's introduction that the students have to solve (e.g., measure temperature before or after or reading the boiling volume of the syringe). The overall picture shows little freedom for the students to decide (parts of) procedures and methods. There are no deliberations (teacher or students) about accuracy in measurements. The procedural 'do' element in Ellen's speech is emphasized by the use of additive and temporal connectors. The use of causal connectors could have shifted the perspective to also include reasons and causal explanations.

Norm: Procedure is fixed and hence there is no need to deliberate over it.

Hypothesis is a guess or prediction based upon everyday experience. Making a hypothesis is supported by Ellen's use of questions in the introductions. It is not stressed *why* one thinks something is 'happening'. This also seems to be accepted by the students as they turn down Beatrice's search for reasons why the temperature will decrease. This implies that the term hypothesis does not have a scientific meaning in this case (see also 10.5.2), but serves as a device for students' learning. Students can, by stating hypotheses, formulate their previous experience and this can also be a way of generating interest among students. However, not all the students are partaking in the generation of hypotheses. This can be seen in connection with the students' responsibility for collaboration, included division of work. Sheila and Ingrid's talk about hypotheses might indicate that they see the hypothesis more as a 'formal school requirement' than something important for observations.

Norm: Hypothesis serves as a pedagogical devise.

*Scientific knowledge*

When Ellen talks about subject matter, she uses (mostly) certain statements – 'this is the science'. This view of science is also strengthened by her avoidance of dealing with differing results and discussing these in the summary the next science day. In classroom talk (or in the recorded material with the group of students), there is just one example in this case where Ellen begins to explore (or challenge) what a student said (John's response on molecules and pressure). However, she does frequently elaborate on students' responses.

The group of students knew they had an unexpected result on boiling under low pressure. For the students, it becomes a 'mystery' when their result clearly is at odds with what is expected. Students did not explore this 'mystery' any further, nor did they ask for Ellen's help to solve it. The answer they got the next science day is what the result should have been and not a reason why they got the result they did. Ellen states correct scientific knowledge. Even if their mystery does not necessarily need to be solved immediately, solving it would perhaps have provided an explanation for the unexpected result.

Norm: Scientific knowledge is certain.
Norm: Differing results are not explored (by teacher and students).

Ellen chose not to introduce entities such as heat, pressure or temperature before the students started to carry out and explain (report) the practical work. The almost total absence of mental and verbal transitivity processes in combination with the pronoun 'you' (i.e. students) is prevalent in this case. This gives a 'hidden' message that thinking and verbalizing are not very important in these activities. This enforces a view that there is little use for scientific theory in carrying out the activities. This is the counterpart of emphasis on do-processes.

Norm: Practical work does not need to be connected to scientific knowledge.

*The 'language' of science – communicating science*

The words that students needed for descriptions and explanations are under-communicated or not there. These words (e.g., water turns into steam when temperature increases – and steam requires more space) might have helped students to 'see' the activity, to observe it (more) scientifically. The words Ellen used and emphasized in the introduction are mostly words that help students 'do' the activity (e.g., through the word water at the expense of steam) – not observe it. However, boiling is explicated and the use of 'feel' in 'reduction of volume of gas' could act as support for observations. For the most part, there is a good connection between what Ellen does (with equipment) and what she says. The exception is boiling under low pressure where she wants the students to read the volume for boiling point, but she herself does not model how this is physically done.

In these activities, there are many entities. Some are difficult (e.g. heat, temperature, pressure). To be able to use these reasonably well within a science context takes time. They need to be explained and students must practice their use. The students were given the 'impossible' task of explaining the activities after they had carried them out. This of course did not go very well, as the students partly lacked the verbal resources for constructing explanations.

Norm: 'Everyday' language is sufficient for describing and explaining scientific phenomena.

Ellen had planned a task sheet that could have supported the students in measuring and making the table. It was however, not given to the students. In the introduction, Ellen only stated that a table was to be made and that the students were to take notes of temperature and boiling volume. Ellen did not model these resources. In other words, there was a lack of semiotic resources that could have supported students in their deliberations about how to obtain and report results. How to read the boiling volume, how to read the temperature and what the table could look like, were left to the students to decide. This can be seen as an extension of the prominence on 'do', and can be connected to the students' autonomy to organize the work within the procedure.

Norm: Resources to support measurement and reporting results are not emphasized.

The procedure itself is presented almost without questions. There are some not-to-be-answered-here questions and some (non-committing) checking of understanding, e.g., 'okay?'. Ellen poses no real questions to students during the presentation of the procedure. When she went through the practical work the next science day, she asked questions for descriptions of what the students did as well as explanations. In these exchanges, there seems to be a pattern where Ellen asks a question, and if no one answers or if a student answers 'incorrectly', Ellen answer herself. Ellen takes over and answers. The 'incorrect' answer is never publically called 'wrong'. This might produce a situation where students are unsure of what the right facts are. The other side of this is that the students do not feel rejected by the teacher publically, which probably makes it easier to contribute the next time. Ellen answers the students' questions promptly. The students' questions are of a more practical type – 'what's on the board' and so on.

When the group of students was writing their report, they knew they had findings that could not be 'right', but they chose not to call for Ellen. Perhaps this reluctance toward posing a subject matter question is a way for students to avoid attention to what they feel they do not understand. There are no incidents (linked to this case) that a student raises a 'difficult' subject matter question in the full class.

Norm: There is little challenging of each other on subject matter.

## 6.5. Rhetorical framing of heat pump

This section draws on all the previous sections in this chapter and integrates the regulative and the instructional together with the other factors that impact the rhetorical framing (physical space, time, resources and competence aims) and how these factors are put into play.

There is one prominent finding in this case. It is the shift in speech function between the regulative and instructional part of the introduction. Speech functions are a feature of the interpersonal metafunction, and they say something about how Ellen relates to the students. When the topic is in the regulative domain (e.g., collaboration), the speech functions are questions or (uncertain) statements, whereas when the topic is procedure or subject matter, the primary speech functions are respectively demands and certain statements. In the regulative domain, it can be said that the practice in this class is quite 'student centred'. Students partake in decisions, e.g., with whom to work, and negotiate some parts of classroom order. In the science subject matter domain, the practice is 'restricted'. Science is presented as certain (statements), there are few choices regarding procedure and subject matter differences are seldom explored.

The norms inferred in the regulative part of the text are:

- Students are implicitly given autonomy to organize collaboration (within the structure of procedure) for how to carry out the practical work and make meaning of it.
- The goal is to carry out the practical activities.
- Purpose is not emphasized.
- The activity shall be easy and simple to carry out.
- Students may challenge the teacher regarding behaviour.
- Appropriate behaviour is (partly) negotiated.

The norms inferred in the instructional part of the text are:

- Practical work emphasizes doing.
- Results will show themselves (happen) when procedure is followed.
- Procedure is fixed and hence there is no need to deliberate over it.
- Hypothesis serves as a pedagogical devise.
- Scientific knowledge is certain.
- Differing results are not explored (by teacher and students).
- Practical work does not need to be connected to scientific knowledge.
- 'Everyday' language is sufficient for describing and explaining scientific phenomena.

- Resources to support measurement and reporting results are not emphasized.
- There is little challenging of each other on subject matter.

First, I will see how physical space, resources, time and curriculum provide a possibility space for the activities and how these factors play together or against the norms. Then, I will return to a discussion of the norms.

*Physical space*

The physical space of the science lab provides both possibilities and limitations for the practical activities. The science lab's main advantages are the closeness to equipment, e.g., hotplates and the infrastructure of the room with power sockets and sinks. The board is small and green[10] writing on a white board is hard to read. In addition, there is a large teacher's desk in front of the board. If teacher chooses to stand by the board she is far from the students. In the science lab, the teacher did not write much on the board but used equipment to show the procedure. This gives some implications for the 'words' given to support observations and explanations as they are only presented by the mode of speech. They are not supported by the mode of writing. When the subject matter is in the mode of speech, it is reasonable that it becomes more 'every day'. Speech does not have the formal structures of science writing. This is also consistent with findings where the entities became more 'every day' or informal in the introduction in the lab, as Ellen chose to stand in front of the teacher's desk and not behind it. She chose closeness to students at the expense of the formal science language.

For the students, the lab presents some restrictions. Their hotplate was connected to a power socket at the back wall. This meant that it was crowded if all students were to stand in front of the hotplate. As the hotplate was on the back bench, they could not stand around it. The bench was narrow and high, and thus unsuited for writing on the personal computer. The students would have to 'choose' if they were to sit by the desk (and computer) or stand by the bench and the equipment. In addition, the seating arrangement made for some limitations as the students' chairs were directed away from (some of) their practical activities. They could choose if they were to write and look toward the board or look at the experiment on the back wall (expansion and condensation + heating of liquids to boiling under low pressure). The students did not seem to regard it as necessary (or possible) to move their chairs. The students were implicitly given the responsibility to organize their work and the problems they might have felt concerning physical space were theirs to solve, there was no intervention from Ellen.

*Resources*

The equipment in these activities were mostly familiar artefacts (balloon, flask any flask could have been used, hot plate, syringe). Ellen handled the most scientific

[10] For some reason only the green board marker was working – lack of basic equipment at school?

equipment herself, the data-logger. The thermometer is also a common enough artefact (most Norwegian households have one). The most salient feature of the thermometer (used in this case) is the scale on which one reads the temperature. For some of the students, the thermometer presented a challenge. The thermometer is one of the 'obvious' instruments in science, but not so for all students. The familiarity of the artefacts is a way of making science more 'every day', making it simpler. Heavy equipment could have served as black boxes for students, as instruments have inbuilt scientific knowledge. This will be further elaborated in 10.5.1. The choice of 'every day' equipment is a part of making the activities easy to understand and simple to carry out.

The syringe is an artefact that in this case has two important features. It affords the expression of physically boiling under low pressure because if one holds over the air inlet and pull the piston, one creates lower pressure. The other feature is that it has a scale that makes it possible to read the volume. There were not enough syringes for groups of two-three students. So, at least some of these practical activities had to be carried out in large groups. They could of course have been carried out by shifts instead. The large groups provide an implication for student collaboration and responsibility for outcome (report). It becomes easy to withdraw from the work. There were no direct approaches by the teacher to get students to collaborate more. This can lead to (amplify) the students' notion of practical work as 'free space', but also it provided students with an opportunity to direct the activity themselves, i.e., social/collaborative autonomy.

Resources such as a prefabricated table would have helped the students in structuring their measurements, but this would perhaps have challenged students and their way of carrying out 'boiling under low pressure' and thus conflicted with the norms of 'easy' and the strong focus on 'do'. Resources for interpretation and presenting knowledge would have given students more to 'think about' and thus reduced the focus of 'do'. That is, if the students could handle these resources together with 'doing' the activities. Perhaps if students had a table, it would structure the science, but the activity would be less 'simple', e.g., the students would have had to find the volume when it started to boil.

*Time*

Time is of considerable importance. In the teacher's presentation, there might be an element of stress. The presentation cannot last too long or else the students might become impatient. This can be seen as a reverse time summons. The teacher is not in (total) control of time. For students, time combined with task activities provides (most likely) a stressing element. The task has to be done. There is no time to think about it, or feel for that matter. The important point is to tick it off as done. This strengthens the focus on 'doing'.

Time could have been divided between the different activities by giving an introduction to each activity just before the students were doing it. This could have made it easier to structure the tasks for the students, but possibly more difficult for the teacher as it would involve time summons, i.e., interruption of the students activity. If Ellen had given the students explicit time for making the hypotheses this could have ensured that all the students in the group could partake in the construction of the hypotheses, but this would conflict with the high level of students' autonomy for how to collaborate during the practical work.

*Curriculum*

The curriculum's competence aim (explain heat pump) was not coupled with aims from *Budding researcher,* e.g., identify variables, estimate uncertainty in measurement, detect sources of error, etc. If the Budding researcher aims were to be incorporated, there would have been even more for the students to be aware. This would have been in conflict with the norm of 'simple'. The activities were coupled explicitly to 'hypothesis' where 'hypothesis' was seen as an educated guess or a prediction based upon previous experience. Ellen said that the hypothesis could be wrong, and thus lowering the list for students' contributions. As not all students contributed to the making of hypotheses, the hypotheses became 'owned' by two of the students. This means that not all students' previous experience was incorporated into the common hypotheses. When the students made their hypotheses, one of the students challenged the others by asking 'why', and this was ignored. This can be linked to the norm of low challenge, which also is at work in the relation between the students.

Basic skills were implicitly a part of the activities (oral and written communication). Regarding the tabular form of presenting results, it was loosely connected as the table had to be made by the students. How the table was dealt with is missing from the material, as students did not hand in the report. Most likely, they did not make a table.

The competence aim 'explain heat pump' requires a firm understanding of the terms heat, temperature and pressure. When the students' understandings of these (complex and interlocked) terms are connected to their everyday experience and everyday language, they have few possibilities to make use of these as scientific terms to observe and explain. In this case, the students used 'everyday' words to communicate their observations and explanations. The question is whether it is possible to acquire a sufficient understanding of these terms in the limited time. However, the teacher made few attempts to support an understanding of what these terms meant. I think limited time in combination with these interlocked terms reinforces the 'everyday' language in the introduction. A stronger focus on the scientific terms would of course be possible but this would require more time spent in the introduction and thus influence the emphasis on 'doing', and it would be necessary to challenge the students' understanding of the subject matter. More weight on terms would thus conflict with 'easy'.

*Norms*
The teacher conveys science as certain knowledge and it is not debateable. There is no exploration of differing results. Science is perhaps even seen as the 'actual' way of observing natural phenomena. Knowledge in science *is* – it is not the natural world seen through science. Norm-breaking would be if the teacher or the students suddenly asked why different results occurred or if this could be seen in another way. If the students in the group had insisted on an answer to why their isopropanol did not boil, this would be a breach of the 'contract' of not challenging each other. There is also a low degree of subject matter challenge between the students. This might be seen in light of the norm that practical work is to be easy and the emphasis on 'doing'.

Practical work is emphasized as doing – not as a 'tool' for meaning-making. There is support for the hands-on activity. However, there is little support for the mind-on activities such as connection to scientific knowledge or methodical aspects of the procedure. This provides a strong focus on 'do' at the expense of constructing meaning. The hypotheses (prediction) could have helped to construct meaning better if explicit time to make them had been given and the hypotheses were required to have backing. The procedure further leads directly to the 'correct' observations. When this does not happen, it is ignored. Norm-breaking would be if the procedure was partly open and the students had to make justifications for their choices. However, this would mean that the teacher and students began to challenge each other on the subject matter. It also would mean that the tasks would be less easy, as there would be need for a deliberation over different results and different ways of thinking. Science would be a lot more complicated (– and more interesting?).

The purpose of activity is vague or very loosely formulated (help explaining heat pump). Why do we do these activities and why do we do it in this way? This question is not addressed very explicitly by the teacher and not at all by the students. The goal is to do the activity, i.e., the procedure becomes the goal. An aim or a goal without an understandable purpose becomes instrumental. Here, the strong focus on procedure and a loosely formulated purpose related to the construction of meaning of provides an instrumental focus. It is then a question if the outcome of the practical work becomes almost meaningless for the students' construction of scientific meaning. This can be linked with the low emphasis on combining scientific knowledge with procedure and the results of observations.

The language used by both the teacher and students is 'everyday'. Terms are used in a loose scientific sense. This can also be seen in the 'missing' support for vital resources for observing, measurement and reporting of results. In some ways, this makes the activities less difficult. There is less to think about, but the activities become less 'science' and more 'doing'. However, perhaps the focus on 'simple to carry out' and the 'everyday language' is obstructing or making it more difficult to make meaning of the practical work.

Students are ‘restricted’ on procedure as it is fixed and science knowledge (as certain), e.g., they do not need to make choices to eliminate errors or uncertainties. This makes it simple to carry out the practical activity, and the goal is to carry out the procedure. On the other hand, when it comes to collaboration, the students are responsible. This has some advantages such as strengthening student autonomy (on social matters), but when there are problems they do not have the ‘tools’ to sort these out, e.g., if they do not reach an agreement between themselves. Norm-breaking would be if the students said that student NN is not contributing, or the teacher talked directly to a student who was not taking part in the activity.

There are no/very few challenges between the teacher and students on the subject matter. The students sometimes challenge the teacher on behaviour. This might be seen as a form of resistance from the students or it might be a way of giving the message ‘we are here – take notice of our level of interest’. Students can give ‘wrong’ answers and is not exposed. This can be seen as positive, as it possibly leads the students to feel more emotionally secure in the class. On the other hand, there is little external pressure to motivate the students in their learning. However, too much pressure and the student would drop out? Norm-breaking would be to start to challenge each other on the subject matter.

Has this, science is certain, low challenge on subject matter, a focus on ‘doing’ together with a student-centred social organization, something to do with the content of the activities or the fact that this was not Ellen’s favourite topic. What happens if the activity and the content are different? To explore this, there is the next case – the DNA-code.

# 7. DNA-CODE – SECOND CASE

This chapter is a description and interpretation of the practical work connected to the explanation of DNA-coding. The chapter is structured as follows: first, there is a section that provides a description of the data material used to construct the case and the boundary between text and context. The second section is a short presentation of the curriculum competence aim including protein synthesis and DNA-coding. The third section is a presentation of context, i.e., the planning in advance of the activity, what happened the day of the practical work and the next science day when the students had a small test on DNA-coding. The fourth section is the text analysis. This section is divided into two parts; regulative and instructional. Each part provides a description and interpretation of the teacher as well as students' semiotic actions, and provisional norms are inferred. In the final section, the rhetorical framing is inferred.

## 7.1. Case material and boundaries

The empirical material used in this case is:

| | Material - duration | Transcription |
|---|---|---|
| Context | Field note April 27th | |
| | Audio Ellen and Gerd planning the week before the practical work.<br>Approx. 3 hours 25 minutes | Roughly transcribed (other parts of content not transcribed) |
| | Video Ellen's presentation of protein synthesis on the board.<br>Approx. 33 min. | Multimodal: writing board speech (not fully transcribed on action) |
| | Audio Ellen and Gerd evaluation after the practical work. Approx. 2 hours 16 min.<br>(the file also contains planning of the rest of the protein synthesis) | Roughly transcribed |
| | Task sheet written by each individual student in the group | |
| Text | Video Ellen's introduction.<br>Approx. 19 min. | Multimodal: action – board speech |
| | Video group of students practical.<br>Approx. 9 min. | Multimodal: action speech |

Table 5: Data material for DNA case

The planning is part of the context, as it played a role in choosing the practical activity, but the activity was not planned in detail.

The teacher's introduction is 'fleeting' from a theoretical introduction of protein synthesis to an introduction to how the practical work was to be carried out. The teaching of protein synthesis will influence the activity, so I have chosen to give a recount of this introduction in the context but not to include it in the text. The text is 'defined' by the beginning of genetic coding. The ending of the text is defined when the students finished their product, their 'word'. However, the practical work was not finished. The students read other students' words and there was a summary by Ellen. Because of limitations on using video in the whole class settings, I have no recordings of this.

## 7.2. DNA-coding curriculum aim

At the end of April, the topic was protein synthesis as part of the theme 'Biotechnology'. The competence aim in the national curriculum states:

> The aims for the education are that the pupil shall be able to
>
> - explain genetic coding and the main characteristics of protein synthesis and discuss the importance of heritage and the environment (Utdanningsdirektoratet, 2006)

This is one of four aims in this theme. This aim is a compound, as it consists of two parts – 'explain' and 'discuss'. I will only go into the 'explain' part, of which this practical work is a part. Genetic coding and protein synthesis are connected, so these entities have to be seen in relation.

As in the case of the heat pump, the students are expected to *explain* genetic coding. So, what is genetic coding – and what does it involve? The DNA inside the cell nucleus, in form of a double helix consists of base-pairs connected to a backbone of sugar and phosphorus. A base can be an A, C, G or a T. Genetic codes are series of triplets of bases, e.g., ACG. On the complementary DNA thread, there will be a corresponding triplet – TGC, as the bases make (chemical) bounds in the pairs C-G and A-T. As the DNA itself does not leave the cell nucleus, a part of the DNA (gene) is copied. The gene contains the 'recipe' for a protein. The copy of the gene is called mRNA. The base T does not exist on mRNA – but the base U has taken its place. Outside of the cell nucleus, the mRNA connects to a ribosome in the cell and the production of a protein can start. Each triplet – also called codon – codes for a particular amino acid. Several different codons code for the same amino acid. There are about 20 different amino acids. So, a particular strand of mRNA will code for a particular protein, where proteins are a molecule consisting of many amino acids. The actual making of the protein (which also can be called a polypeptide) is taking place in the ribosome, where each of the codes on mRNA is coupled with a tRNA with the corresponding code. The tRNA transports a particular amino acid.

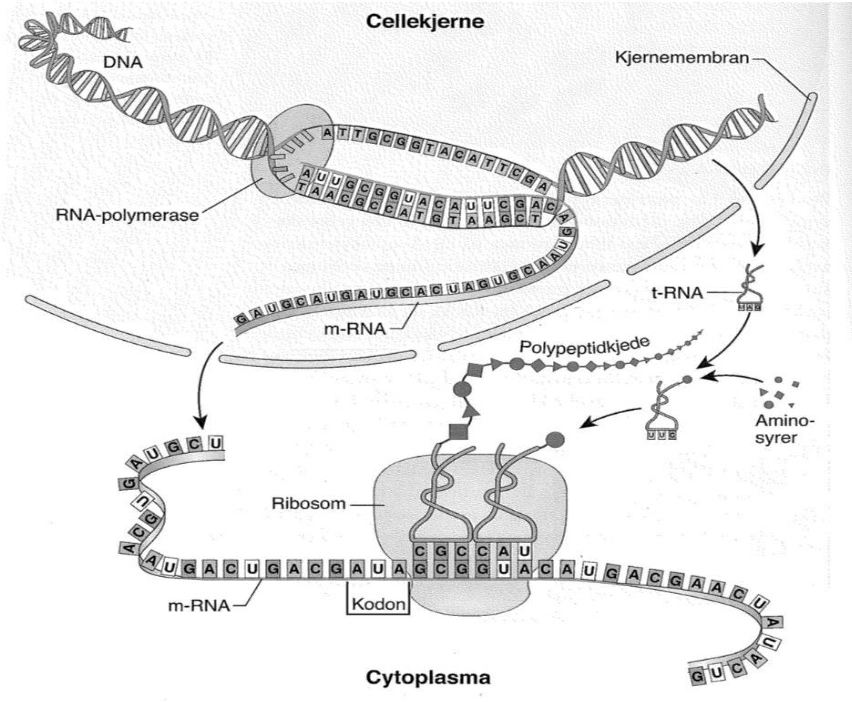



**Figure 7: Illustration of protein synthesis from textbook (Bønes & Fløttre, 2006)**

All of the terms I use in this (my) rather rudimentary *description* were used by Ellen in her presentation of genetic coding and protein synthesis. In this practical activity, students were working with codon and how three and three bases make a 'unit' and these units together form a 'message' (in the protein synthesis this 'message' is the recipe for a protein). The purpose of the practical work 'seigmann[11]-code' is to make a simple model of the mRNA – and thus acheive a firmer understanding of genetic coding. This practical work was strongly guided by the teacher as the excerpts below will show.

According to the national curriculum, the students should have worked with cells (plant and animal) and genetic variation in years 8-10.

## 7.3. Close context

All excerpts given in this section are ordered chronologically.

*Planning*

This planning session, on April 23rd, lasted more than three hours. We planned in some detail the next science day, the day of the 'seigmann-code'. Ellen stated that the aim is that the students are to understand the process of the protein synthesis – but not necessarily every detail of it. Ellen said that she wanted to start with 'teaching', a repetition of the last lesson. We then discussed practical activities that

[11] Seigmann is a type of sweet – formed like small men in four different colours. 'Seigmenn' is plural of 'seigmann'.

could be used, and I introduced an idea of making 'DNA-chains' out of students, i.e., a physical (bodily) representation of DNA. Ellen responded that the practical activity could not take too much time – and she started to search the Internet for possible ideas. After searching for a while and discussing various possibilities, we decided on the 'seigmann-code' from Forskerfabrikken[12]. The 'seigmann-code' seemed a bit 'fun' and as a practical activity, it provided some possibilities. One of the possibilities was that the students could write a message and the other students could read this message. In addition, it was possible to make a small competition out of it. Ellen stated that this practical had to be done in the classroom so students could be allowed to eat the 'seigmann' afterwards. Eating was not allowed in the science lab for health and safety reasons. We elaborated on this no further, so Ellen made the final design for the introduction and the plan for carrying out the practical work herself.

During the planning session, I proposed that students could make a small report afterwards. This was not followed up in our talk.

*The 'seigmann' day April 27th*

This was a six-hour science day. This science day started as most, with Ellen introducing the day's program. Because there was an exam this day, the students' wireless network was down and their computers were off-line. One of the students (Sheila) in the group was not present this day.

First, Ellen asked the students to draw DNA on a piece of paper she handed to them. They were to do this anonymously. Ellen looked through the drawings – no two were alike, but all represented some sort of double helix. Ellen gave no comment to the drawings and wrote 'Protein synthesis' on the board (the drawings were not followed up later). She started to talk a bit informally with the students before returning to subject matter. While she talked about the protein synthesis, she made a drawing on the board. During this presentation, Ellen made several pauses so that the students could catch up with their note-taking. A student asked 'Shall we draw this' and Ellen replied 'draw and write'. I wrote the following observation in the field-note:

> Students are slow to start taking notes… All having their lap-top open. I am not sure if they make drawings.

There was an introduction of entities such as gene, DNA and chromosome. In between, Ellen asked questions such as 'can you roll your tongue?' 'which hand do you prefer to have on top when you fold your hands?' This led to exploration and some talk amongst students. It also generated some student initiated questions about the subject matter – which was very rare – e.g.,

[12] Forskerfabrikken: http://www.forskerfabrikken.no/

| | |
|---|---|
| John: Er det gener som styrer alt?<br>Ellen: Det styrer veldig mye. Det gjør det | John: Do genes decide everything?<br>Ellen: It decides very much. It does |

A little while later Ellen elaborated on this answer. In between, she had written on the board*: a gene is part of the DNA that contains the recipe for a protein, these proteins decide what we are to become*.

| | |
|---|---|
| Er det ikke rart at det er disse proteinene som bestemmer hvordan vi skal bli? Det var litt bombastisk, det er derfor vi diskuterer om arv eller miljø betyr mest, men man sier at gener er muligheter og miljø er (uhørbart) – ok?<br>Det vi nå skal se på er hvordan informasjonen som finnes i DNA overføres og lager proteiner. | Is it not strange that it is these proteins that decide how we are going to be? That was a bit too strong, that is why we discuss if heredity or environment is most important, but you may say that genes give possibilities and environment is (inaudible) – Okay?<br>What we are about to do now is how the information in the DNA is transferred and makes proteins |

Ellen proceeded to ask questions about what proteins are. She did not make an explicit reference to the theme nutrition that the students worked with in the autumn. In the topic nutrition, students had worked with chemical properties of proteins (i.e., that it was a compound of many amino acids) and digestion. She drew on the board a figure much similar to the one in the textbook, see above. She made a point of the fact that mRNA is transported outside the cell nucleus – and she drew the 'same' mRNA once more outside the cell nucleus. She told the students that the mRNA found a ribosome and then she pointed at the mRNA string on the board:

| | |
|---|---|
| Nå kommer noe som er litt vanskelig (venter)<br>Hvor mange aminosyrer skal den kode for? At den skal fortelle at den skal ha <u>den</u> aminosyren og <u>den</u> aminosyren og den aminosyren?<br>Steven: mange millioner<br>Ellen: Vi har bare 20, det holder med 20 aminosyrer, men det gir opphav til svært mange proteiner. | Now comes something a bit difficult. (waits)<br>How many amino acids shall it code for? That it shall tell that it shall have <u>this</u> amino acid and <u>this</u> amino acid and that amino acid?<br>Steven: many millions<br>Ellen: We've only got 20 it is enough with 20 amino acids, but it creates very many proteins |

Ellen waited for several seconds. This can be interpreted as a way of ensuring the students' attention on something Ellen obviously has experienced as difficult for students. However, it is only *a bit* difficult. It can be interpreted as possible to get a grasp on this part of the subject matter or maybe she is reducing the perceived 'difficulty' and at the same time getting students attention. Ellen gave two questions that are related. The first one might be interpreted as how many amino acids *this* string (on the board) will give. Steven's answer (many millions) seems a bit out of place, as the string itself was quite short, it contained only about 20 bases. Perhaps

Steven was thinking about all possible proteins in the world. However, Ellen did not pursue his answer as she simply stated the number of amino acids. By asking questions and getting short responses from the students, Ellen stated after a while:

| | |
|---|---|
| Derfor, når vi vil vite hvilken aminosyre som skal være her (peker på figur mRNA på tavla) så må vi telle tre om gangen. Og ikke spør meg hvordan de har funnet ut dette her for det vet ikke jeg. | So, when we want to know what amino acid that are to be here (points at the mRNA figure at board) then we have to count three at the time. And don't ask me how they have found this out – that I don't know. |

While she said this, she drew a box around a triplet of bases. Then she introduced the tRNA and the ribosome, which I will not go into. At the end of this lesson, she said:

| | |
|---|---|
| Jeg har prøvd å ta dette veldig langsomt. Jeg håper at dere er sånn nogenlunde med. Vi skal jobbe med det. | I have tried to do this very slowly. I hope you have hung on reasonable.<br>We are going to work with this. |

After the mid-lesson break, Ellen introduced the practical work - make a word (a message) in 'seigmann-code' (see next section for a full description).

*Post-practical work*

When all of the student groups had finished their message, they walked around the room to read other groups' messages. In my field note I wrote

> When the students are finished they walk around and look at other words, do they write down the other words? There are some 'messages' that are meaningless – this is commented by some students. All the students seem interested in trying to find the messages, although some are standing too short a time on one place to actually be able to decipher the message. *Perhaps this was an enjoyable activity partly because they are allowed to move around?*
> (field-note 27.04 – speculation in italic)

Ellen had a short summary afterwards (approximately two minutes) were she said the words that belonged to each group. Not all groups had managed to 'write' a readable word. Ellen did not press those groups to say which word they had intended to 'write'.

After the practical work had finished, there was a break. After the break the science day resumed in the science lab, there one of the students led the class through tasks on the science computer program 'Viten'. Then students worked with their cartoon on the protein synthesis. Ellen was, for long periods of time, sitting at the teacher computer working with something. In my field note I wrote that this part of the lesson was driven (only) by the students' own interests. Before ending the day there was another task – the genetic wheel, which Ellen led.

The next science day, May 4th, the students completed a task that was related to the DNA-code practical work and they 'named' the entities that are involved in protein synthesis. They also performed a task of reading the 'real' table of bases that gives the specific amino acids. Beatrice and Ingrid both did the task. By their answers, it seems that both were able to use and read the table of amino acids, and thus transfer from reading of 'seigmann'-table to reading the amino acid-table.

Ellen and I had an evaluation the day after the 'seigmann- code'. Ellen said: "*They did hang on that 'seigmann-thing', mostly, but they do not manage to place it in system, they do not see the connection*." I asked her why she was sitting by the desk at the end of the day – and she replied that she was tired and so were the students "*It is terribly difficult when you are a teacher and become tired*."

*Summary of context:*
Ellen used a dialogic approach to talking about genes and DNA. In the part where it was about genes she 'threw in' some questions about students' characteristics that can be explained genetically. Students were eagerly partaking in this and there was lot of talk amongst the students (e.g., can you not role your tongue?). She asked many questions in her subject matter introduction. All were short response questions (e.g., 'have you heard about DNA?'). Some questions she answered herself as no student took initiative to answer. In the latter part of the introduction, the primary contribution from the students was to identify the base opposite. Ellen asked some 'thinking-questions', but these served more as to structure her presentation, as they were answered immediately by herself. There were some 'wrong' answers from students (i.e., answers that are not what Ellen had in mind). These are not explored nor are they publically called wrong, and Ellen stated the 'correct' answer.

Ellen chose not to use the students' drawing in this lesson and she only very briefly related to the students' previous experience with proteins: "*Then we shall have the word proteins, that you have encountered before. What is a protein?*"A student answered this question.

In conversation with me (not on tape), Ellen gave a more nuanced view of the interplay between genes and the social environment than what she said in class. This was a topic Ellen knew a lot about and she felt (I believe) comfortable in teaching it even if it is often difficult for students, as there are many scientific terms involved in the processes.

Next is the description and interpretation of the texts.

## 7.4. Practical work – making the 'seigmann code'

The practical work is about making a model of the DNA model by the use of seigmenn. The 'seigmann model' can thus be said to be a re-representation of DNA and DNA coding. The task is to 'make a word' by using seigmenn, where 3 and 3 seigmenn code for one letter. This is analogues to the representation of DNA-coding.

The introduction can be divided into two parts. First Ellen introduced the code key for how to find the corresponding letter to a triplet of 'seigmenn'. The letter is thus a re-representation of an amino acid. After this, Ellen presented the procedure. There are several differences between these two parts of the introduction, even if there is no formal division between them such as a break or change of room. The differences are, amongst others, theme, background sound (students) and speech functions.

In the first part, the students were mostly sitting quietly (almost no sound of students speaking 'out of turn' on the tape) and many (all?) were taking notes. This is possible to interpret even without footage of students, as they asked questions such as '*what is written there?*' Ellen had several pauses as she construed the table to make time for students to catch up. There were also several short response questions in this part of the introduction – from both Ellen and the students. When Ellen answered questions about reading the table, Ellen used her hands to point at the table in a systematic way (first, second and third).

The second part of the introduction was Ellen's presentation of the procedure that lasted about six minutes. Therefore, in this part of the introduction there was a focus on how to carry out the practical work. During this time the sound level rose. Students were talking while Ellen presented the procedure. In the middle of the introduction of procedure, there were some questions to the table on the board. Ellen did raise her voice and she also spoke faster as she went on presenting the procedure. In the first, part she stood by the board most of the time, to write and read the table, in this part she walked more around the room. She stopped by the board to write some key words and to make a drawing of how to connect the 'seigmenn'.

The two students focused on in the video recording, Ingrid and Beatrice, had chosen a word, one of the words Ellen suggested. They used their own table (copied from the board) to construct the sequence of 'seigmenn' into the letters they needed to 'write' their word. In their conversation, they talked mainly about the 'seigmenn' as colours and how to link them together (material action). There was never any mention of codon or triplets or DNA for that matter. Beatrice and Ingrid chose the reading direction of the sequence and made this explicit. Beatrice initiated some playfulness when they were doing this practical work. Ingrid initiated a control of the sequence, but this was not a requirement from Ellen.

### 7.4.1. Regulative

The regulative part of communication deals with regulating behaviour, i.e., teacher – student relation and what might be called task organizing and structure. There will be regulative aspects also in the instructional - presentation of subject matter (the table and the procedure). This section will however deal with those parts of the introduction that are concerning purely the regulative. The next section deals with the instructional part of communication.

#### 7.4.1.1. Text description and interpretation

The text description is divided into: regulating behaviour, purpose and goal, dividing students into groups, taking notes, task length and manageability. However, first is an overview of the features in the regulative domain of communication in Ellen's introduction.

Ellen was dealing with the organizing and structuring of the task through the entirety of the introduction, but at the start and end she spent more time on this explicitly. All the communication regarding the regulative is in the form of speech, e.g., division into groups are done through talk and not written on the board. The goal is not written - just told, so is also the expected outcome.

In the regulative part of the introduction, the most frequent speech function is factual statements. The uncertain factual statements are referring to what might be called the manageability of the task, whereas certain statements is about 'this is the task'. See examples below. There are some demands. The speech function strong demand is mainly referring to demands for students' writing. Weak demands are typically coupled to the division of students into groups. When dividing students into groups, Ellen also uses questions as a speech function, see below.

In Ellen's introduction, the most frequent pronouns are 'you' followed by 'I'. The use of 'you' gives a clear responsibility to students. There are also some 'we' used, where Ellen just as well could have said 'you' and thus making a bond of solidarity between herself and the students, but also perhaps blurring responsibility. An example of this is "*we are to put it on a white sheet of paper*", where in this statement Ellen is blurring the 'fact' that it is the students who are going to put the seigmenn-string on the paper (not to be soiled). At some instances, Ellen used 'we' where she could have used 'I', e.g., "*we must draw this on the board*." As the students are not to partake in writing and drawing on the board, this might be seen as 'false' solidarity and a blurring of her power to set the scene. There are, in addition, some real 'we', e.g., 'we are to walk around and read the words'. Here Ellen and the students were to walk around and read the words of other students.

There is a range of different transitivity processes: mental (e.g. you (try to) understand and I think that…); verbal (write on the board, copy notes, read (word)); do-processes referring most often to the organizing of the task. When the topic is coding, the transitivity processes is relational, e.g., "*it is completely identical to the code in the protein synthesis*".

Cohesion is typically elaborations, temporal (then) and additive connectors. There is, though, one example of a causal connector: 'Internet is 'down' that is why we have to write'.

*Regulating behaviour: Teacher – student relation*
At the end of the introduction (especially when Ellen presented the procedure), the students became restless and there was a lot more talk amongst the students. In the sound track, I can hear some of the students sitting close by the recorder saying to each other in hushed voices that they did not understand. Ellen did not address this unrest explicitly, e.g., she did not ask students if there were any problems or for a reason why they were talking – or ask them to be quiet. At the very end of the introduction, she walked out into the classroom (probably) addressing one of the 'talkers' in particular, as she used the singular form of you when she had a brief recount of the procedure. See next section for how she used the phrasing 'okay' during this introduction and how this phrase became more frequent and with a shorter response time in the last part of the introduction. Perhaps Ellen was pressed for time. There was not much time before the break, and the practical work had to be finished before leaving the classroom.

*Structuring the task: Purpose and goal*
Before the mid-lesson break, Ellen wrote on the board: *The genetic code consist of three 'letters' (it's) called CODON.*
As she wrote, she said:

| | | |
|---|---|---|
| 31:00 | Det neste vi skal jobbe med er å forstå den genetiske koden. Den genetiske koden består av tre bokstaver. Den kalles kodon så altså en slik en (peker på tavla) som vi kaller for triplett kaller vi for kodon | The next we are to work with is to understand the genetic code. The genetic code consists of three letters. It is called codon, so one like this (points at board) with three letters we call a triplet we call codon |

Here Ellen gave a goal for the activity that followed, "*to understand the genetic code*". She also established a connection between the 'letters' and the genetic code or codon. This she did by using certain statements and relational transitivity processes (consist of and called/call). On the board, she had written inverted commas around the word letters to make a distinction between bases and letters.

After this, the students had a mid-lesson break (approximately 10 minutes). The timing on the following excerpts does not take account this break, as I stopped filming during the break.

When students came back in after break (some had chosen to sit in the room during the break), Ellen started to divide the students into groups. Then she gave the goal of the activity:

| | | |
|---|---|---|
| 34:00 | Det vi skal jobbe med nå (er) å prøve å forstå den genetiske koden. Dere får en oppgave som dere skal løse. | What we are going to work with now is to try to understand the genetic code. You will get a task to solve. |

| | | |
|---|---|---|
| 43:14 | Det er helt identisk med hvordan koden er i proteinsyntesen. Det er helt identisk. Så, hvis dere har skjønt dette her så skjønner dere hvordan koden fungerer i proteinsyntesen. | It is completely identical with how the code is in the protein synthesis. It is completely identical. So, if you understand this then you will understand the code in the protein synthesis |

The second excerpt was an answer Ellen gave after a student initiated a question "*why do you take red twice?*". The student wanted to know why the letter F was coded green-red-red. Ellen's answer that started referring to reading the table before it 'drifted' into the purpose of the activity.

Both these excerpts contain factual statements. In the first one, Ellen opens with the transitivity '(try to) understand' which is referring to a mental process and it is '*we*' who are going to work with this. This is an uncertain statement (try to) and the use of 'we' is perhaps a way of reducing expectations of the students' outcome and expressing solidarity with students. However, then it is 'you' who is going to have a task – and 'you' who are going to learn it.

Ellen made a point that this is identical with coding in the protein synthesis, a relational transitivity process expressed through a certain factual statement. The statement can be interpreted as the reading and understanding the table of the 'seigmenn code' is seen as equal to the coding in the protein synthesis. Ellen thus coupled the entities 'seigmenn-code' and 'genetic code'. There was no reference to DNA as a model or DNA coding as a model for something 'real'. There is another point to comment on by letting the answer to the student's question 'drift' into "*So, if you understand*…" which makes it perhaps work as a 'motivator' or provides the purpose of why learning this is time well spent. This was the only episode in the introduction where Ellen was relating the 'seigmenn-code' to the genetic coding explicitly.

*Organizing work: Dividing students into groups*

In the start of the introduction, Ellen wanted to divide the students into groups of two. This meant splitting up three boys sitting together. A short note on the collaborative 'climate' amongst these boys: Not all of the boys worked well together – or had never tried to work with some of the other students – from what I had seen during the year.

| | | |
|---|---|---|
| 33:56 | Ellen: Og så kunne jeg tenke meg at dere bare var to stykker. (--) Så - er det mulig at dere tre, dere seks kan fordele dere på tre grupper, må jeg fordele dere for dere eller kan dere gjøre det selv?<br>(*Venter i 5 sekunder)*<br>John: Skal vi tre fordele oss? | Ellen: And, so I could want that you were only two. (--) So is it possible that you three, you six can divide into three groups, must I divide you or can you do it yourself?<br>*(waits for 5 seconds)*<br><br>John: Shall we three split up? |

| | | |
|---|---|---|
| | Ellen: Altså.., kan dere<br>Patrick: Bare gjør det da<br>Ellen: Skal jeg gjøre det?<br>Freddy: Ja<br>Ellen: Da gjør vi …(avbrytes)<br>Steve (avbryter): Vi har gruppa her vi<br>Ellen: Men jeg skulle gjerne bare hatt to på gruppa<br>Steve: Ja<br>Ellen: Dere to?<br>Steve: Ja<br>Ellen: Greit | Ellen: So, … can you<br>Patrick: Just do it then<br>Ellen: Shall I do it?<br>Freddy: Yes<br>Ellen: Then we do<br>Steve (interrupts): We got the group here<br>Ellen: But I would like that you are just two in each group<br>Steve: Yes<br>Ellen: You two?<br>Steve: Yes<br>Ellen: Right |

Ellen's opening here was a weak demand, she insisted on groups of two by using an elaboration of her first weak demand. However, she is open for students' co-decision of who they would like to work with since she ended her opening with a (short response) question.  Ellen waited a long time for an answer (five seconds), which must be considered a long time compared with how much time Ellen usually gave to students to answer subject matter questions. This indicates that she wanted them to sort it out. When Patrick said that Ellen could divide them into groups, this might be because he regarded it difficult to split by choosing one fellow student above another. Steve, on the other hand, was clear on with whom he wanted to work. The result was that Ellen let two of the least eager boys work together. Interestingly, the other four students were not part of the division-problem. As soon as the two students were sorted out, there was no problem to talk about. The rest of the class was not a problem concerning splitting into groups of two.

*Organizing the task: Taking notes*

The 'taking of notes' was a recurring theme in this classroom. Perhaps the words fell a bit differently and the question was posed by another student but:
Is there a Need to take notes? The first excerpt is just as Ellen started to draw the code table on the board. The second excerpt is when Ellen has finished writing the table.

| | | |
|---|---|---|
| 36:37 | Allan: Skal vi skrive dette her opp?<br>Ellen: Ja, dere må ta og skrive opp dette her | Allan: Shall we write this down?<br><br>Ellen: Yes, you have to write this |
| 43:30 | Sam: Du visker ikke ut det der etterpå?<br>Ellen: Nei | Sam: You don't erase this afterwards?<br>Ellen: No |

Ellen started to write the colours of the 'seigmenn' without making it clear that she wanted the students to take notes. The 'problem' was raised by Allan and the response from Ellen was a strong demand. Ellen implicitly refrained from this demand about seven minutes later (the second excerpt). By stating that the table would stay on the board, the students could use it as a resource when they were to construct their letters. Thus, there would be no need to take notes. Sam was re-negotiating the conditions for taking notes – perhaps even without Ellen noticing it. Perhaps she wanted to be compliant to Sam.  Ingrid and Beatrice had copied the code key on the computer and paper respectively. When they worked on their word, they chose to use their own tables rather than the one on the board.

*Organizing the task: Task length*

Discussion of task length was also a recurring incident in this class. At the very end of presenting procedure, Ellen said:

| | | |
|---|---|---|
| 51:00 | Ellen: Ok, kan jeg bare si en ting – dere tar tjue seigmenn. Da tror jeg vi kan lage ord på fem bokstaver, greit?<br>Sam: Vi tar fire, vi<br>Ellen: Det er greit | Ellen: Ok, can I just say one thing – you take twenty seigmenn. Then I think we can make a five letter word, right?<br>Sam: We take four<br>Ellen: That is all right |

By using the phrasing 'I think', Ellen allows for the possibility of making a longer word, but she did not demand it. As soon as this broached opposition amongst one of the students, she withdrew her proposition and did not put any further pressure on the students in this matter. Beatrice and Ingrid had settled for a four-letter word, 'nose'. This was before I started to film so I do not know their reasons for this particular word. See also next section for choice of word to 'write'.

*Structuring the task: Manageability (?)*

Just before Ellen gave the statement about task length, she said:

| | | |
|---|---|---|
| 50:14 | Jeg tror vi skal prøve oss på dette her, men nå er klokka ti på ti og da må vi se om vi klarer å få ordnet dette her | I think we shall try this, but now the time is ten to ten, and then we have to see if we manage to fix this |

This is, as I see it, an interesting statement as it allows for several possible interpretations. The pronouns and processes of 'I think' and '*we* try', combined with the contrastive 'but' plus time and the additive/causal form 'and then', is a complex sentence – and thus the interpretive space is larger. Does it mean that 'we' are to be able to finish the 'making the seigmenn word' before break, or does it mean: are 'we' able to do this - at all? The second interpretation sows doubt that students are able to do this and thus lowers the list of expectations for the outcome.

#### 7.4.1.2. Text – context and regulative norms

The norms are inferred from the teacher's semiotic actions and how these semiotic actions provide possibilities for students' semiotic work. What the teacher says and does provide an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as ‘tacit’ practices or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., a rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Behaviour, teacher-student relation*

Ellen did not explicitly address the ‘unrest’ among students when she presented the procedure, but she talked faster and louder and she moved around the room more. She walked out into the classroom to be closer to students to be able to control them? This can be interpreted as a struggle, of power and resistance, where Ellen was on the offensive by using the room actively and not retreating behind her desk. However, Ellen did not ask whether this ‘unrest’ was caused by subject matter problems. Perhaps she did not want to reprimand the students’ behaviour. This resulted in her pretending to ignore the disturbance from the students. The students were thus ‘allowed’ to disturb and not pay attention. On the other hand, the students did not challenge Ellen by saying loudly that they did not understand or whatever the problem might be. If some students started asking or pointing out difficulties, the teaching would probably be prolonged. This would perhaps not be in all students’ interest.

Norm: Resistance to teaching is indicated by obvious lack of attention
Norm: Unwanted behaviour is not explicitly addressed

*Organizing the task*

The students are involved in decisions that are related to division into groups and task size. In these matters, Ellen asked questions and gave uncertain factual statements that made it easier for the students to respond, compared to if they had to oppose a strong demand. (Students are not involved in decisions on procedure, see instructional.) Ellen agreed with the students’ decisions so she let them have some responsibility toward organizing the work. Ellen made no comments on how the students should carry out the practical work, e.g., by giving explicit division of work. Therefore, within the procedure, students organized themselves.

Norm: Decisions concerning collaboration are implicitly left to students

Taking notes is negotiable in this classroom. This can be interpreted from students not automatically copying the board: they ask if it is needed to copy. Moreover, students did not really need to write down the table as they could choose to look at board. Here, there is a divergence between Ellen’s view that note taking is an important part of the students' learning process and (some of) the students as slow or perhaps even reluctant writers. There is an additional problem to this because taking notes in science often involves drawings, making tables, etc. To use the computer to make drawings and tables were perhaps skills most of these students did not have – at least to a sufficient degree. Many students did not bring pen and paper to science class, which indicates that they themselves did not see it as vital to take notes.

Norm: Taking notes is open for negotiations.

*Structuring the task*
The teacher formulated the goal as a statement. The goal of the practical work was to understand the genetic code. What 'understand' meant in this situation is perhaps a bit unclear, as the practical work was only loosely coupled to the subject matter (see next section). The students do not contribute to clarify the goal.

Norm: The teacher provides a goal for task.

The purpose of the activity was to understand the code in the protein synthesis – but why learn about the protein synthesis? The purpose was given in the middle of the introduction. This indicates that the purpose is not regarded as important. If purpose had been given prominence, it would (most likely) be given explicitly in the beginning to guide the students' attention. The curriculum competence aim was not discussed or put into a larger frame.

Norm: Purpose is of little importance.

By using uncertain statements and a complex sentence, it can be interpreted as if Ellen is lowering her expectations to the students' outcome.

Norm: It is important to partake in the activity and the outcome is less important.

This last norm is constructed in interplay with the instructional text (see directly below).

### 7.4.2. Instructional

The instructional domain of classroom communication is dependent upon the regulative domain, as the regulative provides the structure and the organization of the task. First, I will describe and interpret the previously mentioned two parts of the introduction and then I will infer norms.

#### *7.4.2.1. Text description and interpretation*

This section is divided into two; establishing the code key and procedure. This division is because of the difference between the two parts (sound level, speech functions and theme). In this section, the students dealing with code-key and procedure will be connected to Ellen's presentation.

*Establishing the code key – and students using it*

First, there is a description of the main features, and next there will be description and interpretation of this part of the text.

Resuming after the break, Ellen asked what colours seigmenn have. The students did not hesitate to give a response. Seigmenn come in four different colours: green, yellow, red and orange. There was no Internet connection this day so Ellen had to write the code key on the board. Writing on the board is a slow process and this made it easier to ask questions while constructing the table.

The code key looked something similar to this when it was at the board:

| | | Second | seigmann | | | | |
|---|---|---|---|---|---|---|---|
| | | Gr | Ye | Re | Or | | |
| First | Gr | A | C | E | G | Gr | Third |
| | | A | C | E | G | Ye | |
| | | B | D | F | H | Re | |
| | | B | D | F | H | Or | |
| seigmann | Ye | I | K | M | O | Gr | seigmann |
| | | I | K | M | O | Ye | |
| | | J | L | N | P | Re | |
| | | J | L | N | P | Or | |
| | Re | Q | S | U | X | Gr | |
| | | Q | S | U | X | Ye | |
| | | R | T | V | Y | Re | |
| | | R | T | V | Y | Or | |
| | Or | Z | Ø | | ! | Gr | |
| | | Z | Ø | | ! | Ye | |
| | | Æ | Å | | ? | Re | |
| | | Æ | Å | | ? | Or | |

**Figure 8: The seigmenn code key**

The code-key was an important resource for students in this practical work. If they could use it to 'write' and 'read' letters, this would make their practical work much easier or to put more strongly, the outcome of the practical work was entirely dependent upon their ability to use this resource. If they were unsure of how to use it, the practical work would be difficult from their point of view and their products incomprehensible for the teacher and peers.

In this part of the introduction, Ellen used primarily the speech functions statements and short response questions. There were also some questions from the students regarding the table. This gave this part of the introduction a dialogic character.

The pronouns in this part of the introduction are mainly you (plural), we and I. There are some 'we' that are used to refer to the science community, i.e., '(in science) we call this a codon'. 'We' is just once used as a substitute for 'you'.

Ellen used a variety of transitivity processes in this part of the introduction. The most frequent processes were relational, verbal and material.  Relational processes are most often connected to colours of seigmenn, e.g., the second is green. Verbal processes (e.g., I tell, you mention, I ask, I/we write) are frequent and point to the division of work in the teacher-initiated dialogue. One example of a material process is 'we make a word' and behaviour process is 'you pay attention'. There are few mental transitivity processes.

The entities that are reoccurring are the colours of the 'seigmenn', letter, code and code-key. A typical chain of entities is like this:

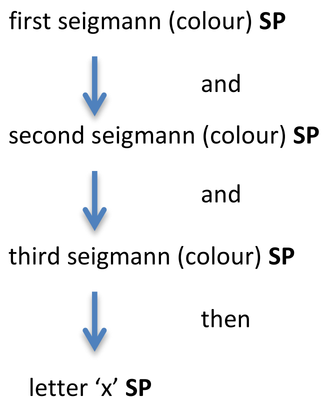



Figure 9  Entity chain – reading the sequence of seigmenn

Here the S indicates the mode of speech and P stands for pointing at the board – table, respectively column left, row top and column right. When Ellen established the connection between 'seigmenn' and the code key:

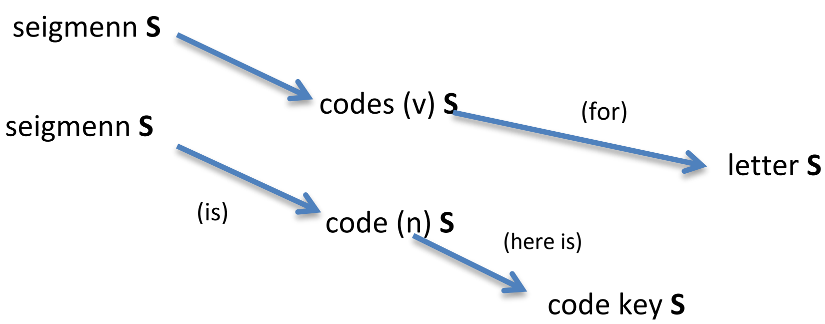



Figure 10  Entity chain – reading the code

In this two chains code is noun (n) and verb (v). Ellen used (only) the mode of speech to convey these connections between 'seigmenn' and the code key.

Regarding the textual metafunction, there are three special features. First, Ellen uses her hands to point out an orderly reading sequence. Second, there are several conditional connectors 'if –(and) – then' to indicate the order of reading the table and the outcome of this reading. Third, Ellen had a long elaboration on the use of codes in everyday life. In this elaboration, she connects seigmann-coding with codes used on computers or cell phones.

***

Ellen started to write the table on the board – she made rows and columns and she wrote first seigmann, second seigmann and third seigmann (see table above). She had not filled in any colours or letters yet. She paused for a moment.

| | | |
|---|---|---|
| 37:56 | Ellen: Skal vi se om vi klarer å få inn hele alfabetet her<br>Susan: Inni hver rute?<br>Ellen: Nå skal jeg begynne å skrive så bare følg med dere | Ellen: Let's see if we manage to get the alphabet in here<br>Susan: In each square?<br>Ellen: I start to write now, so just you pay attention |

Ellen opened this sequence with a statement, a low degree of certainty. It is almost a question: is this possible? She used the pronoun 'we' even if she is the one who was to fill in the table, i.e., 'we' used as 'I'. It is as if she allows for the students' contribution to construct the table or perhaps she is thinking aloud by herself? Susan had not (yet) any idea where this would lead, so the question was 'relevant'. Ellen did not reply directly to this question, but instead she followed up with a weak demand 'you pay attention' and 'I write'. Instead of going into a rather long and complex talk about how to do 'the filling in', she wanted to write while the students observed. This might perhaps be seen as an attempt to let the students have some overview of the layout of the table before they filled in the rest of the table. (This excerpt is after Allan's question about the need to write.)

Ellen wrote the headers of the columns and rows (colours) – and when she wrote the first letter A, Ellen said as she pointed at the table:

| | | | |
|---|---|---|---|
| 39:46 | Points at table - left first row<br>Points at first column – top<br>Points right – first row<br>*Writes: A*<br><br>She walks out into the room | Hvis første seigmann er grønn<br>og andre seigmann er grønn<br>og tredje seigmann er grønn<br>så koder vi for bokstaven a.<br>Altså, tre og tre seigmenn koder for en bokstav. Det er seigmenn som er koden og her er kodenøkkelen | If first seigmann is green and the second seigmann is green<br>and third seigmann is green<br>then we code for the letter a.<br>So, three and three seigmenn code for one letter. It is seigmenn which is the code and here is the code-key |

Ellen modelled reading the table here by a combination of pointing, speech and the written table. She supported the conditional statements (if, and, and – then) by pointing simultaneously and then the result of pointing was the written 'A'. She followed up immediately by two statements (high degree of certainty) where she explained how the code worked and the purpose of the table – it was the code key. The entity seigmenn (plural) is identified as the 'code' – and three seigmenn she linked to a letter.

When Ellen read the table later in the introduction, she used a combination of pointing and speech always in the same order, although with different emphasis and by using slightly different words. She did this six times during the introduction. One time she also emphasized the reading by drawing a circle round the letter 'V', see below.

Ellen then asked a question, 'a code for the letter B': she waited for approximately six seconds and no student attempted to answer. Ellen then answered the question herself by pointing and speaking. By combining the modes of gestures and speech, she perhaps made reading of the table easier for students to comprehend.

Ellen repeated how to read the table twice while filling in the first row. While she did this, she pointed at the table, first, second and third to emphasize what she said. Then she asked for a code for the letter F. The first answer she received was wrong. The first part of the answer (green) was correct so she said 'green – and so…' The next student gave (one of) the correct answer(s) (green, red, red). The other code for the letter F (green, red, orange) was never mentioned.

The third question Ellen asked was also a short response question. She was facing the students and immediately gave one of the 'clever girls' the possibility to respond, Sara had probably raised her hand.

| | | |
|---|---|---|
| 44:44 | Hvis jeg setter rød rød rød, - altså tre røde etter hverandre hvilken bokstav har vi da? Sara<br>Sara: v | If I put a red red red, - three red after each other, what letter have we got then? Sara<br>Sara: v |

Here Ellen changed the direction of the question from first giving the letter – to first giving the colour code. By turning the question around, she can check to see if the students had understood the principle of reading the table.

The response time was practically zero. Sara had understood how to use the table – no doubt. However, when Ellen chose to give Sara the opportunity to answer, she also took away the responsibility for the other students to find out what the answer could be. In this situation, Ellen chose not to challenge *all* students into giving an answer as she was satisfied with Sara's correct answer. This was part of the pattern of the Q&A sequences. The question was always directed to the students as individuals, not to students as a group. If the questions had been directed to the students as a group (the students were already divided into groups), the response time would be longer. The students would need more time to think and to try out their reasonings on each other.

Throughout this part of the introduction, Ellen modelled how to read the table by using short response questions to students and following up the answers by pointing and speaking. However, were all students able to use the table for themselves? Ellen could not be sure of this, even if she did ask ‘is this okay?’ and ‘okay?’ (each with a response time of approximately two seconds) at the end of the introduction of the table. No one responded. Even if she was looking directly at the students, she could not be sure. Ellen’s usual way of checking for understanding was by asking ‘okay?’ but sometimes she also used this more as a statement than as a question (tone of voice indicate that). Sometimes she waited for several seconds to see if the students did make any signs of incomprehension, other times she did not pause after posing ‘okay?’. The use of the phrase ‘is it okay?’ is rather non-committal as it does not specify what the possible problems might be. For students, this question might be difficult to answer, as it requires some overview of the subject matter. In addition, most people (i.e., also most students) have difficulties identifying what the problem might be, as ‘everything’ seems so clear when the teacher says it.

In the video footage of the students, Ingrid and Beatrice manage between themselves to read the table and form their word with seigmenn. Ingrid was given or had taken the responsibility to read the code manual. In the beginning Beatrice also found seigmenn of the right colour, but toward the end she took the responsibility to put them together by using toothpicks. They chose to divide the work between them. This might have something to do with the fact that in the beginning they were using Beatrice’s notebook on which to put the seigmenn. Beatrice’s table was in that notebook and the consequence was that Beatrice could not read her table. However, it might also be because it was more ‘effective’, i.e., quicker to divide the work. Ingrid controlled each of the ‘letters’ – even so, when I asked which letter yellow, red and green was:

| | | |
|---|---|---|
| 7:50 | Ingrid: s<br>Beatrice: Det er e<br>Ingrid: Det er<br>Beatrice: Det er e, Ingrid<br>Gerd: Gul rød og..<br>Ingrid: Nei, den er feil veg | Ingrid: s<br>Beatrice: It’s an e<br>Ingrid: It is<br>Beatrice: It’s an e, Ingrid<br>Gerd: Yellow, red and<br>Ingrid: No, it’s the other way around |

(Time on this excerpt shows that students had worked for about eight minutes with the task and were almost finished.)

To my question, there were two different responses. Beatrice saw that I was pointing at the second ‘letter’, while Ingrid probably thought I was pointing at the third ‘letter’. The second ‘letter’ was meant to be an E and the third S (NESE, or in English: NOSE). Beatrice maintained the view that it is an E without checking this with her notes. Ingrid looked at her notes on the computer and found out that it was turned around. She then proceeded to one last control. It was Ingrid's initiative to control. Controlling the sequence was not explicitly mentioned by Ellen.

They (mainly Ingrid) did use pointing, sequencing and going back and forth between table and the sequence of seigmenn in the process of 'writing' their word. They managed to form the word they had intended, but they did not talk about how to read the table.

*The procedure – and students doing it*
First, there is a description of the main features, next there will be a description and interpretation of this part of the text. The introduction of the procedure was more rushed, as Ellen spoke faster. She also spoke louder as many students were talking with each other. The procedure has a certain lockstep ring to it, but Ellen presented the steps in an intermingled fashion. This means that excerpts that are thematically structured are not necessarily close in time.

In this part of the introduction, the prevalent speech function is strong demands (you shall do or we shall do). However, there is also an offer of eating the sweets after the practical work has finished and there is one choice (almost) as well as statements. Statements are mainly used to give task structure.

More than half of transitivity processes are material referring to something to be done or to make a word. There are some mental and verbal processes where Ellen refers to herself (e.g., I explain and I think that) and some verbal and mental processes where Ellen refers to students (e.g., we read and you be creative). Throughout the introduction, Ellen changes between 'we' in the meaning of 'you' and you (plural), in the end (I think she is addressing one of the students who had been talking), she uses the singular form of you.

The entities involved in this presentation are mainly the artefacts students were to use; seigmenn, toothpicks, sheets of paper, coffee filter. In addition, there are the entities that might be said to be the outcome of the activity; letter and word (for body part).

Ellen wrote some key words on the board; otherwise, she was talking, i.e., she did not show the students how to do this. She wrote: '20 seigmenn' at the left of the board – but later she used the right side of the board for the rest of the written information ('4 letters', 'body part' – with examples). The table was in the middle of the board. Ellen also made a drawing of two seigmenn and a toothpick as a connector between them. Other information such as procedure structure and reading direction, etc. was given in the mode of speech. In her speech, Ellen used primarily three types of connectors: and (additive) and then (temporal – giving sequence) and elaborations. This gave her speech a distinctive character of stepwise procedure – which it was.

***

Ellen started to explain what to do, and she wrote on the board *20 seigmenn*, while she was talking.

| | | |
|---|---|---|
| 45:08 | Nå skal jeg forklare litt på hvordan vi skal gjøre dette her. Og dere skal ta med dere seigmenn i en sånn liten kaffefilterpose og dere skal ha 20 seigmenn og da skulle det være nok til alle sammen og når vi er ferdige med forsøket skal dere få lov til å spise de opp | Now I shall explain a wee bit how we are going to do this. And you shall take with you seigmenn in such a small coffee filter bag and you are to have 20 seigmenn, and that should be enough for all, and when we are finished with the practical work you are allowed to eat them |

The opening of the procedure was an uncertain statement, she was not just going to explain how – she is to do "*a wee bit how*". The rest of this excerpt is the practical work in a nutshell: get 20 seigmenn (in a coffee filter bag – not to be soiled); do the practical task; eat the seigmenn. Ellen had put some thought into 'the eating of the seigmenn'. She had prepared coffee filter bags into which to put the seigmenn. She also brought sheets of white paper so the seigmenn should not lie directly on (dirty) desks, and she emphasized that the students should not mess with them. So, the point of the practical work was eating the seigmenn? Not quite, there was something the students should do first.

| | | |
|---|---|---|
| 46:00 | Dere skal nå lage - hver gruppe skal lage et ord på fire bokstaver | You shall now – each group shall make a four letter word |
| 46:20 | Altså fire bokstaver – det ordet kan dere få lov til å ikke velge selv. Det skal enten – det skal være - kroppsdel | So, four letters – that word you can be allowed to not choose for yourself. It shall either – it shall be – body part |
| 47:04 | Altså det skal være en legemsdel – fire bokstaver (hun gir 7 eksempler) | So, it shall be a body part – four letters (she gives 7 examples) |
| 47:27 | Hvis dere har lyst å lage deres eget så går det også | If you want to make your own, then that is ok too |
| 47:45 | Så er det sånn at det bare er gruppa som vet hvilket ord dere har lagd. Ok? Vær litt kreativ på dette. | Then it is like this it is just the group that knows which word you have made. Okay? Be a bit creative on this. |

While she gave these instructions, she wrote *4 letters – body part* on the board. Additionally she wrote those examples she gave as speech. These five excerpts are close in time, only divided by two questions from students, the first question was about one of the items on Ellen's list of body parts. One other question was about one of the letters in the table on the board that the student could not read. Ellen replied by saying the letter. Between the first and second excerpt, Ellen talked about connecting the seigmenn into words, see below. The rest of the excerpts are divided only by short pauses.

She initiated 'make a word' by saying it should be a four-letter word. Here she could have said a word with three to six letters after their own decision. When she later allowed for a five-letter word, her proposal was turned down by a student, see previous section.  The second of these excerpts starts with what almost seems like an intention of letting the students choose their own word (giving choice), but this is reformulated into a strong demand 'shall be body part'. This is elaborated on in the third excerpt, but later she allows for alternatives (make your own). In the end, she wants the students to be creative. These excerpts, read together, indicate that Ellen was sending a double message to the students. This was perhaps not intended but it gave the students a larger interpretive space. Perhaps it would have been easier for the students if this was given as an explicit choice. Students are (mostly) trying to adapt to the teacher's expectations and when they are to use much semiotic work in the process of interpreting the teacher, focus on task might be lost. I also must admit that I have problems with seeing the purpose of a strong demand for a particular type of word, unless of course the purpose was to touch the body part when reading the words as part of the summary.

Ellen uses the material transitivity process 'make' about the word rather than the verbal process 'write' (in code).  This may seem like a small difference. However, there might be a hidden 'bug' by using the word 'make' contra the word 'write'. When writing, one is communicating something and the purpose of the coded sequence is to communicate what protein to make. Most people would not think of 'making', i.e., arranging physical objects, as a way of sending a message – you have to be a social semiotician to see it that way.

Ingrid and Beatrice had chosen the word NOSE (no: nese) before I started to video record. Therefore, I cannot tell how they decided on that particular word. It was one of the words on the board, so, it was a safe choice.

The next step of the procedure was to put the seigmenn together so the word would be readable. The first of the excerpt is 'in the middle of' Ellen's talk about what word to make.

| | | |
|---|---|---|
| 46:12 | og så skal du legge seigmennene etter hverandre – jeg skal forklare litt hvordan vi skal legge seigmennene etter hverandre<br>(ikke utdypet videre) | and then you (singular) shall put the seigmenn after each other – I shall explain a bit how we are to put the seigmenn after each other<br>(not developed further) |

Between this and the next excerpt, Ellen talked about what word to make (see above). Then there was a question from a student, which she answered before she continued on how to build this together.

| | | | |
|---|---|---|---|
| 48:10 | walks to other side | Men så er spørsmålet hvordan skal vi bygge dette sammen. | But then the question is how shall we build this together. |

| | | | |
|---|---|---|---|
| | of board and makes a drawing of two seigmenn<br>(waits 7 seconds)<br><br><br><br>Draws a line between the two seigmenn's 'bellies' –the line is diagonal | Sånn, vi har to seigmenn som ligger sånn ved siden av hverandre og så får dere tannpirkere og så setter dere tannpirker sånn at den henger sammen sånn, ok? | That's it, we have got two seigmenn that lies like this beside each other and then you will get toothpicks and then you put toothpick so that they are linked together – like this, okay? |

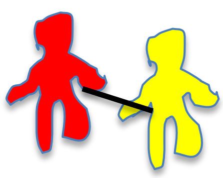
Between this and the next excerpt, Ellen referred to toothpicks as a means to put the seigmenn together and then she stated that *"we should have built this double*..", see further down.

Ellen almost posed a question of how to build the seigmenn into a sequence. She answered this immediately herself through the use of a certain statement that turned into a weak demand, 'put toothpick so they are linked'. In these statements, it is clearly 'you', i.e., students who shall do this. The first 'we' in the excerpt refers to the students, whereas the second 'we' is a real we as we all could see the drawing at the board. The first we (used as you) might blur the responsibility – who is to decide and who is to carry out? Here Ellen decided and the students carried out. Then there was the question of reading direction. Ellen posed the following question:

| | | |
|---|---|---|
| 49:13 | Og så må dere si at det er et sted vi skal starte å lese, ikke sant? Skal vi forvente at vi starter ved hodet på første (?) | And then you have to say that there is a place we shall start to read, right? Shall we expect that we start at the head of the first one (?) |

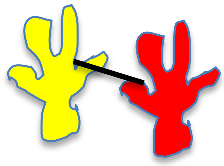
In the above excerpt, it seems that in the start Ellen was leaving students in charge of deciding which direction to read.

While Ellen talked about how to build the sequence, the noise level rose among the students. Many students are obviously not paying attention and some are saying 'I don't understand' in a low voice. Ellen did not stop her presentation of procedure, but continued to state the reading direction from 'head of first one'. This is a problematic statement to interpret.



This was approximately the drawing on the board. Reading from left to right starting at the head makes sense.

However, there is a problem if you see the figure upside down, like this. You still read left to right starting at the head, unless it was built to be read like this – it will not make sense.



Therefore, this was an ambiguous statement from Ellen. Perhaps it did not matter much because one tends to think about it as if the seigmenn are standing (vertically). By interpreting that the reading direction requires 'standing seigmenn', it becomes clear that the second of these drawings is upside down, and thus unreadable.

The students Beatrice and Ingrid solved this their own way.
When Ellen stopped at each group to hand out sheets of paper (to put the seigmenn on), Beatrice asked about how to layout the sequence of seigmenn. This was the only time during the nine minutes it took to complete the word that she came to talk to the students. However, perhaps as I was there – she thought it unnecessary.

| | | | |
|---|---|---|---|
| 0:35 | Ellen comes with white sheets of paper. Beatrice puts the sheets on the desk.<br>The sheets partly hides Beatrice's code table<br>Beatice points in length direction of the paper sheet. | Ellen: kanskje dere kan legge det på det og bruke det …<br><br>B(avbryter): Skal det være sånn? Rekkefølge og sånn?<br>E: Ja, men bruke tannpirkere til å koble de sammen med<br>B: Vi skal hente tannpirkere | Ellen: perhaps you can put it on this and use it…<br><br>B (interrupts): Shall it be like this? Sequence and so?<br>E: Yes, but use toothpicks to couple it together.<br>B: We shall get toothpicks |

In this interaction with Beatrice (Ingrid listening), Ellen focuses on practical aspects of the work (sheets, toothpicks). She did not ask if they understood the table or controlling one of the letters to make sure that they did manage.

Beatrice indicates by the movement of her hand that the seigmenn should lie in length-wise direction and not in the way they were ordered at that moment. See figure below. She seeks confirmation from Ellen, and she receives it.

They had started out placing the seigmenn in groups of three below each other like this:

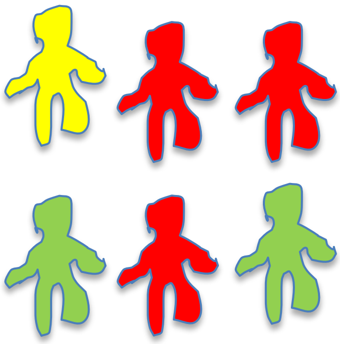


Figure 11: Seigmenn code – reading direction 1

These are the two first letters N (yellow, red, red) and E (green, red, green) of their word. This made it easy for Ingrid to control each triplet as this gave an overview of each letter.

Beatrice posed the same question she had asked Ellen about the sequencing, to Ingrid. Ingrid answered "*but are you really sure that we shall couple them together and not* –" After a short while they agreed on making a long sequence, which made it harder to see each triplet as a unit, but the sequence looked more like the models of DNA.

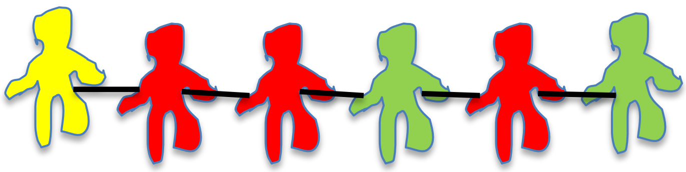


Figure 12: Seigmann code – reading direction 2

How to sequence the 'seigmenn-letters' into words revealed a tension between what Ingrid regarded as practical and easy to read, and Beatrice's wish to do it the way Ellen had presented it. Beatrice did however not relate this to the DNA model in her speech.

During the entirety of the practical activity, Beatrice and Ingrid did not make any references to codon, triplet, DNA or coding. They referred to the seigmenn mainly by the attribute colour. Their transitivity processes are mainly material (action). They also 'played' with the seigmenn, stating the seigmenn were children from different parts of the world. This might be seen as a metaphor for the DNA model – or perhaps just fun.

At the end of the practical work, the students were to walk around to read each other's words. This was not explicitly mentioned by Ellen before Steve asked the following question:

| | | |
|---|---|---|
| 47:48 | Steve: Skal vi få demonstrert | Steve: Shall we get demonstrated |

| | | |
|---|---|---|
| | hvilket ord?<br>Ellen: Det er klart, vi skal gå, da skal vi – skal den ligge på runden og vi skal legge han på et hvitt ark slik at det ikke blir noe søl – så legger dere den på pulten og så skal vi andre gå rundt å lese hvilket ord det er | which word?<br>Ellen: Sure, we shall walk, then we shall – put them on a white sheet of paper – so that there is no mess – then you put it on the desk and then the rest of us walk around reading which word it is |

The initiating question can be interpreted in several ways. First, this can be interpreted in the way Ellen did, as a question for if there would be any summing up. She emphasized through her repetition of the white paper and 'no mess' the practical aspect – (or eating). The 'walk around reading' is perhaps a 'loose' sentence, even if it was formed as a (strong) demand. This is because there is no elaboration. Is one supposed to take notes? Is there 'a prize' for those who are able to read all the words?

However, this question can perhaps also be seen as an attempt to ask for the coupling between word and DNA-coding? That is, the student is trying to ask about how to make meaning of the seigmenn construction. Ellen could have used this question also to create a link between the practical doing and meaning-making, which she did not. But, at this time of the introduction the students were really 'impatient'.

After all students had built their word, the class 'walked around reading' (see context for description of this).

At the ending of the introduction, Ellen made a connection to the DNA string. While she was saying this, the sound of the students was quite loud.

| | | |
|---|---|---|
| 48:48 | Egentlig, så skulle vi ha – så skulle vi ha bygd dette dobbelt så det virkelig hadde blitt sånn som en DNA-tråd, men det får vi ikke til. Ok(?) Vi bygger bare den ene siden av DNA-tråden. Er det greit? | Actually, we should have – we should have built this double so it really had become like a DNA thread, but we don't manage that. Okay(?) We just build the one side of the DNA thread. Is it okay? |

Here, there are some interesting factual statements on which Ellen did not elaborate. Why is it not possible to build a part of a double helix? Was there not enough time or not enough seigmenn? Then it is the word phrasing "*really had become like a DNA thread*" – but this was a model of a model – and could never become 'like real DNA'. Ellen could have avoided this problem by saying something such as 'we make a model of mRNA which is a part of one strand of the DNA'.

The response time for 'is it okay?' was practically zero. During the presenting procedure, Ellen checks for students' understanding or that they are 'hanging on' by the phrases 'is it okay?' or 'okay?'. When Ellen introduced the code-key, she asked short factual questions to check understanding, in this part there are no real questions. During these six minutes of presenting procedure, she asks these okay-phrases 13 times. The response times are between zero and five seconds, with an average of one-two seconds. The okay's that had practically zero response time were 'fake' questions, since there was no time for the students to respond. This perhaps indicates that she was in a rush, as if she wanted to hurry finishing the procedure and students were impatient.

#### *7.4.2.2. Text – context and instructional norms*

The norms are inferred from the teacher's semiotic actions and how these semiotic actions provide possibilities for students' semiotic work. What the teacher says and does, gives an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as the 'tacit' practice or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Procedure and carrying out practical work*

In this practical work, Ellen generated the students' interest (partly) by allowing eating of the sweets. This led to a very practical focus on 'no mess', sheets of white paper and so on. Presumably, this makes the practical work 'fun' and 'popular'. Beatrice and Ingrid certainly enjoyed eating the sweats.

Norm: Practical work is to be enjoyable.

In the procedure, Ellen guides the students firmly. This is seen by the amount of strong demands and lack of possibilities for students' choice. What could have been left to the students' choice, such as the length of the word and type of word – Ellen decides. However, Ellen opens up for, e.g., what word to make and thus creates possibilities for double meaning by first giving strong demands and then giving a choice in addition to the strong demand for being creative. Ellen also invites students to decide the length of word after her strong demand for a four-letter word, a proposition one of the students turned down. She thus opens up the lockstep procedure slightly, but this is not done by giving explicit or clear choices. The students seem to accept the strong guidelines without questioning them, i.e., they tried not to be creative in finding a word. Perhaps they interpreted the ambiguity in Ellen's semiotic actions as 'better to be on the safe side' and followed the first strong demand.

Reading direction is vitally important if one is to read the other words. This was ambiguously presented and was further blurred by the use of 'we', which indicates that the students could decide or partake in the decision. Ingrid and Beatrice first lay out the seigmenn in rows of three, which made it easy to get an overview of the letters, but Beatrice is pressing the matter of making one long row and she seeks Ellen's confirmation on this. However, the students make no explicit reference to make it look like the DNA when they do this. Beatrice perhaps just interprets this as a demand that needs to be obeyed.

There are no causal connectors used in the presentation of the procedure. There are given no reasons, e.g., why the need for a particular reading direction (to be able to read other words and/or to make it look more like the mRNA).

In the presentation of the procedure, Ellen emphasized the practical aspect through stressing sheets of paper, coffee filter bags, etc. so the students could eat the sweets afterwards.

Norm: Procedure is fixed (no explicit choices) and emphasizes material action.

*Scientific knowledge*

Ellen presents science subject matter as true knowledge. This is expressed through certain statements where the transitivity processes are either relational or existential.  There are no doubts, and no reference to that this is a way of seeing the protein synthesis as a model for something 'real'. Ellen express doubt once in relation to science and that is when she said she did not know *how* they had found out that three and three bases formed a unit, but it is found out. Those students who did take notes probably wrote down the sentence*: a gene is part of the DNA that contains the recipe for a protein, these proteins decide what we are to become*. They probably did not write Ellen's oral elaboration of this statement. There is much ongoing scientific research in this field, this makes 'our knowledge' tentative. This was not mentioned.

Norm: Scientific knowledge is true and certain.

When Ellen presented the code key and procedure, it was almost without reference to the previous introduction of subject matter. Ellen used the phrase 'make a word' and not the phrase 'write a word'. The latter would perhaps make a stronger connection to verbalizing at the expense of 'doing'. In the activity itself there is little emphasis on verbalizing, e.g., there is no need to stop and think and formulate scientific knowledge. When students are doing the practical work, there is no reference to scientific 'textbook knowledge'.

Norm: Scientific knowledge is loosely coupled to practical work.

*The language of science and communicating subject matter*
The lecture in the start of the day was littered with scientific terms. These were partly connected to the activity through the purpose and Ellen's contrasting statement "*we should have built this double*.." The students did not make any explicit references to scientific terms during their practical work. However, they did manage to read the table and transfer this when they later used the table of 'real' amino acids.

Norm: Scientific terms are superfluous in practical work.

There are many questions in the introduction. Many of these are generated by the students. When students ask questions, Ellen answers immediately. The questions from students are mostly short and related to what is written on the board. Ellen answers students' questions even if they are 'out of place' concerning what is being talked about at the moment. She thus gives preference to the student who asked the question above the rest of the class, for which 'out of place' questions perhaps only are a source of distraction. Ellen does not discriminate between questions. All questions from students are received with the same sincerity and she answers them. As a part of this 'all questions have equal worth'-politics, Ellen does not applaud good questions such as 'do genes control everything?' by saying, e.g., 'that was a good question'. There is thus no praise that might spur students into asking good questions.

Norm: Practical and scientific questions have equal worth.

Ellen answered all questions from students herself. She did not hand some of the questions back to class or request a fellow student to help. In all of the contributions from students or to students – students are treated as 'the singular' student. There are no questions to be solved together. The questions Ellen posed on subject matter all required short factual responses. If the student did not answer after a short time, Ellen answered herself.

Norm: Teacher controls the information flow

In this case, Ellen received some 'wrong' answers from students. These 'wrong' answers were not explored by, e.g., 'how did you think?'. They were ignored. There might of course be some very sound reasoning behind these 'wrong' answers, e.g., the student interpreted the question in another way. If Ellen were to 'explore' wrong answers in front of rest of the class, this would have required the student to verbalize. This would perhaps put too much pressure on the student. Ellen did not use students' drawings at the very start of the lesson and she herself did the summary of the activity with (no/little) contribution from students. Thus, Ellen does not challenge the students' contributions. On the other hand, students do not call for or make explicit a wish to contribute more or that they want their or other students' contributions explored in greater depth.

Norm: Problematic ('wrong') contributions from students are ignored.

## 7.5. Rhetorical framing of DNA-code

This section draws on all of the previous sections in this chapter and integrates the regulative and the instructional together with the other factors that impact the rhetorical framing (physical space, time, resources and competence aims), and how these factors are put into play. First, however, I will recapture prominent findings and give an overview of norms.

*Prominent findings*

There are two prominent findings in this case. The first is related to the speech functions used in the introduction. Scientific knowledge is given as certain factual statements or as questions given to expose (students' understanding of) certain facts. Procedure is given through strong demands (and some implicit choices) and the social (division of groups) is given through questions or weak demands. Social behaviour was not addressed verbally in this case. To some extent, these variations are 'natural'. The subject matter sets its imprint on how it is spoken of. However, one might ask why are there no hypothetical statements or open questions with several possible answers regarding subject matter. In addition, why are there so few real choices and explicit reasons concerning the procedure? Further, why are there no strong demands in regard to students' behaviour? Are these speech functions an indicator of 'noise' reduction? Are the subject matter and the procedure perceived as easier when one does not need to think about different alternatives? Students' opinions are taken account of in division of groups, otherwise this probably would have caused problems in carrying out the practical work (i.e., problems in student-student relations).

The other prominent finding is the reduction of 'scientific language' or the increase of everyday language the closer one gets to the actual activity. The activity the students did is all about 'seigmenn' and not DNA.

*Overview of norms*

The norms inferred in the regulative part of the text are:

- Resistance to teaching is indicated by obvious lack of attention
- Unwanted behaviour is not explicitly addressed
- Decisions concerning collaboration are implicitly left to students
- Taking notes is open for negotiation
- The teacher provides a goal for task
- Purpose is of little importance
- It is important to partake in the activity and the outcome is less important

The norms inferred in the instructional part of the text are:

- Practical work is to be enjoyable
- Procedure is fixed (no explicit choices) and emphasizes material action

- Scientific knowledge is true and certain
- Scientific knowledge is loosely coupled to practical work
- Scientific terms are superfluous in practical work
- Practical and scientific questions have equal worth
- Teacher controls the information flow
- Problematic ('wrong') contributions from students are ignored

*Physical space and time*
In this practical work, physical space (the classroom) and time (finish before break) are intertwined. The practical work could not be carried out in the science lab, and the practical work was to be carried out after the subject matter introduction. This made for a limitation on time.

The space of the classroom is easy to organize when it is a practical activity that does not require any specialized science equipment. Students simply put their desks together and are 'ready to do the work'. Both Ingrid and Beatrice were still facing the board, i.e., they did not change their position from what they would have had if it were a lecture. The practical activity allowed students to move around more freely and with purpose. For example, Beatrice had to go to fetch one seigmann of the right colour and then they did not have enough toothpicks. This makes the time and space of the classroom 'belonging' more to the students. When there are lectures, the teacher is the only person 'allowed' to walk around. This utility of the room and time can also be connected to the norm that students are involved in deciding their social organization. Practical work in the classroom is thus a different way of using the space compared to regular (literature) tasks or lectures.

As aforementioned, Ellen was pressed on time toward the end, as they had to be finished and tidied up before the break. This probably led to a bit rushed and an unsystematic presentation of the procedure. The students' inattention (or resistance) can be seen as a reversed time summons. The students hurry the teacher to finish the procedure. One may speculate if the inattention among students is connected to the lockstep structure of practical work, see also norms below.

*The artefacts and resources*
The artefacts in this practical work were everyday (seigmenn, coffee filter bags, toothpicks) and thus familiar to the students. There was little 'scientificness' about the objects. The salient features of the seigmenn were their colour (corresponding to the four bases). The toothpicks (to represent bonding) all had the same length (unlike 'real' chemical bonds) and the seigmenn were not fastened to a backbone (i.e., what would correspond to the sugar phosphorous molecules in the DNA-model). It is a question if the homely artefacts reinforce the lack of 'scientificness' in the teacher and students' talk, i.e., that scientific terms are (almost) absent in the actual activity. Perhaps the way of speaking would not be different if they were working with a DNA molecular building set? In this practical activity, students had to transduct from one model (seigmenn and toothpicks) to a quite different model (2

dimensional drawing), both referring to the 'same' DNA or mRNA. The transduction-distance might, so to speak, become greater when the artefacts look so totally different from the textbook models. The seigmann-word is thus harder to connect with (textbook) scientific terms. One might speculate if the homely artefacts actually are counter-productive to the students' semiotic work in science.

The primary resource for this activity was the seigmann-code table. This table was, in the introduction related to seigmenn and to codes in general and not to amino acids. Beatrice and Ingrid copied down the table, but they did not have to, as the table remained on the board during the activity. They chose to copy this table as they saw fit, there were no restrictions from Ellen on the use of tools for copying. The students managed to transfer reading from the seigmann-code table to reading of the amino acid code table. This probably means that they had understood the principle of the reading of the table. However, it is a question of how important this skill is. To explore this there is a need to look into the curriculum.

*Curriculum*

There are many 'difficult' terms underlying the 'simple' competence aim of explaining the genetic coding and the basic principles of protein synthesis. There are many terms and processes of which to keep track. Whether it was time well spent to go so deep into this particular aspect of coding is of course a question. Ellen addressed this question in our planning session. She was not sure how detailed this should be.

The protein synthesis taught in upper secondary school is well-established scientific knowledge. It can thus lead to ways of speaking as if it true and certain. However, there is little to 'wonder' about if the knowledge is (presented as) certain.

It is perhaps difficult to make a firm connection from an activity like this to the (rest of the) protein synthesis. To establish this connection, it might be necessary for the students to spend more time on meta-reflection, e.g., through answering questions such as what does this have to do with the protein synthesis. In this activity, the brief summary was made by teacher. Students continued to work with protein synthesis this science day, but they had the responsibility to make the connections themselves (as this was not made explicit).

On the other hand, this practical work can also function as a 'break' from all the difficult protein synthesis terms. The practical work may then function as a time where students can digest the content or relax and have an enjoyable time. 'Efficient learning' is perhaps not equal to packing time with 'useful' content?

*Norms*

Subject matter is given as certain and incontestable. This might partly have something to do with the topic, which is well-established knowledge at upper secondary level. However, it does not explain why there is a lack of 'thinking' questions or why the DNA is not referred to as a model. This is not because the teacher knows no better. It can be seen as way of reducing 'noise' where science is reduced to absolute facts at the expense of pondering over problems and creating connections. Perhaps this is a way to make the subject matter manageable for students. Ellen might perceive that by taking away what is problematic and uncertain, the subject matter becomes easier to deal with. Students in this class had also expectations of a fact-based science course. This can further be connected to how the teacher relates to the subject matter in the procedure. Scientific knowledge is very loosely coupled to the practical activity and scientific terms are absent. The presentation of the procedure emphasizes material action at the expense of creating links between the practical work and the subject matter in the lecture.

The procedure is fixed, as there are no real explicit choices. The fixed procedure results in less to think about for the students and might thus be seen as more manageable. 'Follow the recipe and you have done the job'. Even so, Ellen seems to be a bit unsure about if the students manage to do this. Some of her statements can be interpreted as she reduces the expectations to the outcome of the work. The most important thing is to *do* the practical work and that the students find it enjoyable. The steps within the procedure have no explicit reasons. This might lead to the problem of not understanding why it is needed to do something in a specific way, e.g., writing direction. Whereas students' opinions are taken into account in the social organization, it is less important in matters of procedure. The only procedural involvement from a student is when Sam rejects the idea of making a five-letter word. This can be understood as a way of reducing the workload. Further, Ellen's use of strong demands when introducing procedure might lead to students' opposition. The lockstep procedure is perhaps one of the sources for the students' resistance, i.e., not paying attention. Although I doubt students make a 'conscious' connection between the lockstep procedure and inattention, perhaps the language used in the presentation of the procedure makes the students feel out of control or without any impact on what they are to do and they thus show resistance?

There is low degree of subject matter challenge in this case. Ellen does not challenge the students' contribution, e.g., by asking further questions when students' responses are unexpected. Students do not challenge the teacher by asking difficult subject matter questions. This can be seen as students' confidence in their teacher and her subject matter knowledge, but it can also be seen as if the students are not curious about science or that they feel powerless in relation to the subject matter. Students' questions are mostly closed factual and not directly related to the subject matter, but to copying. This can be seen as a tacit agreement between the teacher and students. If students do not challenge the teacher by asking difficult questions or requiring reasons for, e.g., procedure, the teacher leaves it to them to do what they can. This can be seen in the low degree in which Ellen intervenes in students' carrying out phase. Ellen seems reluctant to guide and ask questions during their work and organizing the work is the students' responsibility. I think that in doing so, Ellen chooses not to take the risk of more resistance from students. What becomes paramount is that the students partake in the activity and perhaps not so much the 'quality' of their semiotic work. This can perhaps be connected to a view of learning.

Students seem to have taken quite a passive role in the learning process. They listen to the teacher and do what is necessary. This is perhaps reinforced by the teacher's presentations where science is 'facts' and the teacher controls the flow of information and what can pass as right or wrong. The teacher relates to students as singularities in subject matters. For instance, questions are always given to individual students to answer. Students' semiotic work is perhaps viewed as an individual activity. This will possibly further imply that there is little need to develop and use the students' contributions, as there is little to learn from other students.

Although there is a goal and a purpose of the activity, this seems somewhat 'lost' when the procedure is given and carried out. The practical work itself has a strong focus on material action and the reward is eating sweets. If the purpose had been provided at the start of the introduction, it might have guided the students' attention and their interpretation of the presentation. But, perhaps this practical work was not designed to be particularly purposeful; it was (only) meant to be enjoyable? However, if the teacher wanted more focus on the subject matter, the teacher could have required specific outcomes, e.g., in form of post-practical work. However, it seems that many students in this class are reluctant to write. It might be part of the 'make it manageable politics' that the students are not required to write something after the practical work.

In this case, Ellen was very much at home with content, and the introduction to the practical work was theoretically funded through a lecture on protein synthesis. However, the practical work itself became much 'doing' without linking to the theory. Does this have something to do with the recipe-type of practical work? Let us explore this in the next chapter, where students themselves are making their procedure, i.e., an inquiry activity.

# 8. BUDDING RESEARCHER – THIRD CASE

This chapter is a description and interpretation of an inquiry connected to the curriculum theme 'The budding researcher'. The chapter is structured by first giving a description of the material used to construct the case and the boundary between text and context. The second section is a short presentation of subject matter, curriculum aims and investigation plan. The third section is a presentation of context, i.e., what happened the day of the practical work and the next science day when the students made a recount of the activities this day. Then follows a description and interpretation of the inquiry 'testing sanitary towels'. This description and interpretation is divided into two parts; regulative and instructional, each of these concludes with inferring provisional norms. In the final section, the rhetorical framing is inferred.

## 8.1.Case material and boundaries

The material for this case is as follows:

| | Material - duration | Transcription |
|---|---|---|
| Context | Field note May 25th | |
| | Audio Ellen's presentation of two first investigations and 'classroom interaction'. Approx. 3 hours 10 min. | Transcribed (some parts less accurate because of problems identifying which student utters what – and low voices) |
| | Audio Ellen and Gerd evaluation after the practical work. Approx. 19 min. (the file also contains planning of the rest of the protein synthesis) | Transcribed |
| | Audio of students doing a recount of what happened during the 'budding researcher day' on the next science day | Transcribed |
| Text | Audio Ellen's introduction. Approx. 6 min | Transcribed |
| | Video group of students doing. Approx. 1 hour<br>Audio of this group doing | Multimodal: action speech – the speech is partly transcribed from the audio file as it had better sound quality. |
| | Video Ellen describing report. Approx. 5 min | Multimodal: speech and board |

Table 6: Data material for Budding researcher case

The boundary between text and context is quite clear. The text is delimited by the time from between lunch to the end of the science day. After lunch, Ellen started to introduce this inquiry. At the beginning of the introduction, there are some references to the previous investigations (context), but as these references might have some bearing on this inquiry, they are included in the text. Ellen's presentation of the requirement for the report at the end of the day is also included in the text.

The context of this case is the two lesser inquiries carried out before lunch in addition to Ellen and me evaluating the 'Budding researcher day', and the brief recount students did the next science day.
The two students, Ingrid and Fiona, did not hand in the reports afterwards. The report on testing the sanitary towels would have been useful from a research perspective, as it would say something about how the students dealt with differing results and evaluation of their methods. However, as there is no report, I have to rely on the video/audio material and interpret how they handled this in the carrying out phase of the investigation.

There are some other methodical weaknesses in this case. Ellen's primary introduction in the start is only in audio. It lasted approximately six minutes. This means I do not know if she used the board to write key words or how she gestured and used physical objects. The next weakness is when Ellen later used the board to instruct the students on writing the report I filmed this, at the expense of students carrying out their investigation. Another weakness is that the sound quality of the video is poor. The two students were talking in low voices. The sound quality of the audio file is better as the audio recorder was placed between the students. This means that I chose to transcribe the mode of speech from the audio file. The consequence of this is that there might not be full coherence between the modes of action and speech in transcription.

The time given on text-excerpts are all using Ellen's introduction as a frame of reference. This is because Ellen's introduction drifts into students carrying out their plan.

## 8.2. The budding researcher – curriculum aims

At the end of May, one of the science days was concurrent with an exam, so approximately only half the class was attending science. This called for a 'special' day, as Ellen meant it would not be possible to start on the remaining subject matter – ecology. This day was then reserved for 'The budding researcher'.

There are different approaches to *The budding researcher* competence aims. They might be incorporated together with other competence aims, or they might be treated as competence aims in their own right without a direct connection to the subject matter described in the curriculum. This day was focused on 'research', so the content of the 'research' was not directly linked to the curriculum.

Under the theme 'the budding researcher' the curriculum has the following four competence aims:

> The aims for the education are that the pupil shall be able to
>
> - plan and carry out different types of investigations in cooperation with others where you identify variables, estimate uncertainties of measurements and assess possible sources of errors

- carry out and interpret animations og simmple computer simulations to illustrate natural phenomena and test hypotheses
- explain and assess what can be done to reduce uncertainties of measurements and avoid any possible source errors from measurements and results
- assess the quality of presentations of own and others observation data and interpretations

(Utdanningsdirektoratet, 2006, misspelling not corrected)

In my opinion, the first and third aims were particularly focused. There was no direct reference to the competence aims during this day, so Ellen's opinion on which competence aims that were focused is not known.

To focus the reading of this case, I choose to present a brief overview of what a plan for investigation might entail in school science. In section 10.5, this will be dealt with more thoroughly. The plan for investigation depends upon the problem at hand. All the activities this day were experiments. Experiments involve identifying variables and setting up a systematic and stepwise procedure that makes it possible to gather the relevant data or information about these variables. Many experiments are guided by a hypothesis. The hypothesis in school experiments often takes the form of a prediction or an educated guess, often based upon previous experience rather than a theoretical position. The data gathered can be used to refute or strengthen the hypothesis. As part of the plan, one should think of how to reduce or minimize sources of error, e.g., errors in handling equipment or in the reading of the measurements. Uncertainties cannot be (totally) avoided, but it is possible to reduce uncertainty by using better instruments for measuring. To evaluate the level of uncertainty is thus part of measuring. Errors and uncertainties are part of judging the accuracy of the results. This means that there is a need for meticulous record keeping, where variables, results, errors and uncertainties are coupled. This might be in the form of a table. After the plan is carried out, there is a need to combine the results with theory and hypothesis, and to evaluate the result. The last step is to present the investigation. The presentation might be in the form of a report. Science reports are often in the form: Introduction, Method, Results and Discussion (IMRAD). The report is usually a multimodal text that contains written text as well as, e.g., drawings and tables.

Students should have carried budding researcher activities of some sort in both secondary and primary school. In primary and secondary school, there is an emphasis on making hypothesis, keeping records, planning, carrying out and presenting experiments or other investigations, etc.

## 8.3.Close context

There were only eight students present this day, May 25th, as the rest of the students had an exam. It was a six hour science day. Ellen had been travelling the weekend before (Monday was an official holiday) and she came back the night before only to discover rainy weather. The rain made the initial plan for the 'budding researcher day' impossible to carry out. The initial plan was to measure UV-radiation by the use of a data-logger. The measurements of UV radiation would not be good enough with an overcast sky. Therefore, Ellen had to 'invent' something to 'research' 'on the spot'. This means that our joint planning of this day will not be accounted for as part of the context. Below follows a recount of what happened during the two first inquiries (before lunch), based upon the field-note and audio material from class. The last part of this section is about what happened after class, a summary the next science day and Ellen and my reflection immediately after the 'Budding researcher day'.

The excerpts shown in this section are chosen for two reasons. First, they serve the purpose of providing the reader a more authentic experience of what happened this day. The second reason is to give the reader a sense of how Ellen and the students talked about the smaller inquiries that have implications for the inquiry where students made their own investigation plan. All excerpts are given in chronological order.

The budding researcher day was divided into three parts. The first part was about tasting different drinks without seeing (and smelling), what drink it was. This investigation was carried out in the classroom. The second investigation was testing three different cloths, the type you use in the kitchen for cleaning up spills. This investigation was carried out in the science lab. The third investigation was an inquiry where the students were to test and find the best sanitary towel, this was also carried out in the science lab. The 'consumer-test' of sanitary towels will be analysed in detail in the next section.

> The start of this day is a bit different. First Ellen and I talk for a bit. Then Ellen goes to find out if the science lab is free – and if we can be there the whole day. The students are mostly 'curled' over their desks or sitting chatting. The lesson starts ten minutes past. While Ellen is talking about what is going to happen today, she is interrupted several times by students popping their head in asking where the exam is supposed to be.
> (field-note, May 25th)

Ellen starts her introduction by asking:

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|---|---|
| Få høre hva dere gjorde i ungdomsskolen med forskning. Har dere forsket på noe i ungdomsskolen?<br>John: (uhørbart)<br>Ellen: Hva? Altså nå spør jeg forskning, altså forskning, dere hadde ett eller annet dere skulle finne ut av. Få høre hva dere gjorde<br>John: Vi gjorde den pHverdien<br>Ellen: Okey, hvilken hypotese hadde du | Let me hear what research you did in secondary school. Did you research something in secondary school?<br>John: (inaudible)<br>Ellen: What? So, I ask now research, then research, you had something you were to find out about. Let (me) hear what you did<br>John: We did that pH value<br>Ellen: Okay, what hypothesis had you got |

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| da med pHverdi? Hva var det du skulle forske på? Skulle du bare gå ned å måle pHverdi?<br>John: Jeg skulle sjekke om det var surt eller om det var (senker stemmen = uhørbart)<br>Ellen: Hva er det som ..<br>John: (uhørbart)<br>Ellen: Ikke sant, det høres ut som dere har vært ute og målt ett eller annet, men dere har ikke hatt noen formening om hvorfor dere skulle måle det heller. Jeg bare spør hvilken forskning dere har gjort. | concerning pH value? What was it you were to research on? Were you just to go down and measure pH value?<br>John: I was to check if it was acidic or if it was (lowering voice – inaudible)<br>Ellen: What is it that…<br>John: (inaudible)<br>Ellen: Right, it sounds like you have been outside measuring something or other, but you had no opinion about why you were to measure it. I just ask what research you have done. |

The few last statements made by Ellen might be interpreted as if she interprets the student's answer that there was no explicit purpose to the investigation, there were only some measurements. The word 'research' is perhaps a 'big' word for students, as they might not associate their practical work or small inquiries with 'research'.

Ellen then asked me what research is, and I answered that it is about having a question one likes to find out more about, further, I stressed the importance of relating the question and investigation to literature and theory. Ellen then made a distinction between experiments and (regular) practical work, as experiments have no fixed outcome – we do not know the result of an experiment. After a brief mention of the three different investigations, Ellen said:

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|---|---|
| I dag er det jeg som lager, kommer med spørsmål, en hypotese. Og så skal dere teste ut dette her og så skal dere tenke ut hvordan tester man ut den hypotesa. | Today I'm going to make, asking the questions, a hypothesis. And then you are to test this and then you have to think how one test that hypothesis. |

She thus gave the responsibility to the students to find a procedure while she was to support the students by making the questions or the hypothesis. She wrote on the board, while she said, "*It is difficult, impossible, to taste the difference between different drinks when you are blindfolded.*" She had eight different types of drink lined up on a desk. She asked if there were something about the different drinks that could make it possible to differentiate between them and a boy answered: "*It is possible to taste difference between Urge and sparkling water - to put it like that*". Ellen continued:

| | |
|---|---|
| Vi skal nå gjøre forsøket med bind for øynene. Og her har jeg – her står det 80 plastikkopper. Så jeg foreslår at vi deler oss i tre grupper – er det greit? Vi må tenke litt gjennom før vi starter, for jeg har ikke kjøpt mye av hver av disse her. | We shall now conduct the practical work blindfolded. And here I have got – here it is 80 drinking cups. So I suggest we divide ourselves into three groups – right? We must think a bit through before we start, because I have not |

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| Og det vi ikke bruker det går i søpla – gjør det ikke det? Hvis dere ikke har lyst å drikke det opp. Tenk dere, vi er alle seende. Hvor mye betyr det at vi kan se for hvordan vi smaker? Har det noe å si? Nå har jeg stilt et spørsmål til dere. Hva tror dere om det? Skal vi stille oss litt åpen til dette her og se om vi klarer å smake forskjell? Er det noen av dere som er flinke til å smake ? | bought so much of each of these. And what we don't use goes into the bin – does it not? If you don't want to drink it. Think about it, we are all (of us) seeing. How much does that mean for how we taste? Has it got anything to say? I have now asked you a question. What do you think about it? Shall we keep an open mind to this and see if we manage to taste difference? Are some of you good at tasting? |

There was virtually no time to answer these questions except the very last. Ellen divided students into groups of two, i.e., four groups, and she talked in an everyday language about how to carry out the investigation by using different plastic cups for each drink in a rather intermingled fashion. She also talked about how to rinse the mouth between each tasting. She proceeded:

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| Jeg tror det skulle gå slik at alle kan gjennomføre dette forsøket og så kan dere få data fra hele klassen. Er det noe som er lett å skille ut? Hvorfor er det lettere å skille ut? Er det noen smak man smaker bedre enn andre? Hvordan er det med smak, hvor sitter smaken? Og hva slags smaker er det vi kjenner?<br>(3 s)<br>Steven: Tunga<br>Ellen: Ja, det sitter i tunga, smaken sitter i tunga | I think it will turn out that all of you can carry out the practical work and then you can have data from the whole class.<br>Are there any that are easy to separate? Are there any tastes that one taste better than other? How is it with taste, where is it located? And what kind of tastes are we recognizing?<br>(3 s)<br>Steven: The tongue<br>Ellen: Yes, it is located in the tongue, the taste is located in the tongue. |

The questions posed by Ellen are given in a 'flow', there is no time to 'think and answer' for students. Ellen and the students then had a dialog of what different types of tastes we have. There were two students involved in this exchange. Then Ellen returned to establishing a common procedure:

| | |
|---|---|
| Hva slags rekkefølge vil dere ha dette i? Kan dere snakke om rekkefølge<br>John: Vi burde kanskje ikke ha en spesiell rekkefølge fordi da kan man huske hva som er riktig<br>Ellen: Ah! Ikke sant! Det var veldig godt sagt altså | In what sequence will you do this? Can you talk about sequence<br>John: We should perhaps not have a specific sequence because then it is possible to remember what is correct<br>Ellen: Ah! Right! That was very well said. |

Ellen asked the students how the results were to be presented, and she got the response "*write on pc*". This was not further elaborated. She then reminded them on taking notes continuously while doing the investigation.

Ellen went to get the blindfolds. While she did this, I walked and talked with all groups of students, asking if they knew what to do. Three of the four groups had no fixed plan they wanted to tell me about, but the fourth group had thought that because of the different consistencies, it would be possible to group the different drinks (with or without carbonation and thick or thin consistency).

A student had suggestions on how to do this, and Ellen answered:

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| Jeg er med på alt det dere diskuterer. Her fins ikke noe riktig og galt. Det som er – det som vil være galt er om man får et resultat som man ikke kan si noe om fordi vi har gjort det for usystematisk. | I am with (you) in all you discuss. There are no right or wrong here. What is – that which would be wrong is if one gets a result that one cannot say anything about because we have done it too unsystematic. |

These statements might be interpreted in different ways. There seems to be an inherent contradiction between "*no right or wrong*", and the last statement that equals wrong with an unsystematic approach to the investigation. Perhaps the intention of "*no right or wrong*" was to indicate that there are several possibilities on how one may carry out the investigation, and then the last statement would be an elaboration of this. Alternatively, "*no right or wrong*" might be that the results of the students' investigation, i.e., what they taste, are not very important. It is okay that there are wrong answers to the tasting. If the statement is read this way, it can be seen as a way of taking 'pressure' off the students to get it 'right'. What Ellen meant by a 'systematic investigation' was not made explicit or elaborated upon, as she proceeded directly to talk about the different types of drinks she had brought with her.

The groups started to test. Approximately five minutes after the students had started testing, Ellen reminded them once more that they had to write the results. Ellen told the students that they should not answer if the student blindfolded answered correctly (some students did this initially). During the testing, one of the students started to hold his nose. Ellen asked all the students to do this in the next round of the investigation. After the testing Ellen, asked the students to tidy up. When students had disposed of the trash, Ellen started a dialogue with the students about which was easy to taste and which was not. This leads to a panel testing where three students were testing the 'difficult ones' in front of the class.

In the end of the lesson, Ellen said, "*We are to make a report of this, but first you are to have a break.*" Students tidied up the classroom before leaving while doing so there are 'cheerful' voices on the tape.

*The second inquiry*
After the break, the class gathered in the science lab. Ellen showed the students three different types of washing cloths and told them the price of each. Then:

| | |
|---|---|
| John: Er de forskjellige?<br>Ellen: Ja det er det jeg lurer på om det er litt forskjell på hvordan disse er knytta sammen, for jeg lurer på om ikke dette er syntetisk materiale. Det vi skal gjøre er å sjekke på internett. Fordi at de sier at når vi skal gjøre rent så skal en først vri opp kluten i varmt vann fordi da er det - det er enklere å tørke opp når man har en våt klut. Er det faktisk sånn? Jeg bare spør. Når dere skal vri opp – hvordan gjør dere det? | John: Are they different?<br>Ellen: Yes, what I wonder about is if there is a bit difference in how they are constructed, because I wonder if this is not a synthetic material. What we are to do is to check (this) on internet. Because they say that when we are to clean up then one first should wring the cloth in hot water because then it is – it is easier to clean up when you have a damp cloth. Is it actually like this? I just ask. When you are to wring – how do you do that? |

The cloths looked different (colour or pattern), so John's question opens allows new perspectives. Ellen responded to this by relating to weaving (?) and material. She proceeded directly to prepare the ground for the hypothesis (easier to use a damp cloth) and how to wring a cloth. After a student had responded to this question and showed his fellow students, Ellen said:

| | |
|---|---|
| Det vi egentlig skal – det jeg hadde tenkt at vi skulle undersøke i dag: er det faktisk sånn at en våt klut suger bedre enn en tørr klut? Nå er problemet at vi bare har tørr klut en gang | What we actually shall – what I had thought we should investigate today: is it really true that a damp cloth draw better than a dry cloth? Now, the problem is that we only got dry cloth once |

Here she introduces the first of the 'research' questions: damp cloth is better than dry. Her second question 'which one is best?' was given one minute later.

Ellen tried then to establish a procedure for how to investigate or to find the 'best cloth'. She did so in an everyday form of language relating to the students' previous experiences with cloths. She wants the students to "*feel the difference between dry and damp cloth*". She stated that this experiment has a qualitative part; it was not only about measuring. Ellen allowed for the students' contribution in the construction of the plan for investigation by saying "*You have to think about how we are to do this. I'm not really sure. We are doing research also on how to do this experiment*". The students' responses were short.

> *It seems to me that Ellen wants the students to participate and be active in deciding how to do this.* But at the same time when students don't say much – then she do the talking and decides. *Perhaps she does not give the students enough time? Perhaps she should dwell more on this? This was too incoherent??*

(field-note May 25th, speculation in italic)

Ellen structured the investigation into two parts. First, a qualitative part where students were to spill 10 ml water on the table and then wipe it up. The students were to make qualitative statements (she first used the Norwegian word 'synse'[13]) about how easy it was to wipe up with a dry and then with a damp cloth. There was a short summary – which one was best.

The next part of the inquiry was the quantitative investigation. One of the students had suggested that they could use an electronic scale. Ellen makes a table on the board (types of cloth vs. group) and then she recognizes a measuring problem:

| | |
|---|---|
| Nå glemte vi selvsagt å veie det, nå gjør vi en sånn litt ugrei tilnærming. Nå glemte vi faktisk å veie klutene i tørr tilstand, derfor, derfor sier man dersom dette skulle vært riktig så skulle alle sammen veid sine kluter | Of course, now we forgot to weigh it, now we are doing a bit un-ok approach. Now we actually forgot to weigh the cloths in dry state, because, because one says if this should have been correct then all should have weighed their cloths |

She chose to measure the weight of the cloths not used, and these numbers were written in the table as the initial weight of each cloth. The next step was to carry out the investigation:

| | |
|---|---|
| Ellen: Okey. vær så god – sett i gang<br>Steven: Hva var det vi skulle gjøre? Vi skulle ta vann og vri opp – bare sånn at det ikke drypper<br>E: Dere må føle dere fram på det der | Ellen: Okay, please go ahead<br>Steven: What are we supposed to do? We should take water and wring – just so it does not drip<br>Ellen: You have to feel your way on that |

Ellen thus left it up to the students to decide how wet 'wet' meant. Ellen helped the students read the scale when they had a wringed and wet cloth. The students 'shouted' the results to the member of the group responsible for note taking. After a while, Ellen left the scale and the students did the measurements themselves. When the students started to work on their numbers, some had problems finding out how much water the cloth had absorbed. The common table on the board showed a great variation in numbers. This was perhaps not very surprising, as there was no common procedure for how wet the cloth was supposed to be. Should it be dripping or partly wringed?

| | |
|---|---|
| Ellen: Jeg har lyst til at vi diskuterer resultatene. Hva er grunnen til at man kommer frem til slike resultater som dette her? Kan vi si noe om dette?<br>(4 s)<br>Kan vi si noe? Er dette et gyldig | Ellen: I want us to discuss the results. What is the reason for results like these? Can we say something about this?<br><br>(4 s)<br>Can we say anything? Is this a valid result |

[13] 'Synse' might be translated into English as opinion without factual basis.

| | |
|---|---|
| resultat eller?<br>John og Steven: Nei<br>E: Hvis dere skulle gå å velge i butikken hvilken ville dere valgt da<br>Tom: Den billige<br>Ellen: Hvorfor ville du valgt den billige?<br>Tom: Den er billigere<br>:<br>Fiona: Ciffonet (merke)<br>John: Jeg ville tatt mikrofiber<br>Ellen: Hvorfor det –fordi dere fikk den til å veie mest<br>John: Neei, jeg vet ikke, men det har noe med (gradvis lavere stemme) | or what?<br>John and Steven: No<br>Ellen: If you where to go to choose in the shop which one would you choose?<br>Tom: The cheapest<br>Ellen: Why would you choose the cheapest?<br>Tom: It is cheapest<br>:<br>Fiona: Chifonet (brand)<br>John: I would have taken micro-fibre<br>Ellen: Why – because you got it to weigh most<br>John: Noo, I don't know but it has something to do with (trails off low voice) |

Instead of following up Jon and Stevens' response Ellen chose to 'rephrase' the question. This gave an unexpected (?) answer from Tom. Tom's answer does not belong to the realm of science, but Ellen chose to follow it up. Fiona's opinion was however not followed up but John's answer was. After this, Ellen directs their attention once more to the problems with the procedure – how the investigation was carried out. One student (Steven) stated that there was "*human error connected to wringing of the cloth*". Steven then had a longer response in a voice too low to hear in the audio file. Ellen then said:

| | |
|---|---|
| Hvordan skal vi få noe ordentlig resultat ut av dette her? Her er det noen ting med - vi har en prosedyrefeil på hvordan vi gjør det – ikke sant? Jeg la merke til at noen kom med en klut som det rant vann av og noen hadde en klut det ikke rant vann av. Forslag til hvordan vi kan gjøre dette Steven? Sånn at vi faktisk får noe orden på dette her. Det er det eksperimenter dreier seg om – vi er nødt til å tenke gjennom prosedyren vår for at vi skal få noe ordentlig mål<br>Steven: Det var jo det jeg sa | How are we to get a proper result out of this? Here there are something about – we have a faulty procedure for how we do this – right? I noticed that some came with a cloth that dripped of water and some had a cloth that did not drip water. Any suggestions for how we shall do this Steven? So we actually can get this sorted out. That is what experiments are all about – we have to think through our procedure to get a proper measurement<br>Steven: That was what I said |

There is no time for the students to respond to the questions put forward until Ellen's last statement. Steven proposed another procedure and Ellen said:

| | |
|---|---|
| Steven foreslår at vi endrer prosedyren – vi har – da må vi ha kluten godt vridd opp okey? Og så senker vi den ned i 100 gram vann og så veier vi vannet etterpå og ser hvor | Steven proposes that we alter the procedure – we have – then we must have the cloth well wringed okay? And then we lower it into 100 gram of water and then we weigh the water afterwards and see |

| | |
|---|---|
| mye vann som er blitt borte – skal vi gjøre det slik?<br>John: Ja | how much is lost – shall we do it like this?<br>John: Yes |

During this last round, two of the students started to fool around with the water in the beaker – having great fun. Ellen commented on this (in a smiling voice) that every time students are to use water some students end up spilling water on each other. She did not comment that this effected their measurements.

Just before lunch, Ellen had a very short 'lecture' on different materials, and their ability to hold on to water and to dry up. She linked this to hydrogen binding. The last half hour before lunch the students worked with their report on the taste inquiry. Some students used Ellen's computer to search the Internet for information on taste and structure of (school) science reports.

After lunch, the students were to start their own inquiry with sanitary towels, see next section.

*Post – inquiry*

In the evaluation Ellen and I had immediately after the inquiries Ellen referred, to the cloth-inquiry as 'everyday-knowledge' and that this experiment was a bit 'silly' because many students were inaccurate. In addition, she wondered if she should have guided the students more directly.

| | |
|---|---|
| Gerd: Jeg tenkte kanskje en ting og det er at – ble oppsummeringen av øvelsene og det som på en måte var feil med de – ble det for mye sittende hos deg? Eller<br>E: Jeg fikk det ikke ut. Jeg hadde følelsen av at dette fikk jeg ikke ut – det er jeg fullstendig klar over | Gerd: I thought perhaps one thing and that is – did the sum up of the practicals and that which in a way was wrong with them – did that only belong to you, or<br>Ellen: I did not get it out. I had the feeling that I did not get this out – I'm absolutely aware of it |

On a question from me on what she could have done differently, she said

| | |
|---|---|
| Jeg lurer litt på om jeg sånn i etterhånd rett og slett tar – at jeg ser på det de leverer av rapporter – for her har jeg vært lite inne og veileda de undervegs mens de holdt på. Men vi har hatt noen tanker | I wonder a bit if I afterwards quite simply take – that I look through what they hand in, the reports, because here I have not supervised much when they carried it out. But we have had some thoughts |

The next science day Ellen stated that there would be no measurement of UV radiation, as the 'Budding researcher' is 'finished', she then asked if any of the students present at the previous science day could tell something about what had happened.  One of the most enthusiastic students had a recount for the rest of the class about the various experiments. Other students contributed.

*Summary of context*
There was a 'relaxed atmosphere' this day. There was no rush. This can be seen in the start of the day as well as the fact that both of these investigations were done two times with (slightly) different procedures. The students' voices are cheerful and from the tape I can hear no/little 'out-of-task' talk. The students were engaged.

In Ellen's introduction of research questions and procedure, there were many questions. Some of them were 'thinking' or long response questions, however there was often little or no time for students to respond to these questions. In particular, two boys were active in the classroom dialogue. Some students (three) did not raise their voice to speak in 'public' and some contributed very little (three).

Further, Ellen's introductions and establishing of common procedures were in an everyday manner of speaking. The speech was structured by the 'logic of the everyday'. By that, I mean that there is more disconnection between statements than would be in a structured presentation. It might seem that Ellen said what she thought in the 'moment'. The procedures were not written down on the board. This, together with the 'unsystematic' approach to establishing a common and structured procedure, made the students' interpretive space large.

In the first inquiry (taste), there was no support or requirement for how results were to be transducted into writing (table or alphabetical). In the second investigation (cloth), a table was given at the start for how the measurements were to be presented. This could act partly as a support for the students' transductions. (Some students had some problems calculating the difference.)

Words such as variables or uncertainty were not used. Differences in results were connected (only) to faulty procedure.

Next is analysis of the text – where students themselves made their procedure.

## 8.4. Inquiry – testing sanitary towels

Testing sanitary towels is not explicitly mentioned in the curriculum nor is consumer tests. Theory related to this experiment could be the ability of absorbing and holding on to water for different materials. This is not part of the curriculum in general science in upper secondary school. This means that the content of this investigation is unconnected to curriculum aims.

Ellen wanted the students to make their own procedure that would allow them to find the 'best' sanitary towel. As the procedure was the 'content' in this activity, I have chosen to regard it as part of the instructional domain of communication, in other circumstances it could have been treated as part of the regulative, i.e., structuring the task. Ellen's introduction is about six minutes and it is 'fleeting' into the students' activity. At the end of the day (i.e., towards the end of this inquiry), Ellen had a combined summary and instruction on how to write a report. This summary is treated as part of the material, i.e., it is coded. However, as it is after the students' planning and carrying out the investigation it has no direct impact on their actions.

There were few students present this day. That meant that Ellen did more of the guiding (and instruction) directly to groups of students, as the excerpts below will show.

During this last inquiry, Ellen and I talked about the day and the different investigations. I was filming the students' activity and we talk as they carried out. I made a comment to Ellen that there seemed to be problems concerning measurement. I further asked Ellen if the students were to write a report. She replied yes, but this they could do at home. She then said, "*I feel now that we have dealt satisfactory with the 'Budding researcher*'". I commented on the progress of the day and the gradual increasing level of 'difficulty' – from the first and more 'light' observation to the more quantitative measurements.

### 8.4.1. Regulative

The regulative part of communication addresses the structure and management of the task. The first part of this section provides a description and interpretation of the text. In the second part, I infer what seem to be the norms based upon the descriptions and interpretations.

The introduction has quite a short passage that can be labelled 'regulative', but when Ellen, at the end, gave a description of the report, much of this is to structure the students' homework, i.e., regulative.

#### *8.4.1.1. Text description and interpretation*

First, an overview of the features of the regulative part of the text is provided before a more detailed description and interpretation.

The pronoun 'we' is used with three different meanings. First, it is as 'real we', e.g., "*we comment*": this means that both students and teacher have the choice of contributing. There are few examples of 'real we' in this part of the text. Another form of 'we' is the form when the teacher actually means herself, by not opening up for students' contributions. An example of 'we' in the meaning I, is 'we agree on writing a report'. Ellen did not involve the students in the decision of making a report or the different elements of the report. She decided the form of the report. My interpretation is that 'we-meaning-I' occurs three times in this part of the text. The third form of 'we' is meaning 'you'. For example, 'we must have a hypothesis'. Here it is the students, who are writing the report, that 'must have' a hypothesis. In the regulative part of the text, I interpret 'we-meaning-you' to occur four times. The pronoun 'you' is used 14 times.

When ‘we’ are to be understood as ‘I’, it might be seen as a blurring of the teacher’s power to decide. The teacher decides, but it becomes less visible through the use of ‘we’. When ‘we’ are used to express ‘you’, this can be seen as a way for the teacher to express solidarity with the students (‘we’ are in it together), but on the other hand this might also lead to a blurring of responsibility. The pronoun ‘you’ indicates distance between the teacher and students, but it also places responsibility more clearly.

The speech functions in the regulative part of the text are primarily demands. Strong demands are especially used in the presentation of what the report is to contain. There are also some weak demands, e.g., “*Then you are to write a bit about …*” – where the phrase ‘a bit’ lessens the impact of ‘you are to write’. There are also some factual statements. No questions or choices are given.

Ellen made a distinction between ‘experiment’ and ‘practical work’[14]. Experiment is, as I interpret Ellen, an investigation where it is not possible to predict the outcome or result. The result is open. In Ellen’s first part of introducing the inquiry, she corrected herself when she used the word ‘practical work’ and replaced it with ‘experiment’. In the latter part, when she presented the structure of the report, she used ‘practical work’ more frequently than experiment. It is possible that this creates an uncertainty whether the outcome is fixed or not.

During the presentation of the report content, the most prevalent transitivity processes are verbal processes such as ‘write’, ‘explain’ and ‘present’. These processes are connected to the pronoun ‘we’ (in the meaning you), just as often as ‘you’. There are also some mental processes (e.g., evaluate and understand) and processes relating to sensing (I see). The mental transitivity processes are used just as often when Ellen refers to herself as to the students. There are also some attributes of the report (it has a hypothesis and procedure).

Ellen chose to present the report layout systematically and stepwise following the IMRAD structure. She used the board to write down some key sentences that supported her speech. The main form of cohesion was elaborations.

***

The introduction before the inquiry was primarily instructional (as procedure is regarded as subject matter in this case). However, Ellen started by saying:

| | | |
|---|---|---|
| 4:30 | Jeg har lyst til at vi kommenterer, nå skal vi gå videre med et forsøk altså… Da gjør vi det slik at vi deler dere i fire grupper og at hver av dere lager et opplegg for et | I want us to comment, now we are to go on with a practical work, so… Then we do it like this that we divide you into four groups and each of you make a plan for a practical work, an experiment, |

[14] In Norwegian, the distinction between ‘eksperiment’ and ‘forsøk’.

| | | |
|---|---|---|
| | forsøk, et eksperiment unnskyld, et eksperiment<br>Steven: For de andre?<br>Ellen: Dere lager for dere selv og gjennomfører.<br>Steven: Ok | sorry, an experiment.<br>Steven: For the others?<br>Ellen: You make for yourself and carry it out<br>Steven: Okay |

The rest of the introduction to the inquiry is considered to be instructional, see below.

This excerpt shows statements dealing with division into groups and what might be seen as the goal of the activity. These statements might be read as weak demands in this setting. Division of students' groups was no real issue as the students continued to work together as they had earlier that day. Ingrid and Fiona worked together all day. The goal of the activity is to make a plan for the inquiry and to carry it out. Steven's question might be interpreted in (at least) two ways. It might be a question on whether there is to be a common procedure for the whole class or it is possible to interpret it as if one group of students is to make an inquiry plan for another group. The latter was an approach that was never tried in this class, but such an approach to a hands-on activity would require students to make the plan (very) explicit so it would be understood by the other group. If this were his intention with the question, it would be a novel contribution on how to organize practical activities.

At the end of the lesson, Ellen started instructing the students on how to make a report. As some of the students were not finished with the inquiry, Ellen used her 'board-voice' to call for attention (time summon):

| | | |
|---|---|---|
| 1:07:00 | Jeg ser at noen er ferdige – og da tenkte jeg at vi bare skulle bli litt enige om hvordan vi skulle skrive en liten rapport på dette her. | I see that some are finished – and then I thought that we should agree a bit on how we are to write a small report on this. |

Her factual statement is followed up by a weak demand. The first 'we' in this demand is a rephrasing for herself, as she does not involve the students in how the report was supposed to be. The second 'we' means 'you', as it was the students who were to write, Ellen was not a co-writer in the reports. Ellen used the phrase 'small report'. The report here was associated with something short, but her presentation revealed that the students were to write a 'full' report, including errors, uncertainty, evaluation and conclusion. Her expression might thus be interpreted as a lessened role of the status of the report the students were to write, and she made it 'sound like' a reduced workload.

She then went on to ask the students what hypothesis one might have in a case like this. Steven answered: "*most expensive is best*" and he elaborated on his response. Next, Ellen said (by the use of a strong demand) that she required a concrete explanation for how the students had carried out the inquiry. As Ellen required an explanation and not merely a description, it is reasonable to interpret her as if she wanted students to provide reasons for their procedure. Whether students interpreted this demand to include reasons for procedure, I cannot say. (The usual approach in this class was a description of procedure.)

Ellen then continued to talk about the results:

| | | |
|---|---|---|
| 1:08:50 | Og så skal vi ha noe som kalles for *resultat* – bare skill mellom resultat og konklusjon. Resultat er lik *tall* fra målinger. Altså, Dere skal presentere tallene som et resultat. Dere skal ikke konkludere før dere har gjort en vurdering av resultatet.<br>: (5 s)<br>Husk det at under gjennomføringen av forsøket så skal dere ikke forklare det resultat man skal forvente å finne. Dere skal bare forklare hvordan man gjør dette punktvis – hvilken rekkefølge dette kommer | And then we shall have something called *results* – just differentiate between results and conclusion. Results are equal to *numbers* from the measurements. So, you shall present the numbers as a result. You shall not conclude before you have done an evaluation of the result.<br>: (5 s)<br>Remember that under the carrying out of the practical work there you shall not explain the result one expects to find. You shall only explain how one does this stepwise – in what order this is structured. |

While she said this, she wrote the following key words on the board: *Results = numbers from measurement* and *evaluation of result*.

In this excerpt, the words in italic were emphasized in Ellen's presentation, as she put more stress on these words. There is a pause of approximately five seconds where there is no response from students. Perhaps this was a pause made by Ellen so the students could catch up with their writing.

Ellen made thus a distinction between results and conclusion. (This distinction is not always clear to students.) She equates results and numbers, by the use of a certain factual statement. It could, of course, be that the hypothesis would lead to obtaining qualitative results such as 'feeling dry on outside'. However, most likely all groups were (only) measuring, so there was no need to dwell upon qualitative results. Ellen came back to what evaluation of results entailed when she started to talk about uncertainty.

In the last part of the excerpt, Ellen made a distinction between procedure (how it was carried out) and results. But what might "*explain how one does this stepwise – in what order is it structured*" mean? From a science education point of view, there is a big difference between explaining something, which involves giving reasons and/or causal implications, and describing, i.e., giving the facts of how of was carried out. Students do perhaps not make this distinction, and this distinction was not explicitly dealt with in this class during the year. I tend to interpret this as if Ellen is calling for a description rather than an explanation, thus this can be seen as a blurring of ‘explanation’ and ‘description’.

In the very end of the day, Ellen said:

| | | |
|---|---|---|
| 1:12:00 | Så må dere hjelpe meg å rydde opp – alle stoler skal opp (på bordene) og utstyret skal på plass, men ingen går før Ingrid og Fiona er ferdige. En for alle - alle for en<br>(Ingrid og Fiona ler)<br>Jane: Er dere ferdige snart? | Then you have to help me tidying up – all chairs shall up (on the desks) and equipment shall be put back, but no one leaves before Ingrid and Fiona are finished. One for all – all for one.<br>(Ingrid and Fiona laughs)<br>Jane: Are you finished soon? |

All students helped cleaning up before leaving.

##### 8.4.1.2. Text – context and regulative norms

The norms are inferred from the teacher’s semiotic actions and how these semiotic actions provide possibilities for students’ semiotic work. What the teacher says and does provide an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as ‘tacit’ practices or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., a rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Behaviour, teacher and students relation*

There was little ‘behaviour to regulate’ this science day, but then, there were only eight students present. During the cloth investigation, two of the students were playing with water and spilling it (on each other). Ellen commented on this in a smiling voice and regarded it as ‘childish’ fun. She took no further notice of it. There was an amiable ‘atmosphere’ this day. The voices are not strained or hard. Students helped clean up afterwards and there was no talk about ‘I’ve done more than my share’.

Norm: Behavioural issues are dealt with amiability.

*Organizing the task*

Students worked in the same groups all day, so I am not sure why Ellen raised this issue at the start of the sanitary towel inquiry. The students’ groups were different from what they used to be, as so many of the regular partners were absent. To me that did not seem to matter much. The level of collaboration was as usual. Within the (loosely shaped) procedures, students had the possibility to find way of doing things themselves. There was little teacher intervention 'inside' the task. In the inquiry into sanitary towels, however, the teacher did intervene on procedure, but not on how the students divided the work, e.g., taking and sharing notes, see below.

Norm: Decisions concerning collaboration are the students' responsibility.

There was no question from the students on whether to take notes or not. Ellen did not specify the form of notes when students did the 'taste-investigation', in the 'cloth-investigation', the table on the board might have acted as a support to structure students' inquiry. In this last inquiry there was no reference to taking notes from the inquiry students set up. Because the students' investigation design differed, it would be impossible to give, e.g., a table in advance. Ingrid took notes (on the computer) on behalf of their group. Fiona did not see these results as she was seated on the other side of the table. Ellen did, however, require that the investigation plan was to be written down, see also instructional.

*Structuring the task*
The goal was to make a design for an experiment and carry it out. No explicit purpose was given on the importance of making a design. Goal and purpose were not connected to 'the larger picture'. There was no mention of 'real science' or the curriculum objectives or aims.

Norm: A rough goal is provided by the teacher.
Norm: There is no need for purpose.

### 8.4.2. Instructional

The part of communication that addesses subject matter (instructional) is embedded in the regulative (structuring and organizing activities). There will thus be some overlap. It would have been possible to divide the texts differently, but I have chosen to treat all material that directly relates to carrying out the inquiry as instructional.

#### *8.4.2.1. Text description and interpretation*

In this section, there will be a description and interpretation of both what is found as typical during these activities but also moments of special interest. This presentation is centred around some themes presented in the introduction and the students' 'response'. These themes are hypothesis and procedure and measurement. First, an overview of the text.

The pronouns in the instructional part of the text are overwhelmingly 'you'. Mostly, the teacher refers to herself as 'I', and the pronoun 'we' in the meaning 'you' is used five times. There are also a few real 'we'. This gives an impression of giving responsibility to the students. There is not the blurring of power you get if the teacher used ‘we’ meaning ‘I’. However, in this distinction between teacher and students (I/you), a greater distance and perhaps less solidarity will be expressed.

In the first part when Ellen was introducing the inquiry, there are many (30) references to do-processes (‘you do’). There are also some references to verbal and mental processes (respectively seven and six). The mental processes are most often linked to students (‘you think through’). Whereas, verbal processes just as often are linked to the teacher as to students. There are a few relational processes, and these are primarily connected to attributes of sanitary towels. After the students have carried out their inquiry and Ellen was instructing how to write the report, there are mostly verbal processes (write, explain, etc.), but also references to mental processes such as evaluate and think. There are also some material and relational processes.

In Ellen’s introduction, there were mainly two speech functions directing students’ activity, these were demands and hypothetical statements. An example of a demand is “*Write down (the procedure) and then we shall discuss it*.” The hypothetical statements are question-like (semi-questions) and give alternatives for how one might carry out the inquiry. Some of these hypothetical statements could have been labelled as questions, but that does not make any significant difference as both hypothetical statements and (open) questions have a form where there are no fixed responses and they thus allow for several possibilities. One explicit choice was also given “*If you want to have an exact measurement*”. There was one long response question and no short response questions. When Ellen spoke about sanitary towels and their attributes, the speech function was certain factual statements. There were also some factual statements (certain/uncertain) connected to other equipment. When Ellen was instructing on how to write the report, there were demands and four questions. The first of the questions was a long response question that is answered by a student, the other questions were not ‘real’ questions, but they can be seen as a support for the students’ evaluation of their measurement (how accurate).

Ellen introduced two entities: weight and measure. These seemed to be self-evident as there was no elaboration of these entities. There was, though, reference to how to find out weight and measure. Other entities were sanitary towel (mostly referred to as it), in addition to science equipment such as beaker, burette, clamps, etc.

The most prevalent type of text cohesion was elaboration and a few causal or conditional cohesions. There is no footage of the introduction, so it is not possible to comment on other modes than speech. When Ellen presented the report she also used the mode of writing (on the board).

Fiona and Ingrid had many unfinished sentences when they were speaking about what they should do and did. This must however be linked to their use of hands and equipment to create a common meaning. There were no indications that they did not ‘understand’ what the other intended to say, e.g., through the use of questions.

Their prevalent transitivity processes are ‘do’ and ‘happen’. There was something to be done and at times, something happened. There were also some relational and existential transitivity processes, but no use of mental or verbal processes. Their use of entities in speech is a bit ‘muddled’, but then, this must be linked to their use of equipment to support their statements. They used measuring units for volume and other ‘science words’ such as, e.g., absorb. There were few reasons given (e.g., through the use of because) in their speech.

* * *

Ellen started her introduction by drawing on the experience from the cloth-inquiry by referring to the results table on the board:

| | | |
|---|---|---|
| 05:00 | Ellen: Og nå har vi gjort et eksperiment der vi hadde en del ting som var vanskelig undervegs. Hva var det som var vanskelig undervegs i dette forsøket hvis dere kan kommentere litt på det?<br>Steven: Få det så likt som mulig<br>Ellen: Å få det så likt som mulig, ja. Her ser vi egentlig at tallene spriker veldig mye. Men nå må dere ta med dere litt av det dere så her, ikke sant? | Ellen: And now we have done an experiment where we had some things that were difficult. What was difficult during this practical work – if you can comment a bit on that?<br>Steven: Get it as alike as possible<br>Ellen: To get it as alike as possible, yes. Here we actually see that the numbers spread out considerably.<br>But now you must take with you some of what you saw here, right? |

There is one answer to Ellen’s question, and Ellen did not call for more answers. Several other explanations concerning ‘difficulties’ in the cloth investigation would, of course, be possible. Ellen elaborated on Stevens’ answer by using a factual statement that perhaps was given increased certainty by the word ‘actually’. The problems with the previous investigation were attributed to ’faulty’ procedure, as the students’ interpretation of the procedure was (slightly) different. Ellen elaborated on this further with concrete examples from the measurement cloths that were in different ‘states of wet’. There were no references by Ellen or the students to other possible problems, such as, e.g., uncertainty in measurement that also would contribute to ‘spread out numbers’. Ellen’s last statement in this excerpt encourages students to draw on these experiences in the sanitary towel inquiry. What were relevant or important experiences to bring into the inquiry? This was not elaborated.

*Hypothesis and driving question for the inquiry*

Before the students started their inquiry, Ellen gave the task:

| | | |
|---|---|---|
| 06:13 | Vi skal nå gjøre et forsøk med sånne greier som det her. De tar opp vann. Det er samme | We shall now do practical work with these things. They gather water. It is the same material here as in diapers. So, |

| | | |
|---|---|---|
| | materiale her som i bleier. Så spørsmålet er *hvordan* dere vil gjennomføre et slikt forsøk. Spørsmålet er hvor mye vann klarer en å fange opp i en sånn. | the question is *how* will you carry out such a practical work. The question is how much water can one trap in such a one. |

'These things' in the first statement refer to sanitary towels. Ellen was probably holding some samples in her hand (no footage). She elaborated on some attributes of 'these things' before she proceeded to "*So, the question is how will you carry out such a practical work*." Together, this gives a fairly open task, but then she narrows the task down in the next statement. The last statement can be seen as (one version of) the driving question for the inquiry.

The two 'questions' in the end of the excerpt were actually hypothetical statements with (possible) function to stimulate students' deliberation. The first 'question' related to *how* to do it and the second 'question' *what* to do. The certain statement 'they gather water' and the next, where the sanitary towel was given an attribute the same material as diapers, are 'relevant' and 'correct', but interestingly, there was no reference to sanitary towels' function to absorb blood. This might be seen as a more polite or not quite so messy or less embarrassing way of speaking about sanitary towels. Anyway, for this investigation, the question was to find out how much water it was possible to get into the sanitary towel. Ellen had brought with her three different types for students to test. A minute later Ellen elaborated:

| | | |
|---|---|---|
| 07:24 | Vi skal nå starte med. Min hypotese er at de holder på vannet. Det er min hypotese. | We shall now start with. My hypothesis is that they hold on to the water. That is my hypothesis. |

This supposition or 'hypothesis' might be seen as somewhat superfluous as she had stated this as a certain fact previously. However, Ellen returned to the hypothesis after comparing the material in sanitary towels with the material used in the cloths in the previous investigation:

| | | |
|---|---|---|
| 08.15 | Jeg har tre forskjellige og så kan dere finne ut av hvor mye vann det går an å ta opp i disse forskjellige. Det er ikke sikkert at det er noe forskjell overhodet. Det kan godt hende at de er helt like. | I have got three different and so you can find out how much water is it possible to gather in these different. It is not certain that there will be any difference at all. It is quite possible that they are identical. |

As the students were not meant to make their own hypothesis, these different versions of question for investigation and hypothesis could act as a backdrop for students' planning of their consumer test. It is possible to interpret this as two different research questions or hypothesis. The first is how much water does each of the sanitary towels absorb, and then compare the results. The second interpretation is connected to the word 'identical'. If the sanitary towels are identical, this might include more than just if they absorb the same amount of water?

Ingrid and Fiona did not make a 'refined' version or their own version of the hypothesis that suited the test they were going to do. From what I interpret from their semiotic action, they had no specific hypothesis, but were guided by the 'research question': how much water can you put into each of these? This research question was, however, not made explicit.

At the end of the day, the hypothesis was dealt with in full class when Ellen asked:

| | | |
|---|---|---|
| 1:07:40 | Hva slags hypotese tror dere man kan ha når det gjelder slike bind som dette her?<br>Steven: Det er kanskje det at de dyrest, de har spesialisert seg – de er best<br>Ellen: Dyrest er best. Da Steven, dyrest er best, hva er det som er best i denne saken – det er jo litt interessant da – for vi har bare konsentrert oss om ..<br>Steven: Mengden den holder<br>Ellen: Holder på mest væske. Jeg tror vi må skrive vann for det er vann vi har holdt på med | What kind of hypothesis do you think one might have when it comes to such sanitary towels as this?<br>Steven: It is perhaps that the most expensive is best, they have specialized themselves – they are best<br>Ellen: Most expensive is best. Then Steven, most expensive is best, what is best in this case – that is a bit interesting – because we have only concentrated on<br>Steven: The amount it holds<br>Ellen: Hold on to most liquid. I think we have to write water as it is water we have used. |

Ellen asked a question to the class that was answered by Steven. Steven was one of the two students who contributed much this day. He suggested a hypothesis and further gave a reason '(the company) has specialized themselves.' To Steven, this seemed to be associated with the cost for product improvement and not, e.g., marketing. Ellen followed up Steven's response by elaborating and problematizing what 'best' would mean in this investigation. In this follow up, she led Steven to his next contribution, by giving the cue 'we have only concentrated on', a sentence which Steven finished. This response Ellen further elaborated on from Steven's word 'amount', via liquid and ending with water. Interestingly, Ellen's initial question could be interpreted as wider than the actual investigation that had taken place. There is a range of different hypotheses that could have been made in a sanitary towel inquiry. In this context, with the guiding questions given at the start, there was a delimiting choice of possible hypotheses.

*Procedure and methods for measurement*

In this investigation, the students were to make their own procedure to find out how much water a sanitary towel could absorb. First, I give three excerpts for how Ellen presented this to the students. Second, I will interpret how students made their procedure. Methods for measurement and procedure are interrelated, but to structure this I have chosen to present procedure first and then the students' measurement.

Ellen gave the task:

| | | |
|---|---|---|
| 08:30 | Det første dere skal gjøre er å lage en prosedyre for hvordan dette eksperimentet skal gjennomføres. Og så må dere være veldig nøye på – dere får ikke lov til å gå i gang før dere har tenkt gjennom prosedyren. Dere kan godt få lov til å ta en eller to slike og prøve dere littegrann frem for hvordan man gjør det. | The first you shall do is to make a procedure for how this experiment shall be carried out. And then you have to be very careful - you are not allowed to start before you have thought through the procedure. You may well be allowed to take one or two of these and try out a bit for how one does it. |

Towards the end of the introduction, Ellen reminded:

| | | |
|---|---|---|
| 09:55 | Da starter dere først med å lage en *gjennomtenkt* prosedyre. Altså punktvis, en, to, tre, fire fem | Then you first start with making a thought through procedure. That is stepwise, one, two, three, four, five |

After students had started their investigation, Ellen uses her board voice to call for attention and she said:

| | | |
|---|---|---|
| 13:00 | Ta og skriv ned og så skal vi diskutere dette her. Prøv dere littegrann frem først før dere bestemmer dere | Take notes and then we shall discuss this. You try a bit first before you decide. |

All these excerpts are strong demands for making a procedure, e.g., "*you are not allowed to start before*..". The responsible persons are *you* (plural). There is no 'we' in Ellen's demand for procedure. To me, it seems that Ellen wanted students to 'think through'. This might indicate that she wanted students to give reasons or make some evaluation of what they intended to do. It is not supposed to be a 'headless' activity. Ellen highlights the stepwise character of procedure by giving an ordered sequence of numbers. As an elaboration or perhaps as a contrast of these demands, there are two weak demands in the first and third excerpt above by 'try out a bit first'. These weak demands allowed for investigating and possibly finding the 'best' procedure. There was never any entire class discussion where, e.g., different procedures could be questioned or students could borrow ideas from each other. However, Ingrid and Fiona got a question from the neighbouring group concerning their procedure. I will return to this question.

*Students deciding their procedure*

There is a time gap of approximately one and a half minutes between when Ellen had finished her introduction at the board and the audio recorder was turned on at Fiona and Ingrid's desk (the video recording starts three minutes later). In this period, the girls had gathered some equipment and had started suspending the sanitary towel in a stand. Ingrid then gave a proposition for how to do the inquiry:

| | | |
|---|---|---|
| 11:20 | Ingrid: Vent litt, hvis vi holder den slik så heller vi på en måte vann oppå og når det begynner å renne så stopper vi | Ingrid: Wait a moment, if we hold it like this and then pour in a way water on top and when it starts to drip then we stop |

Fiona agreed on this 'plan'. However, half a minute later she brings forth another 'plan':

| | | |
|---|---|---|
| 12:00 | Fiona: Vi kan kanskje ta den andre putte oppi, så ta bort, ta opp og så se hvor mye den har tatt opp | Fiona: We might perhaps take the other put into, then take away, take up and then see how much it has taken up |

Ingrid agreed on this.

These two excerpts show the two different plans the students made. In the rest of the recording, they carried out these plans. By the use of the word 'then', their two procedures are given a stepwise character, but the steps were not elaborated on. They quickly agreed with each other's propositions, without any challenge.  A challenge would perhaps have resulted in arguments for why this was a good procedure. This is perhaps not the 'thought through' procedure Ellen demanded. Moreover, what do these procedures mean? When reading what the students said, it does not seem to be self-evident what they mean.

They started pouring water on the sanitary towel, i.e., following Ingrid's plan. The sanitary towel was suspended in a stand with some clamps so it was approximately horizontal.  Ingrid asked Fiona:

| | | |
|---|---|---|
| 12:27 | Ingrid: Skal vi putte det oppi eller skal vi helle? For hvis vi heller så begynner det å dryppe så mye | Ingrid: Shall we put it into or shall we pour? Because if we pour then it starts to drip so much. |

'Put it into' refers to their second method, i.e., Fiona's plan. Ingrid expressed here that she was aware of some of the problems with the pouring-approach. However, five minutes later Ingrid was pouring water on the sanitary towel using a large beaker with measuring lines every 50 ml. So was the problem 'dripping' related to accuracy in measurement or was it related to cleaning up spill-water from the desk? None made any references to accuracy so it is impossible to make a decisive interpretation.

The next approach they had was Fiona's plan to 'put it into'. They simply put the sanitary towel into the beaker that contained (approximately) 200 ml water. Then Fiona counted to 30 (i.e., approximately 30 seconds). Then Ingrid, who had been holding the sanitary towel so that it was well immersed in water, took it up and let it drip.  When it had dripped for a while (they counted?), they read the water level in the beaker. The beaker had measuring lines indicating every 50 ml. They used this method to measure how much water all three types of sanitary towels absorbed. After putting the second sanitary towel into a beaker, Ingrid said:

| | | |
|---|---|---|
| 27:30 | Nå har den blitt så, den har klumpet seg sammen. Jeg tror det er bedre å ha den fastspent. | Now it has turned so, it has become all lumped. I think it is better to have it suspended. |

Ingrid seemed to regard 'lumped' as a problem. This might indicate that she perceived that 'lumped' effected the ability to absorb water. None of them mentioned inaccuracy of measurement as a problem with this method. But what had Ellen said in the introduction about accuracy?

| | | |
|---|---|---|
| 08:51 | Ellen: Dere må tenke littegranne hva skal dere veie, hva skal dere bare måle, for eksempel måle med. Hvor mye vann som går i en sånn en. Hvis dere ønsker det - å ha et nøyaktig mål, så skal jeg finne noe vi kan måle nøyaktig volum med – ok? | Ellen: You have to think a bit what you are to weigh, what you are to measure, for instance measure with. How much water goes into such a one. If you want it – to have an accurate measurement, then I shall find something we can (use to) measure volume accurate with – okay? |

Through these statements, it is reasonable to interpret Ellen as she giving the students responsibility (through the use of the pronoun 'you') to define the level of accuracy. If they wanted high accuracy, Ellen could equip them with appropriate measuring instruments. These semi-questions or hypothetical statements might be seen as support for students thinking and planning the procedure in relation to variables, accuracy and possibly also uncertainty in measurement. It is reasonable to interpret this, as Ellen gave students choice for how to do and how accurate they wanted to be.

Fiona and Ingrid had perhaps chosen not to be very accurate. Perhaps they did not see the point in very 'accurate numbers'. Perhaps they regarded their approach sufficiently accurate for their need. However, they did not make their chosen level of accuracy explicit.

Fiona called for Ellen so that she could tell about their procedure – Ingrid did express that this was not very important. When Ellen arrived at their desk, she started by asking:

| | | |
|---|---|---|
| 17:10 | Ellen: Skal dere veie eller måle?<br>Fiona: Vi skal<br>Ingrid (overtar): Vi skal måle bare<br>Ellen: Ja, spørsmålet er hvor nøyaktig mål dere skal ha. Da vil jeg gjerne at du bruker en sånn en for å ha nøyaktig (mål) (henviser | Ellen: shall you weigh or measure?<br>Fiona: We shall<br>Ingrid (takes over): We shall just measure<br>Ellen: Yes, the question is how accurate measure you shall have. Then I want you to use such a one to get accurate |

| | | |
|---|---|---|
| | til byrette)<br>:<br>Ellen: Hva mer er det dere har tenkt?<br>Fiona: Jo, vi har tenkt<br>Ingrid (overtar): Vi har 2 til 3 desiliter her og så tenkte vi å helle og når det begynner å dryppe jevnt så stopper vi og ser | (measurement)<br>(referring to burette)<br>:<br>Ellen: What else had you thought?<br>Fiona: Yes, we had thought<br>Ingrid (takes over): We have got 2 to 3 decilitre here and then we thought to pour it and when it starts to drip then we stop and look |

In this excerpt, there is a small break indicated with a semicolon. During this break, Ingrid made a statement regarding a volumetric flask.

Ellen started by asking the question –weigh or measure.  Ellen seemed to differentiate consequently between measuring (of volume) and weight (i.e., measure weight). Ingrid's response is interesting as she said 'just measure', as if measuring volume was perceived as simpler or less 'scientific' than measuring using the weight. It is also possible to interpret her statement as if there is less need for accuracy in measuring volume.

By asking the first question 'weigh or measure', Ellen took the initiative and 'steer' Ingrid and Fiona toward a short response. In this situation, Ellen could have asked the students to tell their procedure. This would have been an approach that would have given the students the possibility for a more open response. Then Ellen renewed the choice of level of accuracy given in the introduction by saying, 'the question is how accurate to measure'. Without waiting for the students' response, Ellen went on to say 'then I want you to use (a burette)'. In this context, this statement can be seen as a demand. A teacher who wants the students to do something has (usually) reasons for it. With a burette, it is possible to be more accurate than it is with a beaker or a volumetric flask. While Ellen was talking, Ingrid filled a small volumetric flask with water. So the next question from Ellen, 'What else…' was perhaps a response to Ingrid's action. Once more Ingrid took over Fiona's answer and she told the plan for pouring water on the sanitary towel. Ellen did not respond to Ingrid's statement, walked away and came back almost instantly with a burette. This can be seen as a renewal of Ellen's demand for a higher level of accuracy without making this explicit. It might also be seen as if Ellen did not approve of the students' plan, as she didn't follow up Ingrid's response.

Ellen then started to instruct Fiona (and Ingrid) in how to use it. Ingrid was at the same time occupied with lowering the sanitary towel suspended in the stand. After the introduction on the burette, Ellen walked away and the students tried to use the burette. From the footage, it seems that they had problems adjusting the tap. As a result (?) of these problems Fiona and Ingrid went back to their own initial plans.

One of the students in the neighbouring group asked a question when Fiona and Ingrid used the method of putting the sanitary towel into the beaker:

| | | |
|---|---|---|
| 28:00 | Frederick: Hvorfor gjør dere det slik egentlig?<br>Fiona: Jo, fordi det gikk ikke like bra så vi skal prøve en annen metode | Frederick: Why are you actually doing it that way?<br>Fiona: Well, because it did not work very well so we shall try another method |

Fiona's answer referred to their first approach, pouring water on to the sanitary towel (using a volumetric flask), which Ingrid and Fiona had evaluated as not working very well, with the reason that the water dripped off too easily. Therefore, Ingrid and Fiona started to use Fiona's plan of putting the sanitary towel into a beaker. Fiona called for Ellen to tell her about this other procedure, i.e., putting the sanitary towel in the beaker and waiting until they have counted to 30 and then let it drip:

| | | | |
|---|---|---|---|
| 28:40 | Ingrid writes on pc<br>Ellen comes<br>Fiona shows a hand movement into the beaker<br>Ellen leaves | Fiona: Ellen<br>Ellen: Ja<br>Fiona: Vi tenkte på en annen måte og ta det i et halvt minutt der og så ett minutt og så<br>Ellen: Okey, ja. Prøv dere litt frem før dere bestemmer dere<br>Fiona: Jammen det her funka | Fiona: Ellen<br>Ellen: Yes<br>Fiona: We thought in another way and take it for half a minute there and then one minute and then<br>Ellen: Okay, yes. Try out a bit before you decide<br>Fiona: But this worked |

Fiona was eager to tell Ellen about their methods, and it was always she who took the initiative to call for Ellen, i.e., Ingrid did not call for Ellen during this inquiry. Ellen walked to another group just as Fiona had said her last statement.

Was Fiona's recount of the procedure 'understandable'? She showed by using her hand that 'take it there' meant into the beaker, but Ellen did not ask any questions about this procedure. There was no question to 'what then' – or how to get 'good enough' results. In other words, Ellen did not ask for clarification or challenge the students' chosen method for measuring. Ellen's statement 'try out a bit' might be seen as giving several interpretations. First, it is perhaps in opposition to Ellen's strong demands in the introduction where she called for a thought through procedure, although she allowed for 'try first'. However, at this point, the students had worked with their inquiry for almost 20 minutes. Moreover, I interpret the students' semiotic actions as they themselves thought this as a proper investigation – and not just 'trying'. This leads to the second possible interpretation of the statement. Did Ellen not regard this as a proper investigation? As none of the parties argued for their view, this is hard to claim. Two minutes later, after the students had finished the putting-into-water procedure with the last of the three sanitary towels, they started to use the burette that Ellen had brought some time before. This was their third method of measuring volume.

Ellen had brought the burette (see excerpt 17:10) and she had proceeded directly to instruct in the use of the burette while she and Fiona together were fastening the burette to a stand:

| | | | |
|---|---|---|---|
| 18:10 | Ellen points at burette<br>and then on the ST suspended in the stand<br>Fiona helps to fasten the burette in clamp<br>Ingrid lowering the ST<br><br><br>Ellen turns the tap<br><br>Ellen holds round the burette (zero point)<br>Ingrid almost finished lowering the ST<br><br>Ellen leaves | Ellen: Hvis du nå tar vann opp til – dere må senke dette her littegrann – vann opp til 50 der. Ser dere det?<br>: (Fiona og Ellen snakker om å feste klemme)<br><br>Ellen: Det går vann opp til 50 der og slipper ned ikke sant, her har du en kran<br>Fiona: og så<br>Ellen: Hvis du slipper ned til null der og hvis du bare heller på igjen, så kan du<br>Prøv dere litt frem for hvordan dette fungerer, ok? | Ellen: If you take water up to – you have to lower this a bit – water up to 50 here. Do you see?<br>: (Fiona and Ellen talks about fasten clamp)<br><br><br>Ellen: Water up to 50 here and then let down – right, here is a tap<br><br>Fiona: And so<br>Ellen: If you let down to zero there and if you just pour more into, then you can<br>You try a bit (to find out) how this works, okay? |

(ST = sanitary towel)

Ellen was instructing how to read the burette and use the tap to let out water. In the first statement in this excerpt, there is an embedded statement referring to the sanitary towel suspended in the clamps, it was too high. This embedded statement lead Ingrid to start lowering the clamps, i.e., she did not have her full attention on Ellen's instruction.

The students filled water into the burette, read off the water level and opened the tap. Water dripped off the sanitary towel, as the tap was turned to completely open. Ingrid uses much time to turn the tap to adjust the amount of water coming through. Then they encounter a problem the next time they are about to read the water level:

| | | | |
|---|---|---|---|
| 20:50 | Fiona points at water level in burette<br>Fiona adjust the burette in the clamp<br>Ingrid touches the ST | Ingrid: Nei, vent da. Hvor mye er det opp til dit da?<br>Fiona: Jeg tror det blir – det blir feil veg!<br>Ingrid: Ja hva er det for noe<br>Fiona: Ellen! | Ingrid: No, wait a moment. How much is it up to there?<br>Fiona: I think it is – it is the wrong way!<br>Ingrid: Yes, what is this<br><br>Fiona: Ellen! |

| | | | |
|---|---|---|---|
| | Fiona points at beaker, ST and burette | Ingrid: Det kan være måle<br>Fiona: Men vi vet ikke hvor mye som er her, her og der | Ingrid: It might be measure<br>Fiona: But we don't know how much that is here, here and there |

The problem was that the burette's water level lines were reversed compared to Fiona and Ingrid's idea about how they should be. When the burette is 'empty', the water level is 50, whereas when it is full the water level is zero. Ellen came and instructed on how to read water level.

| | | | |
|---|---|---|---|
| 18:10 | Fiona points at burette<br><br><br><br>Fiona points at 50<br><br><br><br><br>Ingrid uses her hand to indicate distance on the burette from bottom to 50 i.e. | Ellen: Hvor langt har dere tatt på vann?<br>Ingrid: Vi hadde opp til 19 der<br>Ellen: Ok, se ned der, 50, da har du 50 minus 19<br>Ingrid: Det er 31<br>Ellen: Ja, trettien<br>Fiona: Da fikk vi trettien<br>Ingrid: Den er der<br>Ellen: Dere har tatt lengre ned, ja, dere har tatt for langt.<br>Ingrid: Tatt for langt, vi kan stoppe her?<br>Ellen: Stoppe på 50<br>Ingrid: Skal jeg stoppe den på 50<br>Ellen: Ja, nå driver dere bare å prøver dere frem –ok? Dere bare prøver utstyret littegrann. For vi er nå i den fasen da dere ennå ikke har helt bestemt dere for hvordan dere skal gjøre det | Ellen: How much water have you put into it?<br>Ingrid: We had up to 19 there<br>Ellen: Okay, look down there, 50, then you have 50 minus 19<br>Ingrid: That's 31<br>Ellen: Yes 31<br>Fiona: Then we got 31<br><br>Ingrid: It is there<br>Ellen: You have emptied it to much, yes, you have taken it to far<br>Ingrid: Taken to far, we can stop here?<br>Ellen: Stop at 50<br>Ingrid: Shall I stop it at 50?<br>Ellen: Yes, now you are just trying –okay? You just try the equipment a bit. Because we are now in that phase when you have not yet decided how you are to do this |

The students used their hand to 'measure' the distance and thus how much water the burette contained. Ellen used the mode of speech to tell the difference by subtracting the two numbers. Without elaborating on this any further, Ellen noticed that the water level in the burette was below 50, i.e., it was emptied too much. This leads her to instructing Ingrid by saying 'stop at 50'. In other words, Ellen gave a strong demand on how to use the burette. Perhaps the last few statements related to 'try the equipment' and the elaboration of this might be seen as Ellen's attempt to say that it was okay that the students did not manage this at first. The statement "*we are now in that phase when you have not yet decided how you are to do this*" has several interesting aspects. Who are 'we' – it probably has to be the students because Ellen did not do the experiment. The students had tried for approximately eight minutes and Ellen did not renew her strong statements of a thought through procedure. These, taken together, I interpret as a way of making the (current) inquiry non-committal. Ellen proceeded directly to give a summary of how to use the burette, i.e., by filling water up to zero and stopping at 50 and filling more water. Then Fiona said:

| | | |
|---|---|---|
| 22:40 | Fiona: Jeg skjønner ikke helt<br>Ellen: Nå har dere 31, ikke sant?<br>Ingrid: Ja<br>Ellen Ønsker dere mer oppi der?<br>Ingrid: Nei, den er full og har begynt å dryppe<br>Fiona: Vi tenkte å se når den begynte å dryppe og så stoppe<br>Ingrid: Det er det som er greia<br>Ellen: mmm | Fiona: I don't understand completely<br>Ellen: Now you got 31, right?<br>Ingrid: Yes<br>Ellen: Do you want more into it?<br>Ingrid: No it is full and has started to drip<br>Fiona: We thought to look for when it started to drip and then stop.<br>Ingrid: That's the thing<br>Ellen: mmm |

My interpretation is that Fiona stated that she did not have a total grasp on how the burette was to be used as her statement was following directly from Ellen's summary of how to use the burette. When Ellen answered '31', she had an 'impatient' voice, then Ellen came with a counter-question 'if they wanted more water in the burette'. This question leads in another direction than (my interpretation of) Fiona's statement. Fiona once more raised the issue of their plan, i.e., to see when the sanitary towel started to drip and then stop pouring water onto it. Ellen chose not to comment on this other than the non-committal 'mmm'.

Directly after this, Fiona suggested trying out the other plan, i.e., the one where they put the sanitary towel into the beaker. They carried out this plan for all three types of sanitary towels (see above).

In the end, they did use the burette for all three types of sanitary towels. I speculate if this was because of Ellen's 'pressure' by first giving the burette, then instructing them on how to use it and that she chose not to go into and discuss the other procedures. The students might get the impression that there was, after all, one way of doing this – the teacher's way.

Interestingly, Ingrid and Fiona got very different results for how much water the sanitary towels absorbed. For one of the types there was an approximate difference of 100 ml between the method using soaking it in water and using the burette. They did never mention these very different results, but towards the end they were in a bit of rush to finish as all of the other students waited for them to finish. There was, in other words, no time after the 'doing' to reflect on the results. The rush to finish might also have led to a more 'sloppy' way of measuring the volume absorbed in the last sanitary towel by the use of the burette. The sanitary towel that absorbed the most water (ca. 150 ml) had a long 'flow time', i.e., the tap was adjusted to just a small opening. The opening of the tap was different for the other two sanitary towels, which might be seen as conflicting with the requirement Ellen gave in the introduction 'do it as same as possible'. These different flow times and how they might affect the results were not mentioned.

Ingrid wrote the results on her computer. Fiona had seated herself on the other side of the table, which meant she could not see the results written down. This might of course have had an impact on her possibility to pose questions on the results and to discuss them. Ingrid did not raise the issue of differing results. Ellen did not ask them if they had different results concerning the different measuring methods.

Seen in hindsight, I see some measuring problems that were only dealt with briefly by the students. There was a problem of pouring water into the burette. Ingrid commented the last time she stood on the chair to fill the burette that they ought to have had a funnel. Pouring water directly into the burette by using the large beaker meant that some water spilled on the sanitary towel. In addition, both their approaches that involved pouring water onto the sanitary towel led to spillage. The sanitary towel could not absorb fast enough. This could of course be seen as an interesting result for discussing quality. They stated which one was the 'best' with no reference to how much better and in what respect. Had 'better' anything to do with how they conducted the experiments? Ellen did not push this….

| | | |
|---|---|---|
| 33:20 | Ingrid: Den billige trekker opp mer<br>Ellen: Den billige trekker opp mer, ja | Ingrid: The cheap one suck up more<br>Ellen: The cheap one suck up more, yes |

This was not further elaborated.

In the end of the day, Ellen addressed uncertainties in measurement as part of the summing up:

| | | |
|---|---|---|
| 1:10:33 | Altså, Jeg vil nå at dere skal vurdere dette her. Det kan være at dere syns det er absolutt nødvendig – okey – dere skal vurdere dette. Og hvor usikre er de målingene dere har gjort. For når jeg ser dere holder på så driver dere ikke på i det vi kaller for analytisk skala.<br>(elaborer analytisk skala)<br>Så tenk litt her på hvor nøyaktig *behøver* man å være – hvor nøyaktig *har* dere vært. | So, I want you to evaluate this. It might be that you think this is absolutely necessary – okay – you are to evaluate this. And how uncertain are those measurements you have done. Because when I look at what you are do then you are not doing in what we call analytical scale<br>(elaborates what analytical scale means)<br>So think a bit here on how accurate do one *need* to be – how accurate *have* you been |

The words written in italic were in a stressed voice and thus emphasized in Ellen's speech. As this was given after the students had finished carrying out their plans, this would not guide them in their action. However, could these statements act as a support for the students' work with the report? Since Ingrid and Fiona did not hand in the report and had not explicitly talked about accuracy during their inquiry, the 'consequences' of these statements are impossible to 'predict'. In addition, Ellen had 'decided' how accurate Fiona and Ingrid needed to be by giving the burette and directing the students' attention toward it. It can be seen as Ellen took away the choice given to the students through her semiotic actions during the carrying out phase. However, in this excerpt, the choice of accuracy level seems to be renewed.

#### 8.4.2.2. Text – context and instructional norms

The norms are inferred from the teacher's semiotic actions and how these semiotic actions provide possibilities for students' semiotic work. What the teacher says and does, gives an interpretive space for students, and they act according to their interests. However, the norms can also be inferred from interpretation of what is done but not explicitly said, i.e., what can be regarded as the 'tacit' practice or norms that have become such a part of established practice that there is no need to speak of it.

The norms inferred here have a provisional status, as they are inferred from just one case, i.e., rather slim data material is supporting the norm. The norms are formulated as statements close to practice. In chapter 9, I will formulate cross-case norms.

*Procedure and carrying out inquiry*

The speech functions Ellen uses in the introduction (hypothetical statements and choice) provide expectations that students are to make their own (well-reasoned) procedure. This is reinforced by Ellen's use of strong demands for a thought through procedure, where the students are responsible for the thinking by the use of 'you' at the expense of 'we'. However, what is important to think about when making the procedure or inquiry plan is not made very clear. In the interaction between Ellen and the students Ingrid and Fiona, Fiona tries to give an account for their procedures, but Ellen does not seem very eager to hear about their plans. Ellen asks few questions regarding their plans and none of these questions are of a character that challenges the aspects of the plan. This might be seen as Ellen regarding the plans to be good enough or might be interpreted as 'indifference'. However, as Ellen gives Ingrid and Fiona equipment to measure (the burette), it becomes clear that their plan is not 'good enough'. By giving the students the burette and stating that she wants them to use it to get an accurate measurements, she removes the choice given in the introduction. There is thus a strong implicit directing of the students' procedure. The students, on the other hand, did not ask Ellen why it was better to use the burette as the instrument for measuring nor did they challenge Ellen to tell what was 'wrong' with their initial plans.

Norm: Responsibility for making the procedure is removed from the students.

One would perhaps think that in an inquiry where the task is to inquire and the topic of inquiry is immaterial, that the procedures would be more focused. It was not so in this case, as the different procedures were not discussed. What were the strengths and weaknesses of each of the procedures? Why did the different procedures lead to such different results? In the two other inquiries, there was a brief 'discussion' of procedure, but weaknesses and strength was not explored much. However, in the two first inquiries, this lead to an 'improved research design'. The inquiry was carried out one more time. (This was not usual practice in this class.) As these 'discussions' are brief and without precise terms that might help students to verbalize, the procedural deliberations become shallow. This can perhaps be described as the apprentice way of performing inquiry, where you learn by imitation and action-based reflection.

In the students' semiotic actions, it became clear that they had not made a design to eliminate errors, e.g., by spilling water on the sanitary towel when they filled the burette. In the two first methods for investigation, the students had a low degree of accuracy in their measurement, or high degree of uncertainty (e.g., read the water level in the beaker). Perhaps this was 'good enough'. A part of the design is to judge what is good enough. This judgement is situated and connected to the purpose of the investigation. However, when students do not have the labels to put on these assessments, they become even more muddled than they have to be.

Norm: There is little need to assess procedures and methods explicitly.

The students started 'doing' almost immediately after Ellen had finished her introduction. They made two very rough 'procedures' in the start. Ellen refrained in practice from her initial requirement that there should be a written procedure first, by referring several times to students' 'trying out' and not asking for a description of the full procedure. Ellen thus relates to procedure differently in direct contact with these students than she did in the introduction. Guiding students in their work is perhaps difficult for a teacher, as it means that the teacher has to relate to different viewpoints and the students' different ways of expressing these. Here, Ellen had no structured approach on how to deal with the students' plans. Moreover, when the students talk about their inquiry, they use overwhelmingly material action transitivity processes. They do not talk about what these results might mean.

In the introduction of the day, Ellen emphasized the importance of hypothesis or a purpose as 'opposite' to just finding 'something out'. In the first and second inquiry, there were clear hypotheses or predictions to guide the inquiry. However, in the last inquiry, Ellen provided a 'problem-field' rather than a clear hypothesis, so in reality the hypothesis was dealt with after the investigation.

Norm: Inquiry is mainly 'doing' guided by a roughly outlined plan.

*Scientific knowledge*
The inquiries are related to 'theory', as there are small summaries related to the material in cloth and sanitary towels, as well as different taste. This was mainly the teacher's realm, although some (other) students did find additional information on taste. As the content of the inquiries were immaterial (i.e., not competence aims), the subject matter of the day was scientific procedures. It seems that the result of the investigation ('which is the best') was more important (or just as important) as the procedure for finding out. The purpose became to find the best sanitary towel and not the best possible procedure. In other words, non-subject matter took precedence over subject matter.

Norm: Inquiry needs no firm linking to school scientific knowledge.

*Language of science and communicating science*
When Ellen introduced the procedure for the first and second inquiry, she did this in an intermingled fashion. The words were all 'easy' or 'everyday' but the intermingled fashion where different ideas were developed in parallel were perhaps difficult for students to interpret. The students had to interpret how things were connected and what the procedure was. Easy words do not necessarily make it easy to understand how to go about doing the task. In the introduction to the last inquiry, there was a more structured approach, although with some digressions and the spoken language concerning procedure was 'open' or more question-like. In the introductions this day, words such as 'variables' and 'uncertainty' were never used. It was 'problems with the investigation' and not measuring errors. There were thus few precise terms dealing with procedure. Some of these terms were however dealt with when Ellen presented what the report should contain at the end of the day.

Norm: Everyday language is sufficient to deal with scientific procedures.

In Ellen's introductions, she posed many questions in a row and there is no or little time to think about possible answers. Students are contributing in this dialogue when the two first procedures were made, or rather two of the students are contributing. An opportunity was not given for students to try out ideas on their peers before they talk in plenum. Even if there were just eight students present this day, support for transduction/transformation of ideas might be of importance for some of the students. As there were many questions in a row the students' answers become 'randomized'. Other students have to interpret the teacher's questions as well as interpret which of these questions the student answered and of course the interpretation of the student's answer. By not giving time to think through, the teacher uses a powerful time summon. This might be understood as reluctance from the teacher to involve students in the construction and assessment of the inquiry plans or as the teacher's lack of confidence in the students' contributions.

Norm: Teacher controls the flow of information.

The above can also be linked to Ellen's avoidance of asking questions regarding Ingrid and Fiona's procedure. Ingrid and Fiona did not challenge Ellen directly in the matter of method for measuring. Perhaps their delay in using the burette might be interpreted as resistance. Ingrid and Fiona also readily agreed with each other on their different plans, which resulted in doing both, rather than find the 'best' common plan. However, these patterns of communication reveal a low degree of challenging each other on subject matter.

Norm: Subject matter challenge is to be avoided.

## 8.5.Rhetorical framing of Budding researcher

This section draws on all of the previous sections in this chapter and integrates the regulative and the instructional together with the other factors that have impact on the rhetorical framing (physical space, time, resources and competence aims) and how these factors are put into play.

The section is structured by first recapturing prominent findings and an overview of norms, before turning to the elements of the rhetorical frame; physical space and time, resources, curriculum and norms – and how these play together or against each other.

*Prominent findings*

There are two prominent findings in this case. The first is that there is a divergence between the teacher's introduction and her semiotic action when directly guiding the students' work. The introduction had hypothetical statements and gave an explicit and important choice to the students (on level of accuracy). In guiding, the teacher 'steers' students toward a particular method for measuring and thus removes the given choice.

The other prominent finding is that students emphasize 'do', both in action and speech (transitivity processes). There is little 'thinking through' on inquiry plan and methods – or results for that matter. The teacher does not object to this, but perhaps she even strengthens the focus on 'do'.

*Overview of norms*

The norms inferred in the regulative part of the text are:

- Behavioural issues are dealt with amiability
- Decisions concerning collaboration are the students' responsibility
- A rough goal is provided by the teacher
- There is no need for purpose

The norms inferred in the instructional part of the text are:

- Responsibility for making the procedure is removed from the students

- There is little need to assess procedures and methods explicitly
- Inquiry is mainly ‘doing’ guided by a roughly outlined plan
- Inquiry needs no firm linking to school scientific knowledge
- Everyday language is sufficient to deal with scientific procedures
- Teacher controls the flow of information
- Subject matter challenge is to be avoided

*Physical space*

There was ample space both in the classroom and in the science lab as there were only eight students present. The combination of few students and ample space made the weighing of cloths easier to carry out, as the students could walk over to the teacher’s desk where the scale was located. The students were not required to sit in a particular part of the room as the equipment (except the scale) could be placed at their desk.

Otherwise, the physical space had little impact on the activities other than that students could walk to gather equipment and so on. During this day, students walked freely when they were doing their inquiries, but to me this walking seemed purposeful. I did not notice any ‘just walking about’. The science lab offered, of course, easy access to equipment and to water.

Ellen used the room by frequently standing amongst the students. She used the board to a little extent so much of her introductions and summaries were conducted as she stood in the middle of the room and thus had physical proximity to the students. Ellen fetched the burette and the weight from the store-room. The choice of proximity to the students might have reinforced a more ‘everyday language’ compared to introductions and summaries at the board. (Ellen did use the board but not in all of the introductions or summaries.) Writing on the board while introducing or summaries might have provided a structure and would highlight what was important, e.g., by writing down important terms and key ideas. Further, writing on the board is a slower process (than just talking) and would thus give students more time to deliberate and form questions.

*Artefacts and other resources:*

The artefacts that were investigated (drinks, cloth and sanitary towel) all belong to the realm of the everyday. These are items with which students are familiar through use or advertisement. It might be that these artefacts together with the ‘consumer test’ type of inquiry reinforced the everyday language that was used by both students and teacher. When the students did inquiry in the science lab, they used scientific instruments for their measurements in addition to the stand and clamps.

One of the artefacts used is of special interest, the burette. Did Ellen choose the burette to measure volume only because of accuracy? The argument for choosing it could just as well be that it made the investigation more ‘realistic’. Ellen regarded perhaps the burette as a more appropriate instrument for measuring volume. I think

Ellen's argument for using the burette was accuracy. In the situation of testing the sanitary towels, she took over the students' choice of level of accuracy. She removed thus some of the responsibility the students had been given concerning the inquiry plan. Students had some problems using the burette. The burette was difficult to fasten properly in the clamp – it wobbled. The tap seemed to be difficult to adjust at the right flow and the students had problems in the beginning to read the amount of water. In other words, Fiona and Ingrid had problems using the burette efficiently. Ellen gave some instructions on its use in an everyday manner of speaking. When Fiona stated that she did not understand how to use the burette, Ellen avoided challenging her on what she regarded as problematic.

There was a table on the board that guided the cloth-inquiry, otherwise students took notes and wrote down results as they saw fit. Ingrid was responsible for note taking in the group. She wrote the notes on her computer. The computer screen was facing away from Fiona, so she could not see the results Ingrid wrote. They did not discuss the results or the need to comment on some of the measured values. The division of work thus made it harder to discuss results, errors and accuracy linked to procedure. This can be linked to the students' responsibility to organize their collaboration. For example, no requirement that results were to be discussed was provided. Therefore, if the students saw that it was time-efficient not to share their results (or not necessary), they did not have to. In addition, Ellen's perhaps loose formulation 'take notes' did not emphasize the need for meticulous record keeping. What are important notes to take during an inquiry? This was part of the organizing of the task that was left to the students.

*Time*

The first two inquiries (taste and cloth) were conducted in a quite slow pace. This meant that there was time to do – and to do once more. This provided a possibility to refine methods and get a firmer grip on the problem and observations. Ellen gave the students' time to work with their report on the first investigation during the day.

The start of the sanitary towel inquiry, where students were to make their own plans, had a quite slow pace. There was not allocated, however, a specific time slot for the construction of plans. Students started 'doing' straight away without more than a rough idea of what to do. As there was no defined time to make the inquiry plan, students neglected the strong demand from teacher. Perhaps they did not know what a plan would entail as the introduction, to little extent, provided 'thinking-tools' such as error, accuracy and variables? To students the appropriate use of time seemed to be 'doing'. Ellen did not object to this as she let the students begin doing the practical part of the work just after she had finished her introduction. Ellen perhaps reinforced the 'doing' aspect by saying several times 'try out' without linking try out to explicitly reasoning about procedure and methods.

In the end of the inquiry, Ingrid and Fiona did not summarize their findings or methods. The teacher had a time summon in the end to give directions for the report, but there were no common summaries of results or procedures. At the end of the day, students Ingrid and Fiona had to rush their 'doing' as the rest of the class waited for them to finish so they could go home (a bit early). This means that time was not allocated for common reflection and assessment of results and methods. This was thus left to the individual student (group). This, together with few verbal resources to support them in making this assessment of plan, results and methods, most likely resulted in shallow reflections. This can be seen as not empowering students to take charge of the entire inquiry process. The students are though in charge of (most of) the 'doing'.

In the communication between teacher and students, Ellen often gave many long response questions in a row. There was little time to interpret the questions and formulate answers. This dialogic form reinforced perhaps the pattern that only two of the students contributed (much) in the dialogue. Perhaps these were questions the other six students had not thought much about and they would thus require more time to be able to formulate answers and questions. At the start of the day, Ellen's introductions were in an unstructured manner. This together with (little) time gave perhaps problems of interpretation and focusing on aspects of the inquiries, such as, e.g., accuracy, variables and note-taking.

*Curriculum*

The competence aims of the budding researcher were not explicitly mentioned this day. The day was just reserved to the budding researcher. By focusing solely on the budding researcher and letting the content of investigation be something not drawn from the curriculum competence aims, the inquiries became perhaps more manageable for the students. There would be less on which to concentrate. However, this should perhaps have given greater emphasis on procedure and methods – and the 'language' to deal with this. Here, the results or outcome of the inquiries were just as important, the deliberations over method were shallow and the language used was 'everyday'. The inquiries were to a very little extent connected to scientific procedural knowledge. There was little challenging of procedures and methods between the students and teacher. Ellen did however provide some input on scientific procedural knowledge after the students had finished their work.

For students, it was important to 'do'. This can also be coupled with the goal to make a plan and carry it out where carry out was given prominence. The purpose was not made explicit. An explicit purpose might have directed the students' attention toward a more 'realistic' inquiry that was linked to 'real science' and its methods.

The low emphasis on scientific procedural knowledge perhaps made the inquiries simpler and easier to deal with. This can be connected to low challenge of subject matter between students and between teacher and students.

*Norms*

This was a day where students had the opportunity to partake in making investigation plans and to make their own plan. The teacher introductions had a form where relevant thinking-questions were posed, but these questions where not 'handed over' to the students. The questions were not followed up with time to think and respond. The teacher was thereby very much in control of the flow of information. This made the introduction perhaps function as less empowering than it could have been. This can be seen as together with the low verbal support for labelling parts of procedure such as reducing errors in measurement and identifying variables. All together it made the investigations 'look' simpler and more manageable, but perhaps more difficult to carry out and definitely much more difficult to assess and reflect on.

In the students' inquiry, it seems as the teacher takes control over the students' procedure, but the students first show resistance to the teacher's intervention by applying the methods they themselves had chosen, but in the end they did it 'the teacher's way'. Why they chose to abandon their own approach is not clear, as there seem to be some tacit elements of student behaviour at this point. Perhaps the need to satisfy the teacher led the students to do the entire inquiry in different ways. Neither students nor teacher deemed it necessary to make the purpose of procedure explicit, to challenge the procedure or evaluate the methods.

Students Ingrid and Fiona had a clear preference for 'do' and they put little weight on deliberating on procedure and methods. Ellen did not challenge their stance by a renewal of her demands for 'thought through procedure'. Emphasis on 'do' combined with everyday language and little connection to scientific (procedural) knowledge leaves an impression of 'easy'. The low challenge concerning use of scientific terms, a thought through procedure and deliberations and assessment of methods and results perhaps makes this inquiry resemble practical work. Ellen guided the students heavily, although implicitly, on methods for measuring and this perhaps strengthened even more the resemblance to smaller practical work, as the usual practical work is to follow the recipe provided by the teacher.

There was an amiable atmosphere in the classroom this day. Students enjoyed themselves with their inquiries. The teacher had no/little unwanted behaviour to regulate. The students divided the work between themselves without a problem. However, if Ingrid and Fiona had shared note-taking, they would perhaps have had a firmer common ground for discussing methods and results. Division into groups was also unproblematic. Perhaps this good mood would be spoiled if Ellen had challenged students more on the subject matter?

* * *

After three cases where the subject matter and seemingly also the procedures have been very different, there seems also to be some recurring patterns. What the similarities and the differences are between the cases will be addressed in the next chapter.

# 9. RHETORICAL FRAMING; CROSS CASE DISCUSSION

The purpose of this chapter is to discuss the similarities and dissimilarities between the cases. The similarities lead to the possibility of inferring overarching norms in the rhetorical framing of practical work and inquiry in this class. I will also discuss the other factors that impact the rhetorical framing in these cases.

In this discussion, the following subordinate research questions will be answered:

- What norms are embedded in the teacher's rhetorical framing of practical work and inquiry?
- How do students adapt to and transform these norms in their practical work and inquiry?

## 9.1. Rhetorical framing of practical work and inquiry

Before turning to a more thorough discussion of rhetorical framing and norms especially, I will provide an overview of the cases to aid the memory. The teacher, Ellen, has long experience from teaching science.

| | **Heat pump** | **DNA** | **Budding researcher** |
|---|---|---|---|
| Students in footage | Beatrice, Ingrid, Peter and Sheila | Beatrice and Ingrid | Fiona and Ingrid |
| Duration | Teacher intro: 30 min<br>Students activity: 25 min | Teacher intro: 19 min<br>Students activity: 9 min | Teacher intro: 6 min<br>Students activity: 1 h |
| Location | Science lab<br>First part of intro in classroom | Classroom | Science lab |
| Task | Explore 'heat' as part of heat pump.<br>5 smaller tasks | Build a model of DNA with sweets | Make and carry out investigation plan to test sanitary towels |
| Teacher post-work | Explanation on board next week | Teacher made a short summary | Some points of support for students evaluation of inquiry while going through outline of report |
| Students post-work | Full report ('written', but not handed in) | Read other groups words,<br>Test next week | Full report<br>(not handed in) |

Table 7: Rough overview of the cases

All cases follow roughly the same structure. First, there is Ellen's introduction, next the students carry out the practical work/inquiry and then there is some sort of summarization. The summarization varies between the cases. In the Heat pump case, the students first wrote a report (not handed in) and the next science day the teacher led a classroom dialogue describing and explaining heat pump. In the DNA and Budding researcher cases, there was a brief summary by the teacher where the students did not contribute much.

### 9.1.1. Time

This class had science days, which meant that there were four or six hours science in one day. This provided the possibility to have introduction, practical work/inquiry and summarization in the same day. This could have made it possible to dwell on the practical work and its outcome in a way that is not possible when there are periods of just 45 or 90 minutes. The science days allowed for an option to link practical work tighter with subject matter and to do practical work and inquiry that required a longer time span.

Time summons are important in organizing practical work and inquiry. Time summons might be given by the teacher or they might be institutionalized. To regulate other peoples' time is a mark of power. The teacher and school have the authority to rule the students' time (see section 5.7.1). At Hill, there was no bell that gave the institutionalized time summons. This meant that students as well as teachers had to watch the time. This sometimes led to five minutes breaks being stretched to ten minutes. Ellen did not usually take notice of students arriving a bit late. Thus, the time summons can be tacitly 'negotiated'.

In the Heat pump case, there was an institutionalized time summon that involved a change of physical location. Students had to move from the classroom to the science lab between the first and second introduction. After the students had started to carry out the practical work, Ellen broke off the 'doing' for a third introduction. This was a time summon to ensure that all students had 'understood' the procedures. She was not satisfied with the students' work and thus saw it necessary to give a reminder. During the rest of the day there were time summons in form of the teacher giving messages to the whole class, but students could continue their work. In addition, there were the institutionalized lunch break and end of day.

In the DNA case, it was important to finish before the break. That meant that from the end of Ellen's introduction to the students having to leave the classroom, there was about 15 minutes. This might have led to a slightly stressful situation for both Ellen and the students. In this case, the institutionalized time summon (end of period) influenced the teacher's introduction and possibly also the summary. The summary was very brief.

In the Budding researcher case, there were few time summons. After Ellen had had a short introduction, students worked with their inquiry. Toward the end of the day, Ellen had, however, a time summon and she attracted the students' attention by using her 'board voice' to go through an outline for the report. Fiona and Ingrid continued working with their inquiry while Ellen went through the outline. In addition, there was the end of the day. The practical part of the inquiry had to be finished before the science day ended.

Students always organized the time during the entire carrying out phase of practical work and inquiry. This means that Ellen did not allocate time slots for making hypothesis or discussions during practical work and inquiry. Within the practical task, students had a great deal of autonomy. In these cases, Ellen just once had a time summon that broke off the students' activity. This was when Ellen perceived that the students did not follow the procedure she had given (Heat pump case).

Ellen seldom uses the power of her teacher authority to explicitly structure students' time, the primary source for structuring time is institutionalized time summons. The breaks and end of day thus function as vital 'supplier of terms'. How long the break should be and how time is spent during the task is negotiable in this practice. Students thus influence how time is 'used'.

In the Heat pump and DNA cases, there were audible and visible inattention among students. This I claim causes reversed time summons. Students hurry the teacher's presentation. The teacher will want to avoid this inattention and thus 'rush' toward finishing so the students can start working. This can be seen as the students' resistance toward teaching. In both these cases the visible and audible inattention was during the presentation of the lockstep procedure.

### 9.1.2. Physical space

In section 3.3, I described Hill and the rooms that were most frequently used, the science lab and the classroom. The physical locations give some affordances for the organization of tasks. Power relations will be influenced by how the space is structured. The room shapes the activity and the activity might reshape the room somewhat.

In the Heat pump case, the first introduction was in the classroom. The second and third introductions were in the science lab. Students carried out their practical work and wrote their joint report in the lab. The classroom afforded easier access to the board for the teacher as she could walk out into the room and be close to the students, and at the same time easily walk back to the board to write. In the science lab, this was more cumbersome. In the lab there was a large nailed-down teacher's desk on a podium. This meant that Ellen had a 'long' way to walk if she was to pace between the board and students. Ellen 'had to' choose between a close proximity to the students or board. She (mainly) chose the students. An implication of this is that the board was less used in the second and not used in the third introduction. The science lab afforded infrastructure for practical work in science, such as power sockets and sinks. When the four students carried out their tasks, they could not all stand beside the hotplate (too crowded), and when taking notes and writing the report on one computer not all students were involved (difficult for all to sit so close that they could see the screen). The physical space thus provides some restrictions on students' collaboration. It becomes difficult to, e.g., share information and to make observations and take notes of results simultaneously.

The DNA case was introduced and carried out in the classroom. Only to a small extent did the task influence the physical layout of the room. There was no great need for adjustments of the space. Ellen used the board and had close proximity to students, as she without effort could walk into the middle of the room during her introduction. For the students, this task made no great difference regarding how to use the physical space, apart from being allowed to walk to fetch what they needed.

They sat beside each other at their desks (facing the board), as they had done before the task started. The main thing the classroom afforded in this practical activity was perhaps the possibility to eat the sweets when finished. Eating was not allowed in the science lab (health and safety).

The Budding researcher case was located in the science lab. This day, students used science equipment. Easy access to equipment as well as water is perhaps the main affordances of the lab this day. Ellen spent little time at the board (except toward the end when she went through an outline of the report). The students Ingrid and Fiona had seated themselves on each side of the desk. This made it more difficult to share the notes written on the computer as Fiona did not see the screen.

Ellen often chose to stand closer to the students when she was teaching, and she walked about the room. But at times (e.g., when students were writing the report from Heat pump activities) she 'withdrew' to the teacher's desk and the computer there.

The students' use of the room is usually more restricted. Mostly they are required to sit by their desks. In this class, students chose whom they wanted to sit beside and they moved their desks to be able to sit with friends. When it was practical work or inquiry, students could move more freely around the room. For example, if they had to go and fetch something they could stop to talk to other students on their way. This is a different way of using the room from the institutionalized power where students are expected to sit by their desks and *not* move about. Practical work/inquiry thus offers a free-space from regulation of students' movement, although students cannot do anything and walk everywhere. In this practice, students did not walk into teachers' preparation room. The preparation room was connected to the science lab through a door (often standing ajar). However, the students did not go in. Ellen fetched what was needed from the preparation room.

In practical work and inquiry students are given (sic) some of the rights that ordinarily belong to teachers (move about) and thus the power difference is less during these activities. Both the practical work and the inquiry were 'desk activities'. One may question if the layout of room including desks and benches provides limitations for choice of activities. Because of the layout of the room teacher chooses tasks that fit the available desk arrangement. The use of the science lab also gives rise to some challenges. The layout of space for doing the practical work (benches) makes it very impractical to have the computer beside the equipment. This creates a division of work between the students – taking notes or 'doing'. It thus becomes a question of who has access to what information. In the Budding researcher inquiry, students could have chosen to sit beside each other so both could see the screen. They chose not to, as it was more practical for the 'doing' that they were located on each side of the table.

### 9.1.3. Artefacts and other resources

The artefacts used in practical activities will have some salient features that make them feasible. They have some affordances that make them act as models of some phenomena or that the artefacts can be used to show a phenomenon. This means that the artefacts, including scientific instruments, have to be chosen with somewhat care.

In the Heat pump case, the artefacts were a flask, glove finger (acting balloon), hotplate and syringe, in addition to scientific instruments: thermometer (analog) and data logger (digital thermometer that Ellen handled). As mediums, the students used water and isopropanol. All of these artefacts, except for the data logger, are common enough and 'simple'. They thus afford to observe results without being 'filtered' through a black box. The data logger, on the other hand, produces 'nice graphs', in this case a graph that showed change in temperature. How the logger measures and makes the inscription (graph) is, however, not visible – it is a black box. It is much easier to understand how the analog thermometer works. However, two of the students in the group had problems reading the thermometer. Scientific instruments have inbuilt knowledge in form of, e.g., the temperature scale. Instruments for measuring will be further dealt with in section 10.5.

The DNA-code relied upon everyday artefacts such as sweets and toothpicks. The salient features were the colours (to represent the bases) and thin and pointy (to represent the chemical bond). The familiarity of the artefacts perhaps reinforced the non-scientific-ness that was so prevalent in students carrying out the task. Students did relate to the model as sweets and toothpicks, not as bases and bonding. Perhaps the 'transduction distance' becomes too long for students – from sweets to a model of DNA.

In the testing of sanitary towels on the Budding researcher day, students used various instruments to measure water volume (volumetric flask, beaker and burette). In addition, they used a stand and clamps as well as sanitary towels. The instruments to measure volume offer different levels of accuracy. So, one might say that they afford something slightly different. The apt artefact would give students the desired level of accuracy. Students chose a rather low level of accuracy (through the use of beaker and volumetric flask). The teacher wanted them implicitly to have a higher level of accuracy and thus brought the burette. Through the introduction of the burette Ellen communicates something about what she sees as good enough. The burette caused some problems for students as the scale was opposite from what they (intuitively) regarded as appropriate. They thus have to adjust their semiotic work so it fits the instrument. Ellen gave some guidance on the use of the burette, but when Fiona said she 'didn't understand', Ellen chose not to follow up. To the teacher the burette is a transparent measuring instrument.

The teacher chose almost all of the equipment used in the cases, except in the Budding researcher case, where students themselves fetched the beaker and a volumetric flask. In the Heat pump and DNA cases, Ellen put the required equipment on a trolley or on a desk in the front so the students could take what they needed. The teacher thus decides what artefacts students are to use. This can be seen as a subject matter judgement of what are appropriate artefacts to illustrate phenomena. In other words, the artefacts have some affordances that are vital for exploring the phenomena. These decisions can also be interpreted as part of the power relation between teacher and students, where the teacher 'knows best'.

Other important resources were mostly tables used to record results. Tables are an efficient way of representing results. If the table has a good layout, it is easy to get an overview of results and to recognize patterns in results. Tables structure the information in a particular way and are often information dense. In addition, tables require different reading/writing skills than alphabetical text, e.g., reading left to right is often not a good strategy when reading tables. Badly constructed tables are difficult to read and from which to extract information. In these cases making tables were mostly left to the students. This means they had to link variables and results, and decide what to do with notes/comments on particular measurements, e.g., what to do with faulty measurements. Students have to transduct from observations or measured results into another mode (written tabular). How the students handled this I am not sure, as they did not hand in the reports in the Heat pump and Budding researcher cases. That the teacher did not aid students in making tables may indicate that she had confidence that they managed it themselves, or it might be that she was not aware that this was a possible problem for the students. In the DNA case, there was a table that allowed for the transduction from colours into letters. This table the students did not make, but they were required to read it. This table was of vital importance if the students were to 'write' their own word. Ellen did ask questions and modelled the reading of the table, but she did not challenge *all* students to read and use the table.

#### 9.1.4. Curriculum

The three cases draw on very different scientific knowledge. However, the knowledge base for all three is well-established at the level of general science in upper secondary school. There is, however, a choice of the required level of descriptions and explanations. How detailed do the students have to be when they explain and describe, and how much do they need to reason when it comes to methods and accuracy of results? This is an important but difficult question. The answer 'belongs' in the situated practice and will be made according to the teacher's and students' interest and expectations. The teacher as main rhetor will, however, be the evaluator of what is considered good (enough). In her judgement of what is good enough, the teacher draws on an extensive tradition of what counts in the classroom and what is expected on a prospective exam. School science tradition has its roots in the 'elite' education system. Part of the tradition in school science is that students are to be able to retell facts and standardized explanations (see also 3.5.3.). The tradition influences the shaping of students' expectations to science and how they choose to relate to the subject matter.  In these cases, the teacher chose, in large extent, to simplify subject matter or even disconnect it from the practical work in her introductions (see section 9.1.5).

The Heat pump and DNA practical work relied on many scientific terms. These terms are interlocked which means that they get their definition by involving the definitions of the other terms (see also 10.4.). Working with scientific terms is thus an iterative process where terms are refined through use of different resources in different modes. When learning the terms it is a problem to construe meaning when the terms are interlocked, it is also a problem to use these terms to describe and explain ('think with the terms'). In all three cases, both the teacher and students chose to use an everyday language at the expense of scientific terms, see also section 9.1.5.

In practical work and inquiry, students are to handle different aspects of science at the same time – science as product and science as process – and possibly learn something *about* science at the same time. One can thus say that practical work and inquiry require hard semiotic work and it will be a challenge for the teacher to plan and stage practical work and inquiry in such a way that it secures a good (enough) outcome of the students' semiotic work. In these cases, the teacher chose to emphasise 'doing' at the expense of deliberations over methods and connecting processes with product, see also section 9.1.5.

These perspectives will be further explored in chapter 10, where the curriculum will be unpacked in light of science education literature. In chapter 11, I will attempt to explain why this is a rational practice.

### 9.1.5. Norms

When there are similar norms in the different cases, this indicates that these are relatively stable norms. This means that the practice that is seen as appropriate – 'as we do it' – is fairly fixed. At the same time, there will be differences between the cases as there are differences in, e.g., task and subject matter. A norm might not be prevalent in one case although there might be some remains of it. Thus, it is not enough to just look for similar norms in all cases; the content of the case has to be 'examined' as there might be traces of the norm. Moreover, some of the norms will be singular and belong to just one case. This might mean that this norm is not very stable or that the task has some features that render the particular norm necessary – and unnecessary in the other cases.

The main structure of this section is a presentation and discussion of norms. Then, overarching norms are given in bold italic font before there is a small discussion of how the students respond. How they adapt and transform the norms embedded in the rhetorical framing.

#### *9.1.5.1. Regulative*

The regulative domain of communication deals with behaviour, organizing and structuring the task, see 5.5.1.

*Behaviour, teacher – student relation*

Regarding behaviour, one might see students as the initiators of action and the teacher as the responder. Behaviour is the only part of the rhetorical framing where students have the initiative, so to speak. This gives a slightly different structure to this part. I choose to connect norms to students as well as the teacher's semiotic actions.

In regulating behaviour, the teacher-student relation is highlighted. In these situations, the relation itself becomes the issue. Most of the time, subject matter issues are foregrounded in the communication, although there is still a student–teacher relation, but behavioural issues will be less 'visible'. Moreover, in subject matter dealings elements of regulating behaviour take place. For example, the teacher walking the room while introducing procedure and thus 'control' the students can be seen as a relation of power, but also of solidarity by choosing physical closeness. Students will of course also regulate the behaviour of each other, what is 'possible' to say out loud in the classroom, etc. (how students regulate each other is, however, not investigated in detail, see 4.3). In general, the students were usually quiet when the teacher presented the subject matter. That is to say that they did not always pay attention, but the inattention was quiet. There were, to my knowledge, very few episodes of more serious behavioural issues during this school year.

The norms inferred in the previous chapters are:
Heat pump case:

Students may challenge the teacher regarding behaviour
Appropriate behaviour is (partly) negotiated

DNA case:

Resistance to teaching is indicated by obvious lack of attention
Unwanted behaviour is not explicitly addressed

Budding researcher case:

Behavioural issues are dealt with amiability

In the Heat pump and DNA cases, there is visible and audible inattention among the students. In the Budding researcher case, there is little visible or audible inattention. The inattention might be a sign of the students' indifference toward science (and perhaps school in general) and it might further be seen as a way of showing resistance towards the subject matter. However, I do speculate if students' inattention in the Heat pump and DNA cases was a reaction to the strong procedural demands, as the audible inattention occurred when Ellen presented the procedure. The Budding researcher case is a bit different. This day there were few students present and the day had a more practical emphasis. Students did practical tasks all day, except when they listened to the teacher's short introductions or wrote the report.

***Students may choose to show signs of audible and visible inattention***

In the Heat pump case Ellen addressed students' inattention directly by first singling out one of the (most) talkative students and then she addressed the rest of the class. In this situation, Ellen uses the speech functions questions and uncertain statements. In other words, she avoids a direct confrontation with students. A direct confrontation would involve demands for attention and possibly sanctions. Ellen uses her power to disarm rather than go into a full-scale conflict. In the DNA case, Ellen chose not to address the students' inattention explicitly. She rushed to finish her talk (by talking faster) and walked the room, perhaps a strategy to control the students by physical closeness. As a consequence of her choice to overlook students' behaviour, she does not investigate what caused the inattention. She probably had an explanation herself, but she did not ask the students to verbalize their reasons. In the Heat pump case, Ellen did not ask the students to explain the reasons for their inattention either. Perhaps she regards the inattention as something students just do from time to time. In other words, causes for inattention are seen as naturalness – just an ordinary part of classroom life.

In the Budding researcher case, there was an amiable relation between students and teacher all day. Ellen chose to address those two students spilling water with humour and a disarming approach.

There is a pattern in the teacher's choices for dealing with the relation to students. First, there is avoidance of direct conflict. Second, she does not ask the students to explicate reasons for inattention. Her practice of regulating behaviour works, although there is some inattention from time to time.
***It is appropriate to disarm when dealing with behavioural issues***
***There is no need to explore reasons for inattention***

*Organizing the task*
Organizing the task is about dividing students into groups, dividing the work between students and pacing the work. Pacing is also dealt with under time, see 9.1.1. I have regarded how note-taking is carried out as a part of organizing the work, as note-taking during the practical work is usually a part of the division of work between students. But note-taking also has bearings on the communication of science – so the content of notes is dealt with under instructional.

The norms inferred in the previous chapters are:
Heat pump case:
> Students are implicitly given autonomy to organize collaboration (within the structure of procedure) for how to carry out the practical work and make meaning of it

DNA case:
> Decisions concerning collaboration are implicitly left to students
> Taking notes is open for negotiation

Budding researcher case:
> Decisions concerning collaboration are the students' responsibility

In all three cases, Ellen leaves the practical part of organization of the task to the students. She allows the students to decide or partake in decisions with whom to work. She lets the students decide their pacing by not giving specific time to make the hypotheses (Heat pump) or an inquiry plan (Budding researcher). Further, the work is to be finished when there is an institutional time summons (break or end of day). Ellen lets the students decide how to collaborate and how to divide the work between them by not intervening in the work process. There are, for instance, no explicit requirements that all shall partake in the practical work, discussion of results or writing the report. How to write notes and results and make meaning of these results are for the students to decide. All of these choices are tacitly given to students, except division of groups. In other words, there are no support structures for how students are to collaborate on tasks (e.g., in form of time slots to discuss hypotheses or results). Is it important to collaborate at all? And what collaboration is considered 'good'? Ellen does not exercise her power as main rhetor to set explicit standards for students' collaboration on task. In this matter Ellen implicitly gives students a great deal of autonomy.

***Students are implicitly responsible for how to organize collaboration and what to collaborate about***

First, I like to remind the reader that these students were chosen because they talked together, see 2.2. Compared to other groups in this class, they worked well together.

The students divided the work between themselves in all three cases. In the Heat pump case, not all of the students contributed to generating the hypotheses or report. Beatrice and Peter's contributions were mainly to 'do', whereas Sheila and Ingrid mainly took notes. This saves time, as some students can start doing when others verbalize hypotheses. Moreover, when not all voices give advice to what the report should say, it becomes easier and faster to write it, but differences in opinion are lost. The students did not stop and take time to deliberate over or enjoy the results. They were more concerned about getting all the small practical activities done.

In the DNA case, there also was a division of work where Beatrice became the one to do the practical work of sticking the toothpicks into the sweets while Ingrid controlled their word. One might say that Ingrid had more responsibility toward meaning-making than Beatrice.

Division of work can be seen in the Budding researcher case as well. Ingrid took notes. The other student (Fiona) did not see these results and would thus have a limited possibility to discuss and make meaning of the results.

In the Heat pump and the Budding researcher cases, there was little support for what form the results should be presented. If the point of the writing is to 'hand something in' rather than as a tool for meaning-making, it is quite efficient that only one or few students control the writing process. However, this leads to that differences in results and opinions are not or shallowly discussed. This way of dividing work thus provides little subject matter challenge to all the students in the group. The most important seems to be that students as a group manage to *do* and finish their work within time, not to make meaning of it.

Although I have not looked in detail into how students relate to each other when they collaborate, there are traces of roles attributed to students. For instance, Ingrid is often the one who is taking notes and at times is the 'leader'. These roles students take during collaboration might have something to do with the social as well as subject matter 'hierarchy', which becomes established in a class. When students regularly work together, they might fall into certain patterns for dividing work.

*Structuring the task*

Structuring the task deals with purposes and goals, as well as perceived manageability of the task. This means that which directs the practical work and inquiry and expectations to outcome. The detailed structuring of the task is dealt with in procedure and carrying out.

The norms inferred in the previous chapters are:

Heat pump case:

The goal is to carry out the practical activities
Purpose is not emphasized
The activity shall be easy and simple to carry out

DNA case:

The teacher provides a goal for task
Purpose is of little importance
It is important to partake in the activity and outcome is less important

Budding researcher case:

A rough goal is provided by the teacher
There is no need for purpose

One might see purpose as Ellen's intentions with the practical work. In the Heat pump and DNA cases, Ellen gives a vague purpose. The purpose is given in the middle or toward the end of the introductions. This probably means that the purpose is not a driving force in Ellen's introductions. In other words, the purpose only tacitly guides her introduction. In the Budding researcher case, there is no explicit purpose. There will of course be a purpose but it is not made clear.
***There is little need for explicit purpose to direct practical work and inquiry***

The effect of a vague or missing purpose for the students' work is hard to claim with certainty. However, even if it is impossible to make hard claims in this matter it allows for a possibility to speculate on the effect. First, there is the question if students did interpret these vague statements as the purpose, as the statements concerning purpose were embedded in procedure or subject matter. Next, if they did not detect the purpose of the tasks, students had perhaps little to guide their attention in the introductions. Moreover, the purposes given in the first two cases are perhaps not clear enough to guide attention. It is reasonable to claim that unfocused attention makes it more difficult to interpret, remember and connect the various steps of the procedure. The Heat pump case might serve as an example. When students carried out the five smaller tasks, they had partly forgotten what to do. Although they did not ask for reasons for some of the steps, I perceived no great enthusiasm among the students when I reminded them to repeat boiling under low pressure with another liquid. In hindsight I see that for the students this repetition had seemingly no purpose at all and reasonably they showed resistance. Why do it? But they also did this part of procedure.

In the Budding researcher case, the 'big issue' was the required level of accuracy. There were no reasons why accuracy was seen as important. And why do the inquiry at all? Did the day have any purpose besides being enjoyable? If students do not see the inquiry in the 'bigger picture', it might become meaningless from a learning perspective but meaningful from a perspective where enjoyment is paramount. Without explicit purposes are students shaped to accept meaningless tasks?

I claim (very tentatively) that the missing purpose makes students even more dependent on following the recipe as they have no possibility to understand why this or that is important. Perhaps explicit purposes would have provided the reasons why it was important to spend time on practical work and inquiry?

Students did not call for purposes by asking the question – '*why?*'. This might be interpreted as they had no expectations for explicit purposes or that they did not care much about why they were doing what they did.

* * *

The goal in the Heat pump case can be interpreted as 'carry out the tasks'. The goal in the DNA case was to 'understand genetic coding' and the goal in the Budding researcher case was to 'plan and carry out'. The goal in the DNA case was perhaps too vague to provide a firm connection between the practical task and subject matter, as there were few explicit links between sequencing the seigmenn and 'real' DNA coding. I will claim that this led to the stepwise recipe taking over and it became more important to carry out the sequencing of sweets. In the Budding researcher case, 'carry out' also took over (at the expense of making a plan). In this case, Ellen refrained from the goal of 'planning' by stating that the students were to 'try out a bit' and she did not directly address the students' plans. This means that de facto goals in all the cases became 'carry out'.
***The goal is to carry out practical work and inquiry***
***Goals concerning meaning-making are not or less needed***

In all cases, the students did manage to carry out the work, so one might say that they were successful. During the practical work and inquiry they did pay attention to what to do and less on meaning-making of what they did. It seems to be important to carry out and get results – not what these results might mean. Students' interest and expectations seem to be well aligned with these norms.

* * *

Ellen gave the purposes and goals without the students' participation. This means that the students did not take part in the construction of goals and purposes. If there were any, the goal and purpose are presented to the students. Purpose and goal becomes solely the teacher's responsibility. The teacher is exercising 'curriculum

power' – the institutionalized power in a school system where someone else has decided what is good and proper. Perhaps the teacher has expectations of a clearly defined subject matter that does not require reasons.
***Students are not to participate in construction of goal and purpose***

The students seem to adapt to this. They do not ask for more responsibility to decide what and how to work with the subject matter during practical work or inquiry.

I claim that little involvement from students on construction of goals and purposes remove some of the subject matter responsibility from students. The students have little ownership of what they are to do. They are not empowered to have opinions on the subject matter. This, together with the goal of 'carrying out', might reinforce the importance of the stepwise procedure. The procedure becomes the thing that students can 'hold on to' when the task has an unclear goal and purpose.

* * *

Another aspect of structuring the tasks is that in all cases it seems to be important that the task is easy to carry out. In the Heat pump case, there were many, but operationally simple steps in the procedure. In her introductions, Ellen emphasizes the activities as simple. Even so, her statements might be interpreted that she expresses doubt whether the students manage to do this (also occurring in the DNA case). In the Budding researcher case, the 'easy' is perhaps not so prevalent, but by refraining from the strong demand of an inquiry plan and her emphasis on 'try out' difficulties are removed. In the Budding researcher case Ellen also under-communicated the status of the report. It was said to be a 'small report' and not what it actually was meant to be – a full report. The focus on easy I see as a way for the teacher to express solidarity with the students. She does not want them to have problems with the practical work.
***Practical work and inquiry are to be easy to carry out***

As there were few choices that the students could make, in all cases most deliberations were removed. This perhaps makes it easy to carry out the steps of the tasks. However, as purpose and goals were vague or implicit it becomes difficult for the students to make meaning of the lockstep procedure. So, I claim that without explicit purpose(s) and goal(s) the students need an easy procedure to be able to carry it out. If there are clear purposes and goals the procedure could perhaps be more difficult, but the students would then need to reflect more over what they were doing. So, I make a tentative claim that the focus on lockstep procedures and 'do' reinforce the need for 'simple'. However, the focus on 'do' without explicit purpose might coincide with the students' expectations to school science. This is most likely what they are used to from their previous schooling.

#### 9.1.5.2. Instructional

The instructional domain of communication deals with procedure and methods, scientific knowledge and the 'language' and communication of science, see also 5.5.1.

*Procedure, methods and carrying out*
A procedure tells what to do to investigate a phenomenon. There are reasoned steps in the procedure, so the phenomenon can be explored as best possible. Some methods and procedural steps 'fit' better to some problems or phenomena than others do. The procedure in school science might have various degrees of freedom – or what I refer to as choice. When there are choices to be made, the students need to reflect on what they perceive as the best way forward to investigate the phenomenon.

The norms inferred in the previous chapters are:
Heat pump case:

Practical work emphasizes doing
Results will show themselves (happen) when procedure is followed
Procedure is fixed and hence there is no need to deliberate over it
Hypothesis serves as a pedagogical devise

DNA case:

Practical work is to be enjoyable
Procedure is fixed (no explicit choices) and emphasizes material action

Budding researcher case:

Responsibility for making the procedure is removed from the students
There is little need to assess procedures and methods explicitly
Inquiry is mainly 'doing' guided by a roughly outlined plan

In both the Heat pump and DNA cases, Ellen provides a lockstep procedure with no (real) explicit choices. There were, though, some implicit choices as there were some points that were not made (totally) clear. Thus, in this practice, the procedure is an ordered sequence of actions that have to be followed. Whether or not these actions are 'understood' in the sense of why one has to do each step and why the actions need to be carried out are not seen as important. The procedure simply *is*, it does not require reasons for methods or particular actions. There are no reasons within the procedures why to do this or that. The procedure can thus be seen as an authoritative (or even authoritarian?) device for structuring the students' work. The teacher decides and knows the best approach for carrying out the practical work. This can also be seen in the Budding researcher case where Ellen gives the students equipment and method for measuring without the students asking for another method. This equipment then 'decides' how the measurements are to be carried out. I claim that in this choice of action the teacher made the inquiry more like ordinary practical work. The students' procedure is set aside and the teacher implicitly steers students toward what she sees as apt. Moreover, Ellen does not involve the students (much) in deliberations over methods. In the two first inquiries on the Budding researcher day Ellen involved students to some extent – otherwise not.
***Practical work should follow lockstep procedures***
***Procedures and methods need no explicit reasons***

The students in all cases follow Ellen's instructions on procedure and methods, although they seem to forget some steps when there are many steps (Heat pump case), and try out their own approaches first in the Budding researcher case. However, in the end they do as they are 'told'. For the students, it becomes important to carry out the procedures and methods the 'right way'. I speculate if the students couple 'success' in practical work with managing to follow the procedure. They are able to carry it out and they see some results. As Sheila said in the Heat pump case: "*Then we made it, without understanding*."

Further, I interpret some resistance from the students regarding the lockstep procedures. First, there is inattention when the teacher talks through the procedure (Heat pump and DNA cases). Then, there are the students 'forgetting' parts of the procedure in the Heat pump case. This might be the result of inattention but can also be connected to students not seeing the significance of the parts of the procedure they forgot. This can be linked to the missing purpose, which probably makes it harder to remember what to do. If I had not been there, they would probably have transformed the procedure into something simpler (e.g., boiling under low pressure for just one liquid and not for the required two). In the Budding researcher inquiry, the students followed their own plan first before they did it the 'teacher's way'. Their initial plans had a lower level of accuracy, i.e., they were simpler.

* * *

What is important is to carry out the practical work or inquiry (see also goal). The teacher's introductions in the Heat pump and DNA-code practical work strongly emphasize material action through frequent use of the transitivity process 'do'. The emphasis on 'do' is at the expense of mental, verbal and observational transitivity processes. In the Budding researcher case, there are few material action transitivity processes in the introduction, however in the direct guiding of the students there is a strong focus on 'do'. In guiding the students on the inquiry, there are no questions to assess the procedure or methods. This provides a shift from the 'thinking-questions' in the introduction to pure instruction when the students are carrying out their inquiry. The carry out focus thus allows less emphasis on linking the procedure and methods to textbook knowledge.

***The procedures and methods focus material action at the expense of linking to textbook knowledge.***

In all cases, the students' semiotic actions emphasis 'do'. There are a few attempts to describe and explain in the Heat pump case, but these attempts are in an everyday language (see below) and might be called 'muddled'. In the DNA case, most of their semiotic actions are directed toward doing, and although Ingrid did control the sequence of sweets there are no mention of scientific terms. In the Budding researcher case, Ingrid and Fiona begin immediately carrying out the plan without much deliberation. However, their experiences during the year had been lockstep procedures that had few choices and even less explicitly reasoned steps. When the students had made their plans for the inquiry, Ellen chose not to discuss these with

Ingrid and Fiona (or discuss methods in full class). This would require that Ellen challenged Ingrid and Fiona by asking questions regarding their methods.

** * **

In the Heat pump case, there are frequent references to results that (will) happen. Results are not so much observed and interpreted as just appearing, if procedure is followed properly. This is not prevalent in the DNA case as there were no 'results', but it was something (word) to be made. In the inquiry case, there is more emphasis on observations and measurement – and less on 'happen'. However, results just *are.* The participants refer to 'the best' sanitary towel without connecting this to possible sources of error in the measurement. The interpretation of results is thus somewhat shallow.
Thus, it is not possible to make a common norm through all cases regarding results that 'just happen'.

There was no hypothesis in the DNA case. This is because the problem at hand did not require a hypothesis. In the Budding researcher case, Ellen herself made the hypothesis toward the end of the inquiry. In addition, the students' inquiry was more guided by the questions posed in the introduction. This means that it was only in the Heat pump case that the students made hypotheses.
Thus, it is not possible to make a common norm through all cases regarding stance toward the role of hypotesis.

*Science knowledge*
Practical work and inquiry are fundamentally about generating scientific knowledge that is new to students, even if it might be very well established knowledge in the scientific community.

The norms inferred in the previous chapters are:
Heat pump case:
Scientific knowledge is certain
Differing results are not explored (by teacher and students)
Practical work does not need to be connected to scientific knowledge
DNA case:
Scientific knowledge is true and certain
Scientific knowledge is loosely coupled to practical work
Budding researcher case:
Inquiry needs no firm coupling to school scientific knowledge

In all cases, scientific knowledge is dealt with through the teacher's use of certain statements. There are no doubts about scientific knowledge. Questions are formulated most often to ascertain facts from students. In the Heat pump and DNA cases, there are few/none questions from the teacher about which the students really need to ponder. This, I claim, reinforces a view that students are to contribute with (only) facts – not reflections or connections. The subject matter in these cases is established science, but even so, it is possible to use other speech functions than certain statements and short response questions. The most prevalent transitivity processes are relational when the teacher talks about the subject matter, i.e., entities having attributes or identities. The Budding researcher case is a bit different, as the teacher's introduction had many hypothetical statements concerning procedural knowledge.

The teacher further avoids going into diverging results (Heat pump and DNA cases) and ascribes diverging results only to faulty procedure (context of Budding researcher case). Thus, if you follow the procedure systematically the results will be certain.
***Scientific knowledge is certain***

How the students deal with this norm is difficult to say. However, there are indications throughout the year that many students in the class had clear expectations of a science course based upon facts (certain) and recall of facts. When science is divided into small chunks of facts, it is probably perceived as easier for students, especially if their main strategy for learning is recall. I claim that the teacher expresses solidarity with the students by avoiding 'thinking' and deliberation over diverging results. The students would perhaps feel that they lost control over the subject matter if there was more weight on explications and hypothetical statements. However, is this focus on (school) science as certain and factual doing students a disservice by not empowering students to deal with more complex problems?

* * *

In all cases, Ellen links scientific knowledge loosely to the practical task. This is the counterpart of emphasizing 'do'. In the Heat pump case, the terms used in the introduction are not always used in the scientific sense. In all the cases, there are few scientific terms, and they become even fewer closer to the carry out phase. In the DNA case, there were many scientific terms in the lecture about DNA and protein synthesis, but these did, to a very small extent, become linked to the practical activity. Therefore, there seems to be a shift from 'theory' to 'do'. The realms of 'do' and theory, do not need to be explicitly connected.
***Practical work and inquiry do not need a connection to (school) scientific knowledge***

While students are carrying out the practical work or inquiry, there are few traces of 'scientific knowledge'. In the Heat pump case, the students try to explain the phenomena and their speech is often uncertain statements and questions. One might say that the students' relation to scientific knowledge is muddled while they were doing this practical work. In the other two cases, there are very few references from students on subject matter knowledge. Students do not ask the teacher subject matter questions related to the practical work. They had an opportunity to ask the teacher about their 'mystery' (isopropanol not boiling), but they chose not to do so.

So perhaps, the students do not really see the need of connecting 'do' with verbalized scientific meaning?

* * *

In the two first cases, there are at times indications that Ellen does not simply express that science is certain – but also that it is true. Perhaps, even *the* true way of seeing the phenomenon. As the empirical material to corroborate this is weak, I will not formulate this as a norm.

*Science language and communication*

The 'scientific language' is about the terms used and the way the words are constructed into sentences and clauses. Science uses many ways of representing knowledge. Tables and other inscriptions are a vital part of communicating science theory and empirical results. In the classroom, communicating science will involve the teacher and students' oral interaction as well as the teacher speaking and writing.

The norms inferred in the previous chapters are:

Heat pump case:

- 'Everyday' language is sufficient for describing and explaining scientific phenomena
- Resources to support measurement and reporting results are not emphasized
- There is little challenging of each other on subject matter

DNA case:

- Scientific terms are superfluous in practical work
- Practical and scientific questions have equal worth
- The teacher controls the information flow
- Problematic ('wrong') contributions from students are ignored

Budding researcher case:

- Everyday language is sufficient to deal with scientific procedures
- The teacher controls the flow of information
- Subject matter challenge is to be avoided

In the teacher's introductions, everyday language is given prevalence in all cases. This means that scientific terms are used loosely or avoided. Ellen's introductions to the practical work and inquiry have, at times, an intermingled structure – a bit of this and a bit of that. This is not seen in more theoretical presentations or lectures. The intermingled way of presenting practical work strengthens the communication as informal. The way of speaking becomes 'homely', even if there are many strong demands. In lectures (e.g., before the introduction to DNA-coding) scientific terms and explication of these are emphasized. Thus, there is a contrast between 'ordinary' teaching and introductions to practical work.

In the Heat pump case, the teacher wanted the students to explain the phenomena. However, there were no explications of the interlocked scientific terms (heat, pressure, temperature, etc.) before the students started writing the report. The explication of these terms was dealt with next week. When Ellen went through an outline for the report on the Budding researcher day, she wanted the students to assess the level of accuracy, but there was not much emphasis on accuracy and what accuracy entails before the students started to carry out. The students are thus to describe and explain using their everyday language.

There is almost a total absence of causal connectors in the introductions to the practical work or inquiry. This strengthens the 'everyday' at the expense of 'science language'

***Everyday language is sufficient in dealing with practical work and inquiry***

Students use almost only everyday language in their dealings with practical work and inquiry. They also use their hands to point and artefacts to create meaning. This results in a situated communication between students on subject matter. The 'language' is 'muddled'. On the other hand, this is to be expected. The students are learning and this means that they are to connect terms and ways of speaking with the phenomenon with which they work. However, they are not given tasks or there are no time summons to explicate terms or finding the 'best way' of expressing the subject matter. In other words, there are no support structures for developing a precise science language. Students did not call for a more scientific language – perhaps even the opposite. There were enough difficult words.

* * *

In all the cases, the teacher is in control of the communication. She decides who speaks (students inattention is another matter) and she portions out the subject matter and procedure in her order. Students ask questions in full class. These questions are almost always concerning practical issues and Ellen answers promptly. Questions from students are never returned to the class so another student has a possibility to answer. Thus, the teacher is in control over the flow of information in all cases.

***The teacher should be responsible for the flow of information***

Students do not challenge this or show open resistance to the teacher as a distributor of information. However, at times the students choose to show signs of inattention. I speculate if it is in the students' interest that the teacher is responsible for the flow of information. When the teacher has this responsibility, the students have less responsibility to contribute. In combination with the teacher not asking all students to contribute, she is almost only asking students who want to contribute, most students can take a rather passive (even if attentive) approach to subject matter exchanges in the classroom. Being a student in the classroom becomes easier or less challenging. In addition, the students did not question the teacher's subject matter knowledge. So, in a way, the students 'give' the teacher much of the subject matter responsibility – or the authority to decide.

* * *

In all the cases, there is very little challenge both ways on subject matter. In the Heat pump case, the teacher had a preference to ask non-committal questions such as 'okay?' or 'right?'. In the DNA case, the teacher chose to check the students' 'understanding' of how to use the code key by asking short response questions. The students can choose if and when to contribute with answers. Ellen does not facilitate such so that all students have to participate. In the Budding researcher case, Ellen did ask questions to Ingrid and Fiona but did not follow up these questions by directly challenging their chosen methods. In all these cases, diverging results are not explored, but Ellen states the 'correct' knowledge. Ellen further overlooks 'wrong' answers. If an answer is wrong, she often states the 'right' answer herself. By expressing the subject matter in form of certain statements and short response (recall) questions, differences in subject matter are avoided. If the teacher had used more hypothetical statements or long response questions, there would have been another form of relating to the subject matter that would require the exploration of differences – even if the subject matter is 'true'.
***Explicit subject matter challenge is to be avoided***

The students do seldom pose challenging subject matter questions to teacher or each other. For instance, in the Budding researcher case Ingrid and Fiona chose to carry out both their 'investigation plans'. In this way, they did not challenge each others' ideas – nor argued for the 'best' plan. Low challenge is prevalent in this classroom and I claim that (one of) the driving forces behind that is solidarity. Solidarity between the students and teacher and among the students means that one tries not to make it unpleasant for the other. One tries to give the other a feeling of that ideas are okay (they are at least not bad) and if there are no ideas or the other does not know much about subject matter, there will be no exposure. Perhaps a communication where low challenge is prevalent is trying to avoid daunting the other person, i.e., expressing solidarity. On the other hand, challenge might mean to challenge the subject matter and that might be difficult. However, when subject matter is challenged, it easily leads to a feeling that it is the person who is challenged. 'I am the one who's questioned – and not my expression of the subject matter'. If students are feeling insecure socially as well as in subject matter dealings, it becomes perhaps even more important to avoid challenge.

* * *

In both the Heat pump case and the Budding researcher case, Ellen allowed the students to decide how to write down results and other notes from the practical work. On the budding researcher day, she gave one results table that could help students structure their measurement, and she talked through the report structure. In all, one might say that there is not much focus on meticulous note taking or discussions of good ways of representing results.
***There is little need to emphasize resources that structure measurement and reporting***

For the students (I think) this leads to two connected consequences. With little support on how to make notes and tables, it becomes more difficult to discriminate between important and unimportant (what does meticulous note taking mean?). In the Heat pump case, a prefabricated table or an assessment of the students' outline for a table would have helped them structure their measurements. If the teacher had discussed an outline of a results table before the students had started doing the sanitary towel inquiry, it would perhaps have become easier for the students to discuss the results. Connected to this, when these resources are absent, it might lead to a simplification of the task. Students do not need to be very thorough and there becomes less about which to think.

## 9.2. Some final comments on the rhetorical framing

The students primarily adapt to the norms, but then, norms are jointly created by the teacher and students over time as they seek to establish the practice of school science. When the students transform norms, it is to simplify the task. This can be seen in the Heat pump case when the students forgot parts of the given procedure. If I had not reminded them, they would (most likely) have carried out a simpler version. In the Budding researcher case, the students' initial plans were 'simple', but they ended up doing a more complicated procedure after implicit instruction from the teacher. This can be seen as a tacit challenge of students' plans, as the teacher did not explicitly address problems with their investigation plans. (The students' initial 'simple' methods for investigation in the Budding researcher case must, however, be connected to their previous experience with practical work and inquiry – which was not very substantial.)

The students have quite a lot of freedom and possibility to influence the organizing of collaboration within the activities. In these matters, they have a great deal of autonomy. Whereas, regarding the subject matter, they have little influence as there are few explicit choices, the teacher is in control of the information flow and there is a rigid procedure that is to be followed.

There is much emphasis from the teacher on easy activities, through choice of equipment, everyday language and minimizing workload. The teacher reduces 'things to think about' in procedure and subject matter in general, but there is considerable more to remember (especially in the Heat pump case). The procedures are structured as lockstep. Few explicit choices are given and no internal reasons within a procedure (e.g., this is done because…). In the Budding researcher case, choices were given and students were asked to assess their procedure. However, the teacher removed these during the carrying out phase. The teacher structures the students' activities and reduces the amount of 'things to think about'. There are few challenges for explication from both the students and the teacher. This low challenge is a way of reducing 'problems' or 'things to think about'. What one does not state as problematic one might not perceive as a problem.

Science is certain. This makes less to deliberate on for the students. Science is a matter of true facts. At some incidents, it seems as scientific results emerge from doing the experiments, they are not a way to interpret the world. Practical work and inquiry are presented by the teacher and carried out by the student in a (almost) theory-free way.

There are few explicit purposes for the activities and absolutely no reasons within a procedure (why do the procedure like this). The goals of the activities are often vague, and the de facto goal can be seen as ‘carry out’. Sometimes the teacher expresses some doubt if the practical work is manageable. There is thus a reduction of pressure on students for the learning outcome.

In this practice, power is primarily exercised though the subject matter. The subject matter is certain and differences such as different views or results are not opened up and explored. Procedures become authoritative or even authoritarian, and are not challenged. Results are not discussed. Power is also exercised through institutionalized time summons, but there is very little use of direct power in the relation between the teacher and students.

Solidarity is important in this practice. I interpret low challenge of the subject matter (use of language, procedures and results) as a way of expressing solidarity. Further, I interpret the autonomy that students are given regarding collaboration as part of the teacher’s solidarity with the students. By letting the students decide how to collaborate, the teacher ‘compensates’ for the authoritative/authoritarian subject matter. The students are given an opportunity to decide something, as they are not given power to decide the subject matter.

The students resist through not handing in reports and by repeatedly asking if there is a need to write (copy board), and through not paying much attention. The students do not resist by being rude or showing unsocial behaviour.

I make a tentative claim that there are two main rhetorical framing processes operating simultaneously. The social rhetorical framing dealing with organization and behaviour is somewhat open – to be negotiated between the students and teacher. The subject matter rhetorical framing is narrow, as there are no negotiations and the students have no direct influence, but they do have large implicit influence, as the teacher tries to make practical work and inquiry manageable, palatable and easy for them.

So far, I have unfolded the empiric material. This practice is a practice of science education that is meaningful within this context. From a theoretical science education perspective, there are some problems in this situated practice. How can the gap between what is believed to be ‘good practice in science’ to the actual practice be explained? To do so, there is a need for perspectives from literature before the final discussion.

# 10. SCIENCE and EDUCATION

The purpose of this chapter is to provide a literature background before the final discussion. To structure this literature presentation, I choose to use the curriculum as a starting point in each section, except in the first, and then explore what the curriculum might mean, drawing upon literature in science (and) education. There is to some extent references to 'real science', i.e., professional science, in the curriculum, which means that it is important to bring in some perspectives from sociology and philosophy of science.

Some of the literature used in this chapter is quite old (from the 1990s). In these 20 years, research perspectives might have changed such as from a more individually oriented constructivism towards more social-cultural stances. However, the problems referred to in the research seem to prevail. So, to illuminate the field I have tried to find relevant perspectives – regardless of 'age'.

The chapter begins with how education, teaching and learning can be perceived. The next section addresses the important question 'why learn science?' and explores the (good) reasons for science as a school subject. In addition, as the curriculum emphasizes democracy, this will be dealt with more thoroughly. The democracy objective I connect with 'science for all'. The next section (10.3), is about subject matter and I include perspectives on learning *about* science. Section 10.4 is concerned with communication in 'real science' as well as in school science (basic skills). Section 10.5 has its basis in the curriculum's *Budding researcher*, but also in the objectives of the subject. Science as process is important in the curriculum. As there is reference in the curriculum to 'real science', it is also necessary in this section to delve into some aspects of processes in professional science before turning to practical work and inquiry in school science.

## 10.1. Education

Formal education has two main processes – teaching and learning. Teaching and learning can be seen as reciprocal aspects of classroom communication (Kress, 2010). Both teaching and learning are semiotic work. The participants have interests and expectations when they express themselves and interpret each other.

*Learning*

Learning is semiotic work where the learner forms new signs. The learner uses different resources the learner deems apt in the situation to express some meaning. Learning can be seen as increased capacity to use the signs in (cultural) meaningful ways in different situations. (Selander, 2008)

The social semiotic approach is not the common notion of learning. To explore teaching and learning more, I choose to use Sfard's (1998) metaphors, as they "*underlie both our spontaneous everyday conception and scientific theorizing*." (Sfard, 1998, p. 4). The metaphors are 'transported' through 'our' ways of talking and acting and are part of 'our' reasoning. I propose that the metaphors for learning will enable an interpretation and discussion of how learning was dealt with in this practice. The teacher and students' view of learning underlie how they act in the everyday classroom setting.

Sfard (1998) identifies two different metaphors: learning as acquisition and learning as participation. In addition to these two, Paavola et al. (2004) propose a third, learning as knowledge creation – short for artefact creation metaphor of learning – where artefacts are human made object-like things that might be conceptual or material (Paavola & Hakkarainen, 2005).

The acquisition metaphor sees learning as individual (although the individual may cooperate with other individuals) and the knowledge as belonging to the individual. Learning is about accumulating concepts, and the refining of these into richer cognitive structures (Sfard, 1998). Learning thus becomes knowledge processing with emphasis on the logical (Paavola & Hakkarainen, 2005). The student becomes a consumer or acquirer of the knowledge and the teacher facilitates and transmits (Sfard, 1998). There are some obvious problems with this metaphor; it does not take into account other forms of knowledge than what is 'fixed' and made verbal. In addition, there is the problem related to the social aspects of learning.

The participation metaphor emphasizes the social processes in learning. The learner is seen as a member of a practice – an apprentice, where it is important to communicate and act according to the norms of practice. The individual is seen as part of the collective and the knowing is shared. The teacher or the supervisor will act as guide for the students and bring the students into the 'culture'. The students will have a possibility to adjust aims, objects/artefacts and assessments through negotiations with the teacher. Learning activities are seen as a part of a situated and context-bound practice (Sfard, 1998). This leads to the problem of transfer, how to transfer knowing from one situation to another if the knowing is bound to the situation.

The knowledge creation metaphor transgress the problem of transfer by introducing mediating objects (Paavola & Hakkarainen, 2005). There are different strands of knowledge creation metaphors which build upon different epistemological frameworks. What they have in common is that they are concerned with generating new knowledge, which is not a particular concern for the acquisition and participation metaphors. This new knowledge might be conceptual (Scardamalia & Bereiter, 2006), activity (systems) and practices (Engestrom & Sannino, 2010) or explicit knowledge, as well as physical artefacts (Nonaka & Takeuchi, 1995). Common to all the diverse stances to knowledge creation is that learning is not seen as linear and the learning is time consuming (Paavola et al., 2004). In addition, they all start off with knowledge creation as a social activity, where the individual has a clear agency (Paavola & Hakkarainen, 2005). When new knowledge is created, the teacher does not know the correct answer. This means that the teacher has another role than in 'traditional' teaching. The teacher is the leader of the work process and explores methods and results with students.

*Teaching*
Planning and teaching are iterative processes, where previous teaching and the teacher's interpretation of it influences the planning of the next. The subject matter that is planned and taught has its justification in the curriculum. The formal curriculum given by the authorities states the objectives and (competence) aims. The teacher interprets the formal curriculum into what Goodlad (1979) calls the operational curriculum, the one that is taught. However, that which is taught is again interpreted by the students (the experienced curriculum). Aims guide and direct teaching and learning (Gundem, 1991) and has thus an important role in clarifying what the subject matter is and what a 'good' outcome of the activity is. Clear or precise aims in the form of learning outcome will reduce the interpretative space for teachers, but it is easier to measure the 'quality' of the outcome (i.e., has the student learned what he/she should?) (Gundem, 1991). Biesta (2010) asks the provoking question if we end up valuing what we can measure, and that forms of knowledge that are not easy to measure are removed. Further, this can lead to a 'technician' approach to education, where aims come from 'elsewhere' and it is all about finding the best practical solutions. Skjervheim (1992) associates the technical approach with an instrumental and authoritarian approach to education.

Teaching is obviously a complex activity. The teacher uses different sources of knowledge and incorporates these in planning as well as the on the spot actions (Barnett & Hodson, 2001). Some of this teacher knowledge is about the relation between the students and the subject matter; what the students find difficult, how to present and the judgement of how the students can work with this subject matter. This is what Schulman (1987) calls pedagogical content knowledge and is a mixture of pedagogy and subject matter that results in knowledge about how "*particular topics, problems, or issues are organized, represented, and adapted to the diverse interest and abilities of the students*." (Schulman, 1987, p. 8). In addition to pedagogical content knowledge, the teacher has (should have) knowledge about pedagogy, science concepts, theories and processes as well as knowledge *about* science – or what Barnett and Hodson (2001) call academic and research knowledge. The teacher needs also to know something about the students in the classroom, e.g., their aspirations and interest. This 'classroom knowledge' is entirely situated, although an experienced teacher will draw upon previous experiences and adapt her stance toward teaching as result of the interaction with the students in this particular situation (Barnett & Hodson, 2001). All this knowledge is the basis for the rhetorical decisions the teacher makes as main rhetor.

The teacher is also influenced by the discourse of education in society in general and the 'teacher lore' in the staffroom (Barnett & Hodson, 2001). The teacher lore can be coupled with myths about teaching, as it is strong folk-beliefs and not necessarily based on theory of any kind. Tobin and McRobbie (1996) suggest that there are some strong cultural myths attached to teaching. The first of the four myths they address is the transmission myth. This is the 'folk-view' that the teacher is the principal source of knowledge and that the students are receivers of knowledge. I connect this view of teaching to the acquisition metaphor of learning, as the students are to acquire the knowledge the teacher presents and facilitates. Further, the transmission myth is linked to an objectivist view of knowledge, learning as memorizing and a belief that the teacher should have power over students in most situations. The second myth is that of efficiency. Time is in short supply and covering content is more important than learning with understanding. However, the external pressure from curriculum and school authorities gives restraints for how much time to spend on a theme. This external pressure might, however, be more 'felt' than 'real'. The third myth is that of rigour. The students need to learn so they can continue with science studies. The last myth is to prepare students for their exam by preparing them to retell 'the right answers'.

For many teachers, there seems to be outer constraints to their practice and that their practice is not optimal due to these constraints.

> In common parlance a restraint is akin to an excuse. In ideal circumstances an individual might believe that a particular set of behaviours is appropriate, but because of the context that apply, a different set of behaviours is deemed appropriate.
> (Tobin & McRobbie, 1996, p. 226)

The constraints that the teacher – and I might add students – perceive are real for them and thus influence the choices they make in the situation. The ideal will perhaps always differ from reality, but there will be possibilities. How these possibilities are acted out is closely linked to the objectives of the subject matter.

## 10.2. Why learn science?

This section deals with the arguments for learning science. In this section, there will be some overlap with the coming sections. It is almost impossible to provide arguments for school science without relating these to subject matter. However, this section has the purpose of opening up some subject matter issues that will be further explored in the forthcoming sections. The objectives in the Norwegian curriculum are the starting point before science education literature is used to structure arguments. As the curriculum is a curriculum for all students and the democratic argument for learning science is put forward in the curriculum, this will be more thoroughly deal with later in this section.

The Norwegian science curriculum is science for all, as all students who attend upper secondary school, and that is most adolescents, have the same curriculum (vocational students have a lesser version). So how is this science course legitimized through the objectives?

> Knowledge on, understanding of and experiences in nature can strengthen the will to protect natural resources, preserve biological diversity and contribute to sustainable development. In this context Sami and other indigenous peoples have knowledge of nature that it is important to respect. Natural science shall also help children and young persons attain knowledge and form attitudes that will give them a considered view of the interaction between nature, individuals, technology, society and research. This is important for the possibilities the individual has to understand various types of natural

> science and technological information and shall give one the basis for participation in democratic processes in society.
>
> (Utdanningsdirektoratet, 2006)

The first part of this citation provides the subject a purpose that might be considered as values that are recommended to attain through school science by the use of the words 'protect', 'preserve', 'contribute to sustainable development' and 'respect other kinds of knowledge of nature'. The middle part can be understood as a purpose connected to understanding science and technology as part of our society – as part of our culture. A 'considered view' can be interpreted as a critical attitude (i.e., the opposite of uncritical). The last part is about democratic participation. The values in the first sentence might very well also be linked to democratic participation. These are perhaps values that are wished for in the citizen? In the end of the objectives there is also a sentence about that science (shall) give "*good basis for vocational training, further studies and lifelong learning*". This can imply that the curriculum also puts forward utility for the individual.

What does science education literature have to say about why to learn science?

#### 10.2.1. Arguments for school science

There are different categorizations of the arguments for why to learn science. Variations over the theme are found in several authors (see, e.g., Wellington (2001), Osborne (2010) and Sjøberg (1998)). I choose to start with some of the first and often cited sources, Thomas and Durant (1987) and Millar (1996).

Thomas and Durant (1987) state that 'everybody' agrees that public understanding of science is a 'good thing', but that the arguments for public understanding vary, and that this in turn will effect what type of science is taught in schools – and what emphasis to put on it. They identify nine different arguments for having science as a school subject. They then group their arguments for public understanding of science into three; economic, enhancement of lives of individuals and the welfare of the society as a whole. Millar (1996) refers to Thomas and Durant (1987), but groups the arguments into five categories. Millar's starting-point is that there seems to be a poor outcome regarding students' knowledge, and he asks "*Do many students achieve little in science because they simply cannot see the point of it?*" (Millar, 1996, p. 8). So, why learn science? Millar's five arguments are as follows:

*The economic argument:*

> that there is a connection between the level of public understanding of science and the nations' economic wealth. (Millar, 1996, p. 9)

To maintain wealth requires a steady supply of technically and scientifically qualified personnel. This seems to be a problem in most western countries today and Aikenhead (see e.g. (1997)) calls this the 'leakage of the pipeline'. Thus, it is important to also attract other young people to science and not only those already inclined towards it (Hodson & Reid, 1988).

*The utility argument:*

> that an understanding of science and technology is practically useful, especially to anyone living in a scientifically and technologically sophisticated society. (Millar, 1996, p. 9)

Knowing science is claimed to make individuals make more knowledgeable decisions about, e.g., diet, health, safety and what goods to purchase. Some scientific skills might also be useful outside of school, such as, e.g., measuring and assessing accuracy, representing data and "troubleshooting" (J. Wellington, 2001). However, the principles of science and technology can be difficult to apply in an everyday setting (Osborne, 2010) and there might be problems with transferability (Wellington, 2001). Moreover, modern technology artefacts seldom demand scientific knowledge to use (Sjøberg, 1998). Also, in everyday life, there is little need to 'think scientifically', as 'everyday reasoning' is sufficient (Jenkins, 2007). There is also another aspect of personal utility, the student's need of science for further studies or work. This is an argument put forward in the curriculum.

*The democratic argument:*

> that an understanding of science is necessary if any individual is to participate in discussion, debate and decision-making about issues which have a scientific component. (Millar, 1996, p. 9)

This argument is important for many science educators (see, e.g., (Hodson, 1994; Hodson & Reid, 1988; Jenkins, 1999; Kolstø, 2001; Osborne, 2010)). The ultimate aim for any (Norwegian) school subject is, of course, to prepare students to be full participants in society (Utdanningsdirektoratet, 1994).

Citizens can be seen as consumers of science, as they encounter science through mass-media in the form of, e.g., reports about what is healthy or not. It is thus important that citizens can relate critically to the information and be able to take part in discussions (Hodson, 2010; Millar, 2006). However, there are some problems regarding this argument. Many of the issues that lay people need to consider as part of a democratic society are only partly scientific, there will almost always be components of economic, ethical and other societal elements, as well as affections involved in arguments in the public debate (Jenkins, 1999; Kolstø, 2001). Thus, one might say that these issues are complex. State funding of research is also a democratic issue. Citizens should have the possibility to influence research policy and how taxes are spent.

*The social argument:*

> that it is important to maintain the links between science and the wider culture. Specialization and the increasingly technical nature of modern science is seen as a social problem, leading to incipient fragmentation – and the alienation of much of the public from science and technology. (Millar, 1996, p. 9)

This can be seen, e.g., in ‘new-age language’ where scientific concepts are used in an un-scientific way, and in alternative explanations such as creationism (Sjøberg, 1998). The other side of this argument is that if the public has a greater understanding of science, it will lead to greater support of science and technology (Millar, 1996).

*The cultural argument:*

> that science is a major – indeed, the major – achievement of our culture and that all young people should be enabled to understand and appreciate it. (Millar, 1996, p. 9)

Many theoretical and practical inventions in science and technology have left a strong imprint on how we understand ourselves as human beings and how we understand the world we live in, but perhaps not all inventions are equally appreciated. As part of the Norwegian culture, there has been an emphasis in science education to appreciate nature and such has implied a weight on an eco-friendly approach in school science (Sjøberg, 1998). This argument is found in the Norwegian curriculum.

All of these arguments – to various degrees – will form a backdrop for the curriculum, subject matter and specifications for how to work with it. The chosen subject matter and the balance between different parts of subject matter will depend upon our arguments for science education (Hodson, 2006). If too much emphasis is put on utility, there is a risk that the democratic argument is given an instrumental note to it or that science as a cultural activity might be lost in science education (Smith & Gunstone, 2009).

Underlying the deliberations between these arguments there are some tensions (Wellington, 2001). First, is the aim of school science primarily to shape citizens with a ‘sufficiently good’ understanding of science or is it to shape and prepare the scientists of the next generation? Between the two groups there will possibly be conflicting interests and different needs in respect to content and probably also how the subject is taught. If school science is presented as an enculturation into the disciplines of science – preparing the next generation scientists (economic argument) – this is science education where ‘real’ science is the basis, not the student as citizen (Aikenhead, 2004; Roberts, 2007). The second tension Wellington (2001) addresses is the old conflict regarding whether science as a school subject should be based upon utility for life here and now as well as future including work or the intrinsic worth of the subject itself. This tension can be linked to the question of status, as academic and not directly useful knowledge has had the highest status within the school system (Smith & Gunstone, 2009). On the other hand, if school science is seen as a means to make students participants in local and global communities in which science is an important influential factor, then the utility, cultural and democratic arguments for science is foregrounded (Aikenhead, 2004).

### 10.2.2. The democracy argument elaborated – science for all citizens

Democracy is emphasized in the science curriculum objectives. What might this entail? Science and technology play a large role in modern society. Many of the issues in contemporary public debate are science-related, e.g., energy production and consumption or use of gene technology.

Democracy is in itself not an unproblematic term, as how the ideal of democracy is acted out in society may take different forms, and there are different opinions of both the ideal and how it is done. In this thesis, I choose not to go into what democracy is and should be; it would be outside the scope of this thesis. I see democracy as one of the foundations in the contemporary political system. Partaking in democracy entails taking stances and being able to act accordingly. Further, the stance taken should to the best possible degree be based upon reasoned arguments. In science-related issues, this will mean weighting arguments also from outside science (ethical, economical, political). However, in science issues weighting scientific evidence and methods are of course central.

The curriculum as well as the school system and that which happens in every classroom, is not neutral. There will be ideologies inherent in curriculum (Aikenhead, 2010; Roberts, 1988), as well as in the semiotic actions in the classroom. These different 'levels of ideology' might however not be aligned completely. In the expressed ideology, there is a stance toward the subject matter and students. The stance toward students and subject matter influence each other. If students are regarded as 'in the waiting room' before entering society, this will have an impact on the approach to students, as well as to the subject matter. If students, on the other hand, are regarded as persons who are and should be able to think for themselves and be active participants, an approach to the subject matter is required where students are not only consumers of science facts, i.e., a subject matter that is to be recalled on tests.

Empowering students to take a stance on science-related issues as well as enabling students to actively participate in democratic processes I see as vital parts of enacting the democratic ideals. Science for all envision that it is possible to engage all students' hands and minds in scientific investigations "*and thereby, contributing to their intellectual and moral development as citizens in a democratic community*." (Jenkins, 2000, p. 213). I thus link 'science for all' to the democratic objective in this thesis. School science is part of shaping all students' knowledge and attitudes.

But what might democratic participation be when the issue is science-related? To explore this I choose two different studies in a vast field of democracy and education. One study is from the realm of school the other on how citizens might deal with science in society. I discuss the latter first.

In a meta-study of 31 empirical case-studies of lay persons dealing with science-related problems, Ryder (2001) has identified forms of scientific understanding which were required by these persons. The case studies were over a range of different scientific disciplines and settings, such as public inquiries, health issues, media coverage of science, etc. A number of these studies feature science as controversial in the sense that it is contested or tentative; this might be the reason why these topics where chosen for the studies – and thus provides a somewhat biased view of science. The cases involved individuals making choices whether or not to engage in science. The scientific understanding the lay persons thought were relevant where over a wide range of fields (though, not all fields in all cases):

- Subject matter knowledge (in some cases this was not subject matter knowledge that was taught in school because it was science-in-the-making or was beyond the scope of school science)
- Assessing quality of data and study design
- Interpretation of data (assessing validity and reliability, considering alternative explanations, and that interpretation of data involves other knowledge sources than data)
- Modelling (assumptions within models, modelling errors)
- Uncertainty (e.g., science-in-the-making and the role of consensus - and consequences of uncertainty)
- Communicating of science (the role of disagreement, and how language is used in science)

Each of the points above is further elaborated upon in Ryder's study, but here it will be beside the point to make a very detailed list of scientific understanding related to these cases. Kolstø (2001) has many of the same elements in his list of content-transcending topics that makes it easier to examine socio-scientific issues. One of the points that Kolstø makes that is not incorporated explicitly in the list above, is the need to be able to discriminate between normative and factual statements to be able to judge the trustworthiness of claims. Moreover, Ryder's meta-study presents a view of what type of knowledge citizens needed in actual situations compared to what is emphasized in school science. School science has traditionally focused (solely) on subject matter knowledge and very little on the epistemic or communicational aspects of science. Ryder's recommendations for science education in a life-long learning perspective is to put more emphasis on knowledge *about* science as well as empowering students to ask good (scientific) questions and develop a positive attitude so that they in the future can engage in scientific problems and controversies as informed lay people. For most people, their interest in science is linked to decision-making and that they use other sources of knowledge, arguments from other domains (such as ethic or economy), together with scientific knowledge (Jenkins, 1997; Kolstø, 2001). Judgement and risk are also important factors when dealing with science in the public domain (Jenkins, 2000).

In the article "More than particle theory" Citizenship through school science, Sperling and Bencze (2010) describes and discuss an action project for a group of seventh grade students in Canada. The students made action plans on waste management and they set their plans into 'life'. In the project, the students could involve other people as well as themselves (e.g., family). This project sought to provide a link between learning science and being an active citizen and making eco-friendly choices. The students could choose the representational form for their action plans which resulted in quite a variety of products. In the conclusion the authors state:

> *students' orientations toward citizenship seemed to be enhanced when they had the opportunity and resources (intellectual and physical) enabling them to engage in personally meaningful reciprocal relationships between phenomena of the world (e.g. garbage) and representations of them*".
> (Sperling & Benze, 2010, p. 265)

Both Ryder and Sperling and Bencze are referring to people/students who are using science in a meaningful context. Smith and Gunstone (2009) also advocate for a position where science learning is connected to contextual aspects, but they, in addition, claim that learning the 'habits' of science might enable students to gain the knowledge they need in the future. A contextualized view of science in schools is when there is a balanced presentation of content, process and context (Bryce, 2010). The contextualized view of science will perhaps allow more room for affections, speculations and personal engagement. The traditional way of enacting the science subject leaves little room for affections (e.g., the feelings of wonder or excitement) as well as speculations over the 'big questions' (Fensham, 2002). When engaging in contextual science, students have the possibility of being critical users of science (Millar, 2006; Ryder, 2001). This can be linked with Feinstein's (2011) notion of students as competent outsiders, and he states that what we are currently doing in school is "*producing marginal insiders*" (Feinstein, 2011, p.180). Marginal insiders refer to students who are expected to (only) describe and explain science without connecting science to society at large. Feinstein further claims that when it comes to engagement with science, creating students as marginal insiders probably does more harm than good, see also Fensham . The overall aim of contextualized science is to use science in a process of personal or societal decision-making and thus foster a democratic attitude toward citizenry and personal empowerment (Hodson, 1994, 2010).

Finally, I will present some reflections on the problems that might be associated with science for all citizens[15] in a democracy. First, the learning outcome of contextualized science and science inquiries might be more diffuse or not so easy to measure, giving rise to problems of assessing the products of students' work. There are few correct answers. The process is perhaps even more important than the 'outcome'. This undoubtedly will influence the relation between teacher, students and subject matter.

If a contextualized or personalized approach to science is seen as a necessary requirement, then this opens up the problem of how do we assure ourselves that students can use this competence in other situations? This is the problem of transfer (Beach, 1999). Transfer of knowledge from school to everyday life is of course also a problem in 'traditional' science education. To address the transfer problem calls, in my opinion, for a greater emphasis on meta-reflection by making learning about

[15] To avoid misunderstanding, I view students as citizens although they have not (yet) the right to vote in elections. Students are members of society.

knowledge, methods and results explicit. Learning to learn can be coupled with meta-reflection. Students working with larger and more complex problems need to approach learning differently than when learning ‘facts’.

Another problem is how school is organized through lessons, classes, subjects, and the teachers’ division of work. This compartmentalizing of school makes it difficult for teachers to cooperate (Bjønness, Johansen, & Byhring, 2011). There is also reluctance by teachers to deal with uncertain science and ethical problems (Bencze & Carter, 2011; Hodson, 2003; Oulton, Day, Dillon, & Grace, 2004). Uncertain science and science in society is far from the tradition in which most science teachers are educated (Bryce, 2010). If students are to make their own opinion, this means that they also must be ‘allowed to’ disagree with the teacher. Students disagreeing with their teacher on the subject matter will have an impact on the power relations in the classroom. The teacher is no longer necessarily the one who knows and knows best in all matters.

There is a tension between science for students as citizens and science for future scientists. According to Smith and Gunstone (2009), this does not need to be perceived as a problem, as students who are going to be scientist also are citizens and thus need to see science as part of the whole society.

The last problem that will be mentioned here is the problem of what is relevant scientific knowledge when doing science in context. As Ryder’s (2001) meta-study shows, many people were dealing with knowledge that was outside the scope of school, or so ‘new’ that it had not yet been ‘filtered’ into the textbooks. We also know very little of what scientific knowledge students need to deal with future issues. What type of science knowledge is the issue of next section.

*Some comments at the end of the section*

School science is seen in the curriculum as a part of the democratic and cultural shaping of students. However, I believe that the large number of competence aims act more towards preparing the next generation of scientists (i.e., the economic argument). On the whole, there seems to me to be an unresolved tension in the curriculum between science for all students and science for future scientists. Moreover, if taking a stance in science-related issues and taking action is best learned when the subject matter is contextualized, this raises some challenges for teaching and learning science. There are no formal obstacles to relating the issues in the curriculum to local or global contexts, but the many aims that are to be covered in what is probably perceived as too short a time, as well as the school tradition of rigour, efficiency and exam, prevent science from being personalized. Personalized science would mean that students can take stance and act.

For students, it is highly likely that they need to see an explicit purpose of what they are doing (learning). Aims without purpose might become instrumental. The purpose can be linked to the activity but there is also a need to see the bigger picture: What learning science can contribute to students’ life – present and future.  Perhaps if students see the science course as preparation for further studies in science (which they are not going to), their learning becomes more 'acquisition' and they see less of a point for creating meaning in school science.

The remaining portion of this chapter is exploring in more depth science subject matter, communication in science and process aspects of science. At the end of each of these sections, I draw some connections back to 'science for all'.

## 10.3. What is science knowledge? Subject matter in science.

The objectives in the curriculum provide the following stance toward science subject matter:

> The laws and theories of natural science are models of a complex reality, and these models are changed or developed through new observations, experiments and ideas. In our general knowledge it is important to realise that natural science is developing
>
> (Utdanningsdirektoratet, 2006)

Scientific knowledge is seen as models of reality, not reality in itself, and that these are developing through (an interplay) of empirical and theoretical work. Later in the objectives, there is reference to science as having different disciplines, but these are to be integrated into a holistic school subject. The curriculum is divided into content themes that are partly interdisciplinary. Within each of these content themes there are several competence aims that specify what is to be learned.

This section will give a short overview of 'real science', before turning to literature on science subject matter and what 'learning about science' might entail. Practical work and inquiry is not here regarded as 'what' but rather as 'how', so it will be dealt with in full in a later section.

### 10.3.1. 'Real science' - and scientific knowledge

As a description of 'real science' would be (at least) a thesis in itself, I will only seek to explore what the curriculum stance toward science might denote.

Modern science is characterized by fractionation of science into sub-disciplines and the emergence of new disciplines (Jenkins, 2007). There has also been a blurring between technology and science (Jenkins, 2007). School science will draw on these disciplines and sub-disciplines. For example, the themes 'Energy for the future' (heat pump) and 'Biotechnology' (DNA-coding) are both drawing upon both old and well-established scientific knowledge, as well as new knowledge and technology.

The scientific community is constantly creating new knowledge, although some of the 'old' knowledge still 'works well', e.g., Newton's law of gravity, and is considered part of the established body of scientific knowledge. According to Ziman (2000), what is agreed upon as established knowledge between researchers may vary. There is not *the* canon. However, science in the making also gives new insights to the established body of knowledge, e.g., to Newtonian gravity. There is thus a provisional or tentative aspect of science (Giere, 1999; Ziman, 2000). Chalmers (1999) states that any part of the web of aims, methods, standards, theories and observational facts can be progressively changed and that the rest of the web is the background for which the change can be made.

The objectives in the curriculum state that laws and theories are *models* of a complex reality. What might this imply? To explore this I turn to Giere, a philosopher of science. He positions himself toward a naturalistic methodological commitment. The naturalistic approach tries to avoid a priori claims (Giere, 1999) about knowledge in science. In his argumentation, he sees laws as models. These models are representations and interpretations of reality. As an interpretation, the model will be partial. These models fit more or less with the reality the model is aiming to map. Thus a good theory will be a good fit with reality, but it is not reality. It is a representation of reality. The question of 'truth' becomes a question of how good a fit the model represents (Giere, 1999).

> So the model of the world held at any given time might have been different if historical contingencies had been different. On the other hand, most scientists and philosophers, and not just scientific realists, regard the truths about the world as fixed.
> (Giere, 1999, p. 77)

The curriculum advocates a view of knowledge in science that is perhaps not the 'common' stance toward scientific knowledge. Science is sometimes 'accused' of empiricism. An empiricist stance implies a view that knowledge is based upon direct sensing and that nature shows itself through the senses. Empiricism in scientific epistemology is understandable, as there is a strong belief that direct experience provides secure knowledge (Ziman, 2000). Perhaps the 'objective voice' in science writings sustains this stance, as the phenomenon gets a life of its own (Halliday, 2004; Sutton, 1998). Abd-El-Khalick (2011) claims that even if scientists do science – and do it well, this does not mean that they think more clearly than others about underlying epistemological and ontological beliefs. Epistemological and ontological frameworks are rarely made explicit during the apprenticeship of scientists (Bryce, 2010). The practice of the scientist might be more 'advanced' than the espoused views of the practice.

Baird (2004) gives another perspective on models, where models are physical representations of some aspects of reality. Models might be made in reciprocity between different 'facts'. The historical case of modelling the DNA is an example of this. Pieces of facts such as the known bases, knowledge about chemical bonding and that there was some type of backbone on which the bases came together in a physical ball and stick model. The salient features of this model were bonding distance and the atoms/molecules. Non-salient features were, e.g., that in this static model there was no allowance for atomic movement, and the atoms were represented as balls. So, a model highlights some features of the phenomenon it represents and suppresses other. Another point Baird (2004) makes is that the model makes it possible to generate theory in interchange with existing theory, but through the physical objects as the first steps of theory generation. The physical model might be treated as a (almost) non-verbal resource. To understand a model, there is a need to know what part of the model denotes what part in the real object. The 'thingyness' of models can thus act as both a separate way of understanding and as a part of generating verbal knowledge (transduction from physical model to verbal expressions).

The curriculum has incorporated 'modern' themes such as biotechnology and energy for the future. These are themes that both draw on what we might call established knowledge as well as 'science in the making'. There is much research in these fields. Some of this research is corporate, i.e., it is driven by commercial interest. This might give rise to some challenges, as corporate interests might not be concurrent with communal interests. For instance, results might be withheld if they are not in the interest of the company (Ziman, 2000).

### 10.3.2. School science and subject matter

School science often analytically splits into three or four parts; learning science (facts, laws, theories, relations etc.), doing science (methods and processes) and learning about science (NOS). Hodson (2009) incorporates a fourth part engaging in socio-political action. Doing science will be dealt with in section 10.5 and engaging in socio-political action was briefly dealt with in the previous section. First, I will give some critical comments on school science content and then present something that might be an alternative, before presenting some perspectives on learning about science.

*The relation between school science and 'real' science*

If 'real science' is what scientists do then this practice requires both long formal and informal training to be able to apply theoretical models and procedures of the discipline. So it would be wishful thinking to think that students could be 'a little scientist' (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Jenkins, 2007). School science is different from real science in many ways. Resources such as equipment, labs and time provide very different conditions for school and 'real' science. In addition, there is a substantial difference in students and researchers' scientific knowledge. But perhaps the most important difference is the scope. Students in school are to *learn* science. This implies that they also have to deal with the established body of knowledge, whereas 'real science' has the aim of producing new knowledge. What type of science is taught in schools?

> Historically, secondary school science education has allied itself with academic science –Its function was essentially pre-professional and its content determined, however vicariously, by the academic scientific community. (Jenkins, 2000, p. 211).

Contemporary science courses have their roots in a tradition where the aim was to educate future scientists (Fensham, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). This can be connected to the economic arguments for learning science in school (see 10.2.1), where it is seen as important that schools provide those students who are planning to continue studies in science with a solid foundation (Roberts, 1988). Smith and Gunstone (2009) claim that a science-centred curriculum, i.e., a curriculum that starts with the premises of science and not students, fails most students.

As the body of scientific knowledge has 'grown' – the curriculum has 'grown'. Fensham states there seems to be themes taken into the curriculum but few are taken out:

> Hence, the science content, which is now intended to be covered by all students in the compulsory years, exceeds what was previously expected for all but minority of students – ignoring the previous dictum of better learning and a disastrous recipe for 'science for all'. (Fensham, 2000, p. 150)

A packed curriculum is for future scientists (Smith & Gunstone, 2009). The Norwegian science curriculum has many competence aims. There are 51 verbs that specify what the students should be able to do and there are most often many entities connected to each competence aim. Further, many of the aims are on a low taxonomic level, as they are given as 'describe', 'elaborate' and 'explain' (i.e., give established explanations) and there are relatively few 'assess' and 'discuss'. I claim that the curriculum can be read as if the primary purpose of the subject is to prepare students for further studies.

When the competence aims require descriptions, elaborations and explanations, it is most often connected to established scientific knowledge. In fact, most of the aims rely on established scientific knowledge, but there are also competence aims that deal with the uncertain (e.g., "*discuss the importance of heritage and the environment*"). However, when there are many aims and little time, the more open aims are perhaps treated shallowly. This I connect with the myths of teaching (efficiency and preparing students for exam), see section 10.1. Further:

> The science in classrooms are often given an 'air' of certain, that it is apolitical, reduced from a creative activity to little more than a series of algorithms – and it has a certain positivist ring to it. (Jenkins, 2000)

The "*ideology of objective truth*" as Lemke (1990) calls the presentation of facts, not to be argued with and without reference to theory dependence, research interest and so on. "*Science is presented as authoritative, and from there it is a small step to its becoming authoritarian*." (Lemke, 1990, p. 138).

If students lack trust in the relevance of the curriculum content or the teacher's presentation of it, it might be a hindrance for students' (future) learning (Fensham, 2000). If students do not understand why they are doing this, or they do not share the enacted objective, they might be regarding science as 'somebody else's' and will likely lead to resistance. As Osborne states:

> even our future scientists would be better prepared by a curriculum that reduced its factual emphasizes and covered less but uncovered more of what it means to practice science. (Osborne, 2010, p. 52)

*Learning about science*

There seem to be overlap between how students talk about their own practical work and what they believe scientists do (Kind, 2003). So, what is done in science class is probably important for the students' view of 'real' science. Students need to know something about how scientific knowledge is produced, evaluated and communicated, to be able to relate critically and constructively to scientific findings (Hodson, 2009). In other words, students need to learn *about* science.

There seems (to me) to be, more or less, an overlap between how the terms 'nature of science' (NOS) and 'learning *about* science' are used. Perhaps the term 'learning *about* science' is broader, as it (possibly) involves more than nature of science. I choose to use 'learning *about* science' but will of course use 'NOS' where author does.

There is no general agreement about what nature of science entails (Lederman & Lederman, 2011), as this implies a 'definition' of science. However,

> nature of science refers to the characteristics of scientific knowledge that are directly derived from the process/method used to develop the knowledge. (Lederman & Lederman, 2011, p. 336)

Nature of science thus refers to epistemological questions about science – how do we investigate and find evidence for conclusions. In addition there will be ontological questions, e.g., how 'real' are the scientific models and explanations. Even if there is disagreement on what this means for science, as there are different positions to what scientific knowledge is and how it comes about (Longino, 1990), there is little disagreement about NOS when it comes to what ought to be taught in compulsory science (Lederman & Lederman, 2011). They identify some characteristics of scientific knowledge that are important in school science:

- Scientific knowledge is tentative or subject to change
- Scientific knowledge is empirically based or derived from observations
- Scientific knowledge is subjective as it is theory-laden and involves personal background
- Scientific knowledge involves inference, imagination and creativity
- Scientific knowledge is socially and culturally embedded

In addition, they specifically mention the difference between observation and inference and the difference between theories and laws (Lederman & Lederman, 2011).

Hodson (2009) also incorporates that understanding the language of science, scientific methods, history of science, the relationship between science and technology as well as awareness of ethical, economic and environmental implications, are parts of learning about science.

I have a comment before I start to explore the individual items. In my interpretation of Lederman et al. (1998, 2007), they emphasize what students/teachers ought to know about scientific process and knowledge. This is, as I see it, a declarative view of NOS knowledge. It is something to know. This is perhaps just a step from *telling* students the truth, but this time it is the 'truth' about epistemology and ontology. Hodson (1993a, 1994, 1998, 2003, 2009) has, as I read his authorship, a more functional approach to learning about science. He combines learning *about* science with inquiries, contextualized science and personal agency. In this thesis, I advocate that if school science is to fulfil its role as part of the democratic shaping of students, it is vital that learning about science is part of empowering students so they can relate critically to scientific knowledge, both in their own investigations or research made by professional scientists.

Scientific knowledge is tentative (Chalmers, 1999; Giere, 1999). This is opposed to the myth that science is certain and absolute (McComas, 1998). This myth is perhaps still prevailing in many classrooms? The Norwegian curriculum objectives can be read as a stance where scientific knowledge is seen as tentative. However, many competence aims deal with established knowledge. So, the teacher has, thus, to make connections from established knowledge to the production of knowledge where the knowledge is more tentative.

Observations are interpretations and from observations scientists infer 'statements' that can be used to generate further knowledge. Observations are theory dependent (Chalmers, 1999; Longino, 1990). In school science, there is a myth that observations provide direct and reliable knowledge about the world and from these observations it is possible to use induction to confirm the truth (Hodson, 2008), i.e., a positivist stance. The objectives in the Norwegian curriculum do not provide a specific stance or interpretation of observations, but it is not unreasonable to read the curriculum such that it gives a view of observations as interpretations, but it is less certain if these interpretations are seen as theory dependent.

Lederman and Lederman (2011) claim that scientific knowledge is subjective. This point is perhaps somewhat expanded by Longino (1990), as she claims that scientists through their collaboration minimize the 'effect of the individual person', although it is not possible to eradicate it completely. In a school science perspective, this can be seen as opening up differences in results by assessing methods, uncertainty and explanatory framework. Peer 'review' has thus a place also in school. This point is emphasized in the *Budding researcher* competence aims.

In the science education community there seems to be much weight on the creative and imaginative sides of producing scientific knowledge. The same is also seen in the objectives of the Norwegian curriculum. However, why is there so little talk about the need for perseverance and logic? Perhaps we would do a 'good deed' if we were to let students know that there also is a hard toil to create knowledge. This might make them feel less ‘alone’, as scientists struggle as well.

Osborne et al. have a caution toward making lists of ‘advisable’ ideas-about-science in school science. It might be presented as row of discrete parts without connection that can be taught in a decontextualized way (Osborne et al., 2003). So, what approach is feasible to take when addressing these issues in the classroom? The implicit approach relies on that the students learn *about* science while doing science inquiries (Schwartz, Lederman, & Crawford, 2004). This can be seen as the apprentice approach, learn the trade while you are doing it. The explicit approach derives from reflecting on science and making this reflection explicit (Abd-El-Khalick, 2011). Further, Schwartz et al. (2004) states that there is an instructional component of NOS elements in relation to inquiry and that these NOS elements should be planned through objectives and assessments. However, relatively little weight seems to be put on learning *about* science in schools.

> Epistemological and related issues generally receive scant treatment in science education at any level of within the educational system (Jenkins, 2000, p. 218).

Why is this so? The teacher’s views and knowledge of the important ideas about science will influence practice (Bencze, Bowen, & Alsop, 2006; Tsai, 2002). However, on this point there are also contradictory findings. It seems that teachers adapt to students or what the teacher perceives as students’ abilities (Hodson, 1996). In a study of 12 teachers in New Zealand, with a teaching experience of 2-23 years, some interesting results ‘appeared’. The teachers were interviewed on their nature of science views and their practice was observed. This research indicates that teachers change their stance in response to the subject matter and perceived ability of the class. Teachers are more inclined towards an inductivist stance with biology topics and those students regarded as having lower ability (Hodson, 1993a). In general, this group of teachers were less inclined to cede control to students perceived as less able (Hodson, 1993a). Some similar findings were made by Kang and Wallace (2005). Their study, based upon interviews and observation of three experienced teachers, indicates that the teacher with the most ‘advanced belief’ about science chose not to include tentativeness in the outcome of practical work. Science is secure knowledge was the message to the students doing practical work, even if he himself held another opinion. Kang and Wallace provide some possible explanations. ‘Real’ science is being separated from school science, i.e., there is another set of ‘rules’ for school science and students are consumers of science rather than producers. The authors claim this leads to separating students from science. The teachers must negotiate between their epistemological beliefs, instructional goals and how they perceive the students’ needs (Kang & Wallace, 2005). Some of the same conclusions are drawn in a study where NOS was not among the important elements when pre-service teachers were planning and carrying out lessons. The students’ interests and needs were more important, as well as helping students develop their scientific practice (Abd-El-Khalick, Bell, & Lederman, 1998). Explicit NOS seemed to be less important than other content. In a study of four primary teachers’ engagement with methodological and epistemological questions in the classroom, Waters-Adams (2006) found that the teachers' beliefs about the children and their learning superseded their view of NOS. To deal with NOS and inquiry, the teacher needs both the knowledge and pedagogy for handling these issues (Schwartz et al., 2004). My view in this thesis is that the teacher's initial beliefs *about* science are of less importance. What is interesting from my perspective is what the teacher *does* (semiotic actions). However, of course, the teacher needs to have knowledge about epistemological and ontological questions.

The students seem to change their views on NOS to more 'advanced' views when NOS issues are treated as part of inquiry, especially when it is used in combination with discussions, reflections and/or argumentation activities (Deng et al., 2011). This is also reported by Yacoubian and BouJaoude (2010).

*An alternative subject matter?*

What we do not know, is what kind of science students will encounter as adults, or what science they need to learn at school to deal with problems and choices in the future (Muller & Young, 2008; Sawyer, 2008). This means that school has an important mission in enabling students to see themselves as persons who are interested in science-related questions and can handle these questions sufficiently well.

The curriculum project Beyond 2000 formulated some recommendations for school science. A problem they identified in the current system was that too many students finish their education in science with good results and yet "*lack any familiarity with the scientific ideas they are likely to meet outside school*" (Millar & Osborne, 1998, p. 2-3). Their arguments were that individuals need to understand how scientific evidence and claims are made, as well as assessment of risk and ethical implications of choice. School science also fails to sustain the feelings of wonder, curiosity and inquisitiveness. This they attribute to the curriculum as a 'catalogue of discrete ideas' lacking coherence and relevance. In addition, they pointed at unclear aims, assessment based on memorization, and the low emphasis on those scientific issues that permeate contemporary life.

Two of their recommendations are very relevant here:

- Recommendation 3: The science curriculum needs to contain a clear statement of *aims* – making clear *why* we consider it valuable for all young people to study science, and *what* we would wish them to gain from the experience. These aims need to be clear, and easily understood by teachers, pupils and parents. They also need to be realistic and achievable. (Millar & Osborne, 1998, p. 2011, emph. in origenal)
- Recommendation 4: … Scientific knowledge can best be presented in the curriculum as a number of key 'explanatory stories'. In addition, the curriculum should introduce young people to a number of important ideas-about-science. (Millar & Osborne, 1998, p. 2014)

A key explanatory story might be exemplified by how matter can be broken down - in several steps – to sub-atomic matter. The point of the stories, rather than 'the atom', is to create a sense of understanding that our everyday observable world is connected to a scientific way of seeing the world. The stories thus form a framework for inter-related ideas, without being loaded with detail.

*Some comments at the end of the section*

By avoiding teaching and learning *about* science, such as science as tentative, as interpretative and as models of reality, there is a risk that the students are given an image of science that is distorted compared to the enterprise of professional or 'real' science. School science might become so simplified that it provides little contribution if students are to use the knowledge in socio-scientific issues. However, the school tradition in science and in science teacher education puts little weight on epistemological and ontological issues. One has to read the curriculum very careful to identify the stance taken toward knowledge, and the many descriptive and explanatory aims (established explanations) perhaps sends a signal that is contrary to 'tentativeness' and 'models'. Another aspect of the curriculum stance toward epistemology and ontology is that it seems to be contrary to folk-theories about science. Perhaps both the teacher and students' expectations to generating scientific knowledge are (slightly) positivistic. Perhaps teaching and learning become less complicated if the results of practical work are true and knowledge is certain?

From a 'science for all' perspective, it seems to be important that the curriculum is not packed, so students can work properly with the scientific ideas and methods in order to become competent outsiders. This can imply that students work with science connected to problems that they find relevant or useful. Or, if it is not directly useful, the teacher has the task of arguing for relevance. Moreover, it is important to make reflections *about* science explicit for the students. If the students are to be able to be proficient users of scientific ideas and results in science-related issues, they need to have some understanding of the epistemology and ontology of science through learning *about* science. The teacher has thus to facilitate the exploration of differences in scientific ideas as well ideas *about* science in classroom communication.

## 10.4. Communicating science

In the science curriculum, there is an emphasis on basic skills. The basic skills listed are; being able to express oneself orally and in writing; being able to read; numeracy; and being able to use digital tools. These are to be incorporated into the competence aims. Here, the weight is put on oral and written communication.

*Being able to express oneself orally and in writing* in the natural science subject means presenting and describing one's own experiences and observations from nature. In the natural science subject, written reports from experiments, fieldwork, excursions and technological development processes are an important part of the work. This includes the ability to formulate questions and hypotheses and to use natural science terms and concepts. Arguing for one's own assessments and giving constructive feedback is important in the natural science subject.

(Utdanningsdirektoratet, 2006)

As the school science draws on genres, concepts and representational resources from the scientific disciplines, it is necessary to say something about what 'the science language' is before returning to communication of school science.

### 10.4.1. Communication in 'real science'

Halliday (1993) suggests that there are some difficulties that are characteristic to scientific English. The same difficulties I presume would also be seen in scientific Norwegian. The first I will draw attention to is the interlocking definitions. Interlocking definitions means that describing and explaining one entity also implies the need to describe and explain other entities. This can, for example be seen in the case of heat in classical thermodynamics. Heat is connected with temperature, pressure and volume. When describing or explaining heat, it is 'impossible' to avoid at least one of the other entities. The technical terms of science organize the world differently from everyday words (Martin, 1993). Technical taxonomies give rise to another problem. According to Halliday, the concepts have little value in themselves. One of the things that contribute to making science a powerful tool for making meaning is that concepts are highly ordered constructions. These taxonomies serve as classifications. In addition, classification systems constrain thought and make alternative ways of classifying incommensurable (Hodge & Kress, 1993). Further, Halliday (1993) points out that lexical density is high in science a text, i.e., there are many technical words in a short space and these words cannot just be 'substituted' with 'plain speaking' without a loss of meaning. The last of the difficulties I will present here is what Halliday calls grammatical metaphor, i.e., a transformation of a grammatical class (verb) into another (noun). This is the nominalization that is so frequent in science. For example, expansion is a noun based upon the process (verb) to expand. This nominalization allows processes to become actors in sentences. Nominalizations play thus an important part in creating the high lexical density. In addition to these there is also what Halliday labels 'semantic discontinuity and special expressions which I will not go into here.

The science language is thus 'packed with' meaning. However, that is not all there is to 'science language'. Lemke (1998a) shows how several modes such as verbal text, mathematical equations, tables and figures in various forms interplay in a scientific text. His point is that these do not just add meaning to each other, they multiply meaning by providing different information and thus the reader of the text has to make connections between these representations. Science is thus fundamentally multimodal. Meanings can be constructed across several modes.

> *meanings are made by the joint co-deployment of two or more semiotic modalities, and such co-deployment is likewise needed for canonical interpretation.* (Lemke, 1998a, p. 110).

These representations have evolved into a form that gives familiarity even if the content is novel (ibid.). To understand the fuller function of the scientific text, one must study how the text is used, by whom, in what circumstances, and so on (Lemke, 2002). To relate critically to a scientific text embodies a range of competences apart from just decoding it.

Moreover, science is a social activity both through team-work and through peer-review and conference presentation (Ziman, 2000), as well as through the daily work where gestures, models and equations are at play alongside the spoken language (Lemke, 1998a). When science or technology 'is in the making', the language used to express provisional meanings is more metaphoric and there is much use of drawings/models and gestures (Nonaka & Takeuchi, 1995). According to Ziman (2000), reporting results through the extended dialogue between researchers is important to transcend from claims to 'scientific knowledge' in its fullest sense. This includes to lay open the evidence behind the claims.

### 10.4.2. Communicating school science

From the curriculum, I will highlight some of the terms used and explore what they might imply in a school setting. These are terms and concepts, writing, the genres of describing, explaining and argumentation, questions and classroom talk in general, as well as student-student talk during practical work. Hypothesis will be dealt with more thoroughly in the next section. Explanations are not explicitly mentioned as part of basic skills, but as both the Heat pump and DNA-coding cases are to result in explaining the phenomenon, explanations are explicated here.

I have chosen not to use the term 'science literacy' for two reasons, although it is a widely used term in science education literature. First, there is no unified view of what science literacy means, see e.g., Roberts (2007). This means that science literacy is a term that can be used for several purposes. The second point is based in the origin of the term as literacy is more oriented towards individual and useful competences - which might be assessed (Werler, 2010).

Students are to be socialized into what counts as science. From my point of view, this process of socialisation is driven by communication, see chapter 5 for further elaborations on this. How can this communication be described?
Sutton (1998) gives examples on how the language of science changes form from when knowledge is made to it 'arrives' in textbooks – or in the teacher's talk, I might add.

> (B)ut the problem is that learners encounter this product without experiencing any of the uncertainty and the controversy that was involved in establishing it. .. 'Air *is* a mixture of nitrogen and oxygen.' Just like that. These useful summaries of what we know today are not wrong, but what they fail to explain is that most of the words in those sentences were human inventions, hotly debated before they became an accepted part of current science. (Sutton, 1998, p. 30)

In addition, the writing style in academic papers (e.g., 'experiments were conducted' and not 'we did an experiment') has become an established part of the science language. Sutton (1998) claims, supported by the work of Halliday and Martin, that phrases such as this separate the investigator from that which is investigated and thus creates distance and objectivity. In school science the language (alongside other resources for communication) is used both as an "*instrument for figurative interpretation* and *as a means of attempting to transmit*" (Sutton, 1998, p. 35, emphasize in original), but Sutton claims that the latter aspect is emphasized.

*Words and artefacts*

One aspect of interlocking terms is that as they rely on each other, it might be difficult for a teacher to explicate and for students to make meaning of them. Ogborn et al. (1996) differentiate between entities that are to be explained and entities used to explain some other phenomenon. This means that the teacher and students need to work on those entities that 'drive' the explanation of the phenomenon. For students, these 'preliminary' terms might hold a promise that it is to be understood later in light of the explained phenomenon.

According to Halliday (Halliday, 2004), the technical vocabulary might not be a problem in itself, but the way these words are connected together as a whole. The structure of sentences and the use of nominalizations are part of the problem, also logical connectors seem to be difficult (J. J. Wellington & Osborne, 2001). The connectors are important as two of the underlying ideas of science are causality and sequence (Wellington & Osborne, 2001). From a social semiotic point of view: the scientific terms are multimodal and students have to juggle between modes (Lemke, 1998b). This implies that students have to learn different ways of expressing the terms and determine what is appropriate in the particular setting. Students will often struggle with the transduction from one representation to another, see also chapter 5.2.4.

Artefacts are essential in meaning-making in school science, and can be seen as (yet) another way of representing a phenomenon. Students use the artefacts according to their interests and previous experience. Artefacts act as cultural tools. According to Lidar et al. (2009), there is a need to know how to use the cultural tools (artefacts), as there are conventions for use. *"(I)t is not the artefact in itself, but the meaning of the artefact that mediates action*." (Lidar et al., 2009, p. 18). This would mean that it is not sufficient to provide students with 'equipment' or 'representations' and believe that they can use them appropriately without guidance.

*Reading and writing*

Norris and Phillips (2003) are concerned about a neglected part of literacy in science, the students' ability to read and interpret a scientific text. In their view, reading is an iterative and interactive process and means being able to interpret, analyse, comprehend and critique texts. Therefore, reading in their view is far more than just decoding words and finding 'the right answer'. This is a position for which I have much sympathy, and I acknowledge that reading science is not prevalent in many classrooms (my own included). However, I have some comments to their view. First, they claim that reading science requires a substantive knowledge of science content, and I might add – knowledge about science. This makes reading and interpreting scientific texts (from media) a difficult task for many students. Second, Norris and Phillips seem to put very little emphasis on social context and the norms toward knowledge in that context. The view of science literacy in the broader sense will affect how literacy as basic skills are performed in the classroom (Feinstein, 2011).

Wellington and Osborne (2001) claim that much of the writing in a science class are low demanding activities. They classify copying (the board) as low demanding and of little educational value. They also associate copying with a transmission- view of learning. In my view, copying the board is useful to some extent. If students have time to think while they are copying, this writing can be a source for, e.g., generating questions and aiding memory. However, the copying perhaps needs a clear purpose. To let students know the purpose of writing is important, as the students themselves might not see the relevance of writing to their learning. What the social purpose of the text is, for whom it is written and the topic will influence choice of genre (Macken-Horarik, 2002). Writing is an important part of science as it helps to organize and structure information, descriptions and explanations (Veel, 2000). A more heuristic approach to writing will require that the students try to put their 'thinking on paper'. There is thus a provisional aspect of the text produced and the text can be refined (Knain, 2008; Wallace, Hand, & Prain, 2004). Writing then becomes a tool for clarifying terms and processes, also by applying other modes than just alphabetical writing. Students need to be taught the genres of school science such as lab reports and the teacher needs to support their students in writing processes (Hanrahan, 2009; Macken-Horarik, 2002).

*Describe/Explain/Argumentation*

Mortimer and Scott (2003) differentiate between empirical and theoretical descriptions and explanations. An empirical description is statements that accounts for directly observable features of a phenomenon, a theoretical description would go beyond this. For example, the 'the water is boiling' is an empirical description, while 'the water changes state' would be a theoretical description of the same phenomenon.

Explanations focus on processes how and why things are as they are (Martin, 1993). What is a good explanation in science? (I have to admit that this has been hazy to me.) Braaten and Windschitl (2011) have categorized different epistemological positions toward explanations and their role in school science. Their categories for explanations are: explanations by the use of scientific laws, e.g., classical mechanics; explanations using statistical or probabilistic models, e.g., genetics or nuclear radiation; explanations using of causal factors, e.g., the underlying causes (multiple) for an event; explanations using major theories such as kinetic molecular theory; and a pragmatic approach to explanations where the context decides what constitutes a good explanation. From the stance of genre in the science classroom Veel (2000) has identified different forms of explanations which are partly overlapping with Braaten and Windschitl's categories, and further Veel states that there is a hierarchy in explanations, as the more 'advanced' explanations require more use of nominalizations and logical relations. However, the point is not a detailed account of different forms of explanations, but to show that there are a wide range of explanations and that what is appreciated as a good explanation will have to be connected to the subject matter – and students. Moreover, Braaten and Windschitl (2011) have pointed out the conflation of the term 'explanation' that seems to be frequent in science education literature. The first of these is explanations as explications, i.e., clarifying the meaning of a term or explicate the reasoning behind an utterance. This group of 'explanations' has great importance in the classroom because it makes phenomena more explicit, but might not necessarily be scientific explanations. Another group of 'explanations' are (simple) causation where an effect is attributed to a simple cause and thus the danger of simplifying the relations. The last group is 'explanation' as justification or argumentation, but as the authors point out, argumentation does not necessarily need to be an explanation.

From a social semiotic perspective, Ogborn et al. (1996) see difference as a driving force in communication. The difference might create a need to explain or explicate some phenomenon, as there is something 'unresolved' in the matter. They differentiate between two types of difference; between what students do not know and what they need to know; and between what students already know that runs contrary to scientific explanations and the scientific view. This means that there has to be an amount of 'challenge of views' and to make these differences explicit when the teacher stages explanations/descriptions. I would also like to add that there are differences in methods and results in practical work and inquiry that need explication, see also 5.5.2.

Argumentation is central in inquiry as students are to weight evidence and seek different explanations. The role of argumentation in science is twofold; it is learning the importance of argument in developing scientific ideas in the scientific community; and it is from a public understanding of science perspective, to be able to argue and question, i.e., critical engagement in science-related issues, as well as obtaining a more realistic image of inquiry (Driver, Newton, & Osborne, 2000). Argumentation on scientific issues (and especially socio-scientific issues) presupposes a quite extensive knowledge base (Kolstø & Ratcliffe, 2007). According to Driver et al. (2000), students are given few opportunities to practice argumentation in science class. They point out some possible reasons for the situation. First, there is the pressure of covering the curriculum, second there is the teacher's lack of skill to facilitate and organize discussions and last, but not least, the teacher's limited understanding of the nature of science.

*Talk in the  classroom*

By shifting between different communicative approaches – interactive vs. non-interactive and dialogic vs. authoritative – the teacher can, e.g., explore ideas together with the class or mark a key idea as 'fact' (Mortimer & Scott, 2003). When the teacher engages students, i.e., interactive communicative approach, the 'thinking questions' and students' own questions are of importance (Mitchell, 2010). Lemke points out that in the classroom most questions posed by the teacher are such that the teacher already knows the answer to them. The sequence of teacher initiation, response by student and evaluation by teacher is often called IRE (Mortimer & Scott, 2003). The student expects an evaluation, so if there is none this will be interpreted as a wrong answer (Lemke, 1990). The last part of the sequence might be feedback or an elaboration instead of an evaluation (IRF). The teacher's elaboration might also lead to new responses from students (Mortimer & Scott, 2003). Staging the classroom dialogue is thus an important task for the teacher. However, I like to add that as part of staging the dialogue the teacher needs to consider who is to respond and how can all students participate in the dialogue – or perhaps the teacher will be satisfied with a few responders. The teacher uses several modes such as speech, gestures and artefacts to stage descriptions and explanations, while students often are limited to words to express themselves (Pozzer-Ardenghi & Roth, 2007). This might be one part of the explanation why students find it hard at times to contribute to the classroom dialogue.

It might be salient to let students challenge content and the ways it is presented (Mitchell, 2010). When the teacher is talking to the students, the teacher may choose to use vernacular ways of expression. In an ethnographic study of an urban classroom, this type of talk seemed to promote students' meaning-making of science, as long as it was alongside the 'science language' (Brown & Spang, 2008). It might be easier for students to marshal their thoughts if they can express themselves in an everyday language. Yerrick et al. (2011) claim that students can express themselves in matters *about* science even if they lack the 'formal language of science'.

Students do not necessarily see discussions as real learning or that they might learn from other students' contributions and not only from the teacher (Mitchell, 2010). The teacher has thus to be very conscious of how science is communicated in class, also because the teacher acts a model for how science is expressed.

*Students and practical work talk*

In relation to practical work, it is important that students have a purpose of activity and the methods used, as there are many things to think about – and the student might end up not thinking about many of them. This makes it important to spend time talking about the practical work before and after (Mitchell, 2010). Roth and Lawless (2002) exemplify how students who are unfamiliar with the knowledge domain have an oral language that is brief, inconclusive, incoherent and constantly changing topic – from the researchers' perspective. It also seems that when the content is unfamiliar, the students communicate more through gestures, pointing and objects. When the student is becoming more familiar with the subject matter the communication becomes more verbalized – "*it is through a slow evolutionary process that students develops the competence to talk about the phenomena independent of their presence."* (Roth & Lawless, 2002, p. 381)

Knain and Hugo (2007) point out that the 'texts of the everyday' or the vernacular speech combined with use of tools and equipment can act as a resource for science texts (in the mode of speech and writing). This involves transduction where students create their 'own' expressions as they see fit.

*Some comments at the end of the section*
Talk is one of the main modes in classroom communication. When the teacher stages dialogues or facilitates students' talk, there is a transformation between everyday speech and the more scientific ways of expressing subject matter. Perhaps giving the students possibilities to express themselves in more than just words might help students in their meaning-making. Students will often find the 'language of science' difficult because of interlocking terms, causal connectors, genres as well as transduction between modes. The genre explanation will not look identical, as it depends upon what is to be explained. This might prove a hindrance for students making their explanations. The teacher has thus to have a clear idea of what is the expected outcome. For students, science communication might be trying, especially if they struggle with both meaning and the form to express this meaning. They need to feel emotionally secure when they try out their meanings. The teacher, as main rhetor, has thus an important task of establishing norms (together with students) for what and how science is to be expressed, that what counts as good enough or apt in the practice.

When a student has deciphered the language code of science and is able to use it, he or she is an insider. For students who are going need to be (sufficiently) proficient outsiders, they need to know something of genre, different sorts of statements and some general language features to be able to read science encountered in media and reports. When reading science outside of textbooks, it is important to assess the trustworthiness of the source, as the competent outsider cannot have in depth knowledge to match the expert. Another vital part of being a competent outsider is to understand the role of argumentation and peer review in the making of scientific knowledge, as well as being able to identify different types of arguments and the knowledge base upon which they draw. However, perhaps most important, as I see it, students need to be able to ask relevant and informed questions. Writing has a role in structuring students' knowledge, as well as providing the students with some insight on the language of science through, e.g., use of multiple modes. These are competences that are developed generically as the language is social (as is all other communication).

## 10.5. Science as process

This section is about practical work and inquiry in science; The methods and processes that are applied to obtain the 'facts' that can be expressed and from which new meaning can be constructed.

From the objectives in the Norwegian curriculum:

> Practical and theoretical work in laboratories and in the field using different theses and research questions is necessary to gain experience with and develop knowledge of the methods and approaches in natural science. This may contribute to developing creativity, the critical eye, openness and active participation in situations involving natural science knowledge and expertise. Varied learning environments such as fieldwork in nature, experiments in the laboratory and excursions to museums, science centres and business

> enterprises/industries will enhance the teaching in natural science and impart a sense of wonder, inquisitiveness and fascination.

(Utdanningsdirektoratet, 2006)

From the introduction of the *Budding researcher*:

> This involves the formulation of hypotheses, experimentation, systematic observations, openness, discussions, critical assessment, argumentation, grounds for conclusion and presentation. *The budding researcher* shall work with these dimensions of education.

(Utdanningsdirektoratet, 2006)

I read the first sentence in the first of the citations above as a connection between practical work and learning about science. Approaches to science, are in the Norwegian version of the curriculum, phrased as 'ways of thinking'[16]. There is thus created a connection between theoretical, practical and epistemological aspects of science. The curriculum's aspirations for what practical work can achieve is creativity, critical eye, openness and active participation and further wonder, inquisitiveness and fascination. From the curriculum perspective, there seems much to be gained from doing practical work and inquiry.

In this section, I will highlight hypothesis, observations methods and measurements. I will also try to clarify and distinguish practical work and inquiry. As much of the empirical material is related to experiments of some sort, this section will primarily deal with experiments; that is not to underestimate other forms of investigations in science.

### 10.5.1. Processes in 'real science'

There has 'always' been a multitude of ways scientists have investigated scientific problems and today there are even more possibilities for different approaches (Chalmers, 1999). Chalmers (1999) states that there is no universal method in science, *the* scientific method does not exist. The methods in science vary according to that which is studied. There is a difference between what constitutes 'good' scientific practice between disciplines and the practice change as, e.g., new instruments and new knowledge emerge. In disciplines such as physics and chemistry, experiments play a central role. An experiment studies the phenomenon outside its 'natural' context (Ziman, 2000). Experiments are often a short form for controlled experiments (Gyllenpalm & Wickman, 2011). The purpose of the experiment is to gather 'facts' that are relevant to the theories in a research community – 'facts' that (might) achieve acceptance as communal knowledge.

The gathering of these 'facts' is embedded in a complex social practice (Latour & Woolgar, 1986). According to Latour and Woolgar (ibid.), there are complex webs inside a laboratory, where technicians, programmers and researchers work together, but where there is a division of labour between them. The research process is an interaction of physical objects, inscriptions in forms of articles as well as inscriptions provided by the lab technicians. A vital part of the research is to keep meticulous records and other forms of inscriptions as well as handling inscription devices (i.e., measuring instruments that produce graphs or 'numbers'). The results in the form of

[16] Norwegian: Tenkemåter

inscriptions make the physical objects that were the basis for these inscriptions, superfluous. In the result of the work, the report or journal article the "*bench space will be forgotten, and the existence of laboratories will fade from consideration. Instead, 'ideas', 'theories', and 'reasons' will take their place*." (Latour & Woolgar, 1986, p. 69). The messiness of the research process is thus eradicated from the final result. There are aspects of the process of 'making facts' that are important in relation to the curriculum objectives and those are hypothesis, observations and measurement devices – and their role in the critical assessment of results.

Ziman (2000) states that hypothesises are embryotic theories. They exist in a network of other (perhaps rivalling) hypotheses, theories and empirical data. The requirement for on what grounds one is proposing a hypothesis is different in differing disciplines of science. From a hypothesis, there can be deduced predictions that are testable. However, a hypothesis does not necessarily fail if the outcome of the testing is negative. This can be related to the complex relationship between observations and theory in science (Ziman, 2000).

Observations are central in science. The conceptual framework that guides the observer has implication on how the observations are interpreted (Chalmers, 1999). Thus, it is possible to generate different knowledge about same phenomenon (Longino, 2002). Longino (2002) outlines the two traditional positions regarding observations: the first is that they are objective; the other position regards observations as subjective. However, she claims that through social activity (such as, e.g., discussions) combined with 'results or real world', there is a place between subjective and objective. The individual makes the observations but they get their meaning through the social, i.e., they are interpreted and 'negotiated' in a research community. In science, it is important to eradicate the subjective influence, though it is not logical to assume that the personal influence can be eradicated completely, but through elaboration of procedures one can minimize the influence of the 'personal' (Ziman, 2000).

Much of the observations in science are accomplished by the use of inscription devices (Latour & Woolgar, 1986) or measuring instruments as Baird (2004) calls them. Measuring presupposes a representation, a model of possible measuring outcomes. This knowledge is built into the instrument. For example, the knowledge or model of temperature measured in Celsius is built into the thermometer the students used when measuring how 'hot' the water was. Moreover, according to Baird, this is not the only aspect of measuring instruments. They are 'working knowledge' in the sense that they create phenomena (or inscription). The instrument's output needs thus to be reliable, regular and public. There is further much tacit or 'hands-on' knowledge in handling instruments. In addition, when the instrument becomes advanced, the job of the analyst becomes de-skilled. For example, the data-logger that measure temperature provides a 'nice graph' of how temperature changes over time, by the use of an analog (traditional) thermometer, this would be a much more labour intensive operation. There is thus less thinking to be done during the process of measurement with a data-logger, but interpretations afterwards are needed, whatever measurement instruments that are used.

How facts are evaluated is part of the 'culture' within that particular discipline, the scientists learn the communal standards as part of their training (Ziman, 2000). However, facts, hypotheses and instrument development are not just accepted in the science community, they are discussed, criticized and perhaps refuted through discussions (in speech and writing). Thus, critical assessment of empirical material, methods as well as models, are a part of doing science. Theory and empirical facts form a complex relationship. Neither supersedes the other. Theory may emerge (be interpreted and inferred) from data or theory can be falsified or strengthen by data, but there will always be a theoretical perspective (Chalmers, 1999).

At the end of this short account of 'real science' - a 'but' on experiments:

> it is surprising to see how much wild theorizing can be triggered off by 'effects' due to faulty experimental techniques." (Ziman, 2000, p. 94)

### 10.5.2. Practical work and inquiry in school science

School science has a long tradition of 'hands-on' practical work. Practical work may take different forms, and there are different definitions and views for what practical work, see e.g., Lunetta et al. (Lunetta et al., 2007, p. 394) or Millar (Millar, 2010, p. 109) and inquiry (Grandy & Duschl, 2008, p. 305) entail. Inquiries can be categorized in different ways, see e.g., (Knain & Kolstø, 2011). There are different forms of inquiry from practical to literature inquiries (Norris & Phillips, 2008), and the inquiry may vary considerably in length, for examples of this see, e.g., Knain and Kolstø (2011). Gyllenpalm et al. (2010) provide a taxonomy of different instructional approaches to practical work/inquiry, where they divide the different approaches according to degree of freedom. Freedom is, e.g., when a student can pose the question or make a problem formulation. They provide three possible degrees of freedom; connected to problem formulation, methods and representing results. I would like to add that for problem formulation and methods, there might partly be 'freedom' (or choices), where the students can decide some aspects of, e.g., procedure. Students are then given a choice of how to do some of the elements in the procedure. In a pedagogical setting, the teacher has to deliberate as to what degree of 'freedom' to give the students.

*Practical work*

Traditionally, practical work can be described as cookbook or lockstep recipe 'style'. The 'cookbook – style' is very common in science education (Abrahams & Millar, 2008) and it consists of a fixed procedure and often a work-sheet where students fill in the results. In an analysis of instruction sheets (i.e., recipes), Tiberghien et al. (2001) found remarkable similarities between the six countries they studied, which led them to ask the question if there is an international paradigm to practical work at upper secondary and university levels. Further, they found that the primary objective often was to identify and become familiar with objects and phenomena. The students were required to make a direct report of observations and were seldom asked to explore relationship or test a prediction. One of their conclusions is as follows:

> in typical labwork, only actions with objects and observables and a small range of specific theoretical aspects are involved; there is little emphasize on the *relationship* between the domain of objects and observables, and the domain of ideas related to theoretical aspects. (Tiberghien et al., 2001, p. 503 emphasize in origenal)

The cookbook practical has been much criticised because it is 'hands-on' and 'mind-off', as there is little need for students to think beyond the procedures (Hodson, 2006; Windschitl, 2004). The cookbook- or recipe-based practical work is typically heavily guided or solely decided by the teacher (Abrahams & Millar, 2008; Tiberghien et al., 2001). Gyllenpalm et al. (2010) describe the difference between two of the most common approaches to recipe based practical work; expository and discovery, where the discovery is staged differently, as the results are hidden from the students in the start. The students are to 'discover' the 'right result' by following the (stepwise) procedure.

In an interview study of pre-service teachers, there seemed to be a conflation of the terms (controlled) experiment and 'lab task', in addition, there appared to be a strong inclination among these pre-service teachers that an experiment has a fixed outcome (Gyllenpalm & Wickman, 2011). One reason (one may speculate) might be that teachers do not distinguish between practical work as a teaching device and as scientific methods.

The arguments for 'cookbooks' are that they are manageable for the teacher in a class (Windschitl, 2008) and teachers may think this is the (only) way (low achieving) students can manage practical work (Hodson, 1993a). There is another reason for doing practical work based upon recipes and that is that some activities may require high precision for health and safety reasons and it is thus important for students to get used to following the stepwise instructions (Lundin, 2008).

*Inquiry*

To be a bit more specific, one may say that a "*scientific inquiry, at its core, is about acquiring data and transforming that data first into evidence and then into explanations.*" (Grandy & Duschl, 2008, p. 305). An open inquiry is where students themselves pose the 'research questions', whereas in a (regular) inquiry the teacher provides the problem or question (Gyllenpalm et al., 2010). Hodson (1993b, 2008, 2009) divides an inquiry into four 'phases'; planning, carry out, reflection and reporting. He first emphasizes that the 'phases' are not entirely separate and the order of 'phases' might not follow each other directly. This account of inquiry is directly opposed to the 'myth' or the 'folk-theory' that there is a fixed and stepwise method of doing inquiry – *the* scientific method (McComas, 1998; Windschitl, 2004, 2008). "*It is clear that it has nothing to do with the ways in which professional scientists are educated or in which way they work*." (Jenkins, 2007, p. 275). 'The scientific method', where there are well defined steps that lead to a conclusion, can be linked to a positivistic view of inquiry (Grandy & Duschl, 2008).

Hodson (1993b) claims that there is a need for the students and teacher to spend time on the reflection phase (after the 'doing'). The reflections provide a possibility to explore different possible explanations and relationships between entities, i.e., to suspend judgement. In an open inquiry with 14 pre-service teachers, Windschitl (2004) found that the students had partly congruent and partly simple understanding of science inquiries. Although the students saw the process of developing questions, collecting and analysing data as non-linear, all of them designed their inquiry to find a relationship between two variables. However, the largest problem seemed to be that the students did not relate their inquiry to theory – their reasoning was restricted to relation based reasoning (Driver et al., 1994). This implies that in a simple model of inquiry, the students do not see the 'need for' tying data to claims and developing alternative explanations (Windschitl, 2004).

*The need for purpose and goal in practical work and inquiry*

One of the problems with practical work (and inquiry) is that the students might not see the purpose of what they are doing. When the purpose is not made explicit, the students might not connect the practical activity firmly to what is to be learned (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000). Recognizing and addressing this issue is, according to Millar (2010), central to improving the outcome of practical work. When the purpose is unclear for the students it is not unreasonable to think that this will lead to resistance from the students, especially when the teacher wants students to engage in form of investigations that are new to them (B. A. Crawford, 2007). Högström et al. (2010) conclude their single case study of a practical work in secondary school with that the teacher should be explicit on the objectives for the practical work and act accordingly, as the students interpret from teacher's actions, as well as speech, what is important. Duschl and Grandy (2008) claim that when students do not see the goal of the inquiry, it will effect negatively on their learning outcome. In the absence of a clear purpose, there will be a need to direct students' activity (ibid.). Hart et al. (2000) attributed the 'success' of the lesson they studied to clear purpose (as well as aim) and that the purposes of the activity were not too many. They pose the question if 'we' want to get too much out of the practical work and that this diminishes what can be achieved (Hart et al., 2000), i.e., the problem of discriminating between important and not quite so important.

*Practical work and inquiry as a way to learn about science*

One argument for doing inquiry (and partly practical work) is that the students learn something about 'real science'. Understanding of science and how scientists work, and developing 'a scientific habit of mind', are two reasons why we should engage students in practical work and inquiry (Lunetta et al., 2007). However, that requires that the practical activities are of a type that does not actually give an oversimplified version of what scientists do and what science is. To avoid the oversimplification of inquiry I believe there is a need to consider what problems that are scientific, but also manageable in school science with limitations of time, equipment, etc. In addition, the reflection on results, explanations, as well as methods are not to be underestimated. In other words, to avoid the oversimplified inquiry, it is necessary to make learning about science explicit for students, see also 10.3.2.

It takes time to establish an 'inquiry-habit-of-mind' amongst students. It may take years to develop a classroom practice where students take larger responsibility for the practical work or inquiry (Grandy & Duschl, 2008). This can be a challenge for a teacher who has only a year with the students to 'transform' the students' attitudes towards more investigative work and where students themselves take more responsibility.

*Practical work and inquiry as a way of leaning scientific terms*

Another reason for doing practical work and inquiry is to learn concepts and to connect and utilize these concepts (Lunetta et al., 2007). It appears as much of practical work is oriented toward learning concepts (Tiberghien et al., 2001). Although, there is a problem of connecting practical and theoretical aspects of science both in practical work (Abrahams & Millar, 2008; Hodson, 1993b; Kind, 2003; Mitchell, 2010) and inquiries (Windschitl, 2008), and the theoretical connection seems to be of little importance when the students and teacher interact during the practical work (Högström et al., 2010). Duschl and Gitomer (1997) claim that teachers see teaching as dominated by tasks and activities rather than concepts and scientific reasoning. If this were so, then one would anticipate a teacher emphasizing how to manage the practical rather than what it means. The teacher's emphasis on 'how to do' is also in line with Abrahams and Millers findings from science classrooms in the UK (Abrahams & Millar, 2008).

*Observations and inferences in practical work and inquiry*

Observations and measurements and inference from these, are central in practical work and inquiry. Practical work and inquiry will often rely upon students making observations of a phenomenon.

> In the laboratory, for instance, students are asked to perform activities, make observations and then form conclusions. There is an expectation that the conclusions formed will be both self-evident and uniform. In other words, teachers anticipate that the data will lead all pupils to the same conclusion. (McComas, 1998, p. 63)

Scientific observations are not just everyday observations. To do scientific observations, there is a need to discriminate between what is important to observe, and what is less important. To carry out systematic observations in science require a structured approach – it is not enough to 'look'. The structure needs thus to be made explicit by the teacher or students. Moreover, many students are not able to link between a theoretical entity and the physical entity. The teacher might see this connection as so obvious that it is not needed to dwell upon. Hodson addresses this as one of the myths of science – that "*validity and reliability of observations are independent of the opinions and explanations of the observer, and can be confirmed* *by direct use of the senses of other observers*" (Hodson, 2008, p. 41). The view that one can form conclusions directly based upon observations can be connected to empiricism, an epistemological stance that is not advocated in the curriculum, see also 10.3.1. The "*inferences are explanations about what is observed in the natural world, but are human interpretations as opposed to being directly observed by the senses.*" (Lederman & Lederman, 2011, p. 337). It is easy to observe and explain if you have accepted the scientific story, but the students do not have the necessary knowledge (Millar, 2010).

Högström et al. (2010) conclude their study by stating that it is important to help the students' ability to observe (what to look for) if the practical work is to be an experience with a desired learning outcome. This will include that the students have verbal tools for describing and explaining of the observations. Further, I link this to learning *about* science and that scientific observations are *one* way of seeing the phenomenon. Perhaps students need to re-observe after the classroom dialogue to see the phenomenon more scientifically.

Many students seem to believe that it is possible to measure a 'true' value by reducing errors such as occurring from human action or faulty instruments (Leach, 2002). The 'belief' in true values can be ascribed to a naïve view of measurement, where measurements are without uncertainty (Evangelinos, Psillos, & Valassiades, 2002). Further, they claim that it is important to expand the students' notions of measurement and data reasoning. The precision of a measurement will depend upon the instrument used, and thus it is important to judge what possible level of precision it can have.

*Hypothesis in practical work and inquiry*

A hypothesis can serve three different purposes; it can be explanatory, i.e. ,a speculative theory or what Ziman (2000) calls an embryotic theory, or it might be a generalizing hypothesis giving an empirical generalization (i.e., 'law'). The third group is hypothesis as prediction (McComas, 1998). The two first will be related to existing theoretical frameworks, whereas predictions have an important role in education (but not in 'real' science).

Hypothesis as prediction gives rise to some problems. When students are making a prediction or 'hypothesis' for a given experiment, they do this the wrong way around compared to 'real' science. In real science none(?) would first set up an experiment and then wonder what can I find here. In school science, this is quite common. As the experiment or practical work often is set up to provide the 'right' answer, making a 'hypothesis' becomes a game of guessing. This guessing can be quite stressful for the students as they know that there are 'right' and 'wrong' predictions (Gyllenpalm & Wickman, 2011). This use of 'hypothesis' is a pedagogical tool for making the students aware of their own preconceptions or misconceptions (Gyllenpalm, Wickman, & Holmgren, 2009). Eliciting the students' previous understanding can be quite valuable from a teaching perspective, but why not just call it 'a prediction'? Another aspect is that 'wild guessing' is, in my experience, not uncommon among students – unless the prediction is worked with and reasons are given *why* this or that will happen.

*Practical work, inquiry and interest*

One of the important factors for doing practical work or inquiry is that it presumably generates interest among students (Lunetta et al., 2007). In the curriculum, there are many positive words connected to practical work; creativity, critical eye, openness, wonder, inquisitiveness and fascination.  There seems to be an enormous potential for both cognitive and more affective outcome of practical work.

In practical activities – when students experience the unexpected – it can be a powerful perception that engages the student to learn more about the phenomena. The unexpected can generate a need for explanation, and will create a difference from what the student initially were thinking (Ogborn et al., 1996). An observation and interview study (29 students) by Toplis (2011) in England suggest that students see different reasons why practical work is important. First, practical work generates interest, participation and autonomy. In practical work, students interact with each other perhaps more so than in regular teaching. The students in this study meant practical work makes them able to visualize concepts and ideas and to provide episodes that made it easier to recall the subject matter. Abrahams (2009) claims that for most students 'whiz, bang and pop' practical work generates an interest in the situation, but it is unlikely that this gives the students a (long-term) personal interest for science. Students like practical work better than theoretical exercises, but not necessarily for its own sake (Abrahams, 2009; Toplis, 2011) or because they claim to learn more from practical work (although a few seem to do) (Abrahams, 2009). Abrahams' (2009) study is based upon interviews with students and their teachers related to short practical work, where the teacher instructed the procedure, and few choices were left to the students. In inquiries, where students generate their question and find the methods for investigating, it is more likely to believe that students become more personally interested. Their autonomy will be greater as they themselves 'own' the problem and the methods. Doing an inquiry usually spans a longer period of time and this, I presume, makes it more likely that students ponder more about the phenomenon and the methods.

*Students-teacher relation in practical work and inquiry*

Practical work in some degree and inquiries to a larger degree involve both learning how to do and learning the subject matter – at the same time (Barrow, 2006). This requires that the teacher makes a judgement of what one reasonably can expect from the students (Knain & Kolstø, 2011). According to Mitchell (2010), students have a lot to think about during practical work, and this can easily lead them to make limited meaning of it. Teachers' consciousness about reducing the amount of 'noise' during the practical activity is thus important, i.e., those factors that take away students focus on what this is about (Millar, 2010).

The teacher's role during practical work and especially inquiry is different from the tradition where the teacher is the presenter of subject matter. A more dialogical approach to teaching is needed (Anderson, 2002; Grandy & Duschl, 2008). This implies the need to ask students questions, be able to help students connect between results of experiment and explanations, etc. In the classroom study by Högström et al. (2010), they found that the teacher and student interaction during practical work had quite a short duration, but these interactions lead students to interpret what the teacher saw as important, with the consequence of what the students should concentrate on during the activity.

For a teacher, there are several challenges when doing practical work and inquiries in class. Time seems always to have been a problem when doing practical work or inquiry (Barrow, 2006; Crawford, 2007; Klainin, 1988). Time can be seen from a teacher perspective and from a student perspective. Seen from the teacher's position, there will often be too short of time to prepare sufficiently for practical work or inquiry. There will perhaps be problems finding time to check equipment and procedures, as well as to link 'the doing' with 'the explaining'. For students, it is essential that they have enough time to make meaning of what they do.

In addition, there is the pressure from assessment (e.g., in the form of exams), curriculum or parental resistance (Anderson, 2002). The teacher's personal learning history and view of learning, as well as inquiry and learning about science, is important for what (prospective) teachers do in the classroom (Eick & Reed, 2002). Prospective teachers (and I might add: teachers with little experience with inquiry and learning about science) need to have 'hands-on' experience with inquiries themselves and the tools for handling inquiry processes in the classroom (Crawford, 2007).

*Some comments at the end of the section*

Practical work and inquiries have a great potential in school science, as it is possible to combine subject matter and learning *about* science while 'doing'. Perhaps inquiries have more potential than traditional practical work, as inquiries require that students have the freedom to make choices regarding problem, methods and reporting. This increases the students' autonomy.

However, practical work and inquiry are far more difficult for the teacher to handle than just allocating time for carrying out and providing equipment. Students need purpose and goal, of which most often the teacher will be the provider. Then, the teacher also needs to follow up on the goal and purpose when guiding students. I see one substantial problem area when carrying out practical work and inquiry, which is students will do things differently, arrive at different results and make different meaning of what they do. The teacher can approach this problem in at least two ways. There is the tacit approach where students are just expected to get their observations and conclusions 'right'. The other approach needs well prepared guidance where students are challenged through all phases. To guide an entire science class can be a trying exercise, so the teacher needs a plan for how to structure the support. The support is very important in reflections over results, not least when the students are to deliberate over epistemological questions. Learning *about* science 'has to be' made explicit.

There is also another problem related especially to inquiry, and that is the students' view of learning might not be well aligned with 'creating knowledge'. Creating knowledge is hard work; it is not only fun or creative. This will challenge both the students and teacher in the classroom.

Connected to 'science for all', the practical aspect of the subject can play a major role. If students are to practice assessment of methods, uncertainty and results, this might provide some insight into how 'real' science is made, or at least a less distorted image. Practical work with lockstep procedure and weak connection to meaning-making gives an unrealistic image of 'real' science. However, that is not to say that practical work has no place in education where 'science for all' is paramount. Practical work might act as a connector between the phenomenon and established theory, as well as practice of specific competences (e.g., assessment of measurements). This 'requires' a firm link to theoretical framework and possibly giving students explicit choices.

Further, if 'science for all' and students as competent outsiders are aims, then it is probably very important that the goal and purpose belong to the students, as opposed to instrumental goals that are only relevant in a school setting. I connect students' ownership to contextualized science, where science inquiries become a part of some real issue, not just a school issue. Related to this is students' practicing to ask relevant questions and being able to relate critically to their own methods and results as a step toward relating critically and asking questions about science presented in, e.g., media.

# 11. DISCUSSION

This chapter is a discussion of the research question:

*How does the rhetorical framing of practical work and inquiry reflect 'science for all'?*

Where 'science for all' are seen through the lens of the curriculum and research literature presented in chapter 10. The rhetorical framing is a construct that deals with both the regulative and instructional domain of communication, and as the research question belongs to the instructional domain, most emphasis will be put on this. However, the instructional domain is embedded in the regulative. Moreover, rhetorical framing enables certain forms of semiotic work and suppresses other forms of dealing with the subject matter. This is the issue of the mid-section of this chapter.

This is a practice that works. There are no big conflicts between Ellen, her students and the subject matter. Ellen teaches and the students work. However, there are unquestionably tensions between this practice and practice prescribed in the literature, see chapter 10. So, why does this practice work? This is the issue of the first part of the chapter.

The last part of the chapter is making some proposals for how rhetorical framing might be if practical work and inquiry are better aligned with a 'science for all' perspective.

Moreover, in this chapter I will draw upon the empirical material and literature perspectives presented in chapter 3. These perspectives add to the 'thickness' of explanation, as it allows the voice of the teacher and students to be more prominent.

## 11.1. The practice works: In what respect? Why?

The practice described works in many respects. Students get passing grades and they do not quit school. Moreover, there is a friendly 'atmosphere' in the classroom as the teacher and students get on reasonably well. This should be satisfactory – should it not?

### 11.1.1. Low resistance as an overall aim

In this practice, power is exercised largely through institutionalized power such as the time summons and demands from curriculum. Moreover, power is exercised through how the subject matter is dealt with in class. For example, science is certain and procedures and methods are to a very small extent negotiable. At the same time it is important for Ellen to communicate well with the students. Through her actions and speech, Ellen expresses solidarity with her students and avoids falling out with the students by dealing with unwanted behaviour in a non-confrontational way. My interpretation of the practice is that it is important to keep resistance from students low. In other words, underlying this practice there is a tacit aim of keeping resistance from the students as low as possible. This is done in several ways. I categorize the main strategies to keep resistance low as simplifying subject matter, avoiding subject matter differences or low degrees of challenge in the communication and by giving the students collaborative freedom.

*Why is low resistance sensible?*

The students are not very interested in science. I think I can safely claim that their main aim is to pass. They see no significant personal use of what they learn in science (see 3.4.2.1). Science is just a school subject that has to be learned. In addition, students perhaps have learning strategies that are more oriented toward recall (cf. acquisition (Sfard, 1998)) and they easily fade out when they are supposed to do a task. Students have become 'school-wise' (Larson, 1995). They know how to respond to teaching and learning in such a way that they can use minimum effort to achieve passable grades.

The teacher avoids challenging the students on subject matter. The teacher challenges on the students' hand-ins, but very seldom in the spoken classroom communication. The students will, however, probably not perceive this as a low-challenging situation (see 3.4.2). In the interview, there are clear indications that the students meant that the science subject was difficult. If the teacher had 'pushed' the students more, i.e., given more challenges in form of choices or clearer expectations for outcome, the students would probably have resisted. For instance, the students would be even slower to start on tasks, pay less attention or perhaps even give up completely. Keeping low resistance ensures that there is a flow in the subject matter communication. The teacher takes responsibility for the communication and that is in a form that the students do not perceive as (totally) unmanageable.

The teacher simplifies the subject matter to make it more palatable for students. There is more emphasis on facts and less on thinking. This is, to my interpretation, in students' interests and according to their learning strategies (recall) and view of learning as acquisition – science is something to remember to test and not something you need for making decisions in 'the real world'. Students are 'doing school' and they do it with as little effort as possible. Their main interest is to do 'enough' and divide work as efficient as possible. They do not seek to expand their semiotic work to more elaboration on methods, results or scientific knowledge than the teacher requires – quite the contrary. Keeping low resistance ensures that the students 'learn enough' science to pass tests and complete the science course. These findings are aligned with (some) other research, see e.g., Larson (1995) or Furberg and Ludvigsen (2008).

The teacher leaves it to students how to manage their collaboration on tasks. The students thus have power to decide how to organize their collaboration. On the other hand, the teacher decides 'everything' when it comes to procedures and methods. I surmise that freedom of collaboration makes it necessary to have lockstep procedures; else, the students' work would be entirely open and the outcome very unsure. The other way around, one might say that the lockstep procedures make it necessary to provide students with a ‘space’ where they can make some decisions so that practical work and inquiry are perceived as less authoritarian. However, the lockstep procedures become something students can hold on to – it becomes *the* structure of the activity. Freedom of collaboration and lockstep procedures become two sides of the coin. Keeping low resistance by giving students freedom to organize their collaboration ensures that the students have some influence on the practical work and inquiry, it thus give them some power. By giving students this freedom, they have a possibility to lower the expected outcome (which at the outset is somewhat unclear in all cases).

The teacher relates very differently to the students and to the subject matter through her choice of speech functions. Frønes (2011) claims that school is more oriented toward personal relations than subject matter. It becomes thus important to have a good relation with the students. With little resistance, there are little (power) struggles in the classroom. One can go about ones’ business and do the required minimum. However, I surmise it is a fragile equilibrium. With this equilibrium, there is a practice that works in respect to ‘school outcome’. The students pass and they pass with as little effort as possible. It is a ‘pedagogy of indulgence’ where the ‘atmosphere’ is friendly. It is ‘safe’ to be a student (and teacher) in this science classroom. Dale’s (1993) term ‘pedagogy of indulgence’ refers to a way of tackling students’ self-perceived low achievement by reducing workloads and reducing expectations to outcome. Indulgence can be seen as a structural problem in Norwegian schools (and society as well?). Further, Dale (1993) connects indulgence with low professional focus in schools. Teacher development is left to the individual teacher. Setting appropriate standards and functional norms are not done collectively at school. This is also something that Ellen could confirm (see 3.5.1). School leadership was not very interested in teacher development, and how the teacher dealt with the students, as long as there were no complaints.

If the resistance become more outspoken, the working conditions for both the teacher and students might become worse. There would be less attention from the students and there is a risk that they would fail the subject and possibly drop out of school. However, if resistance were more outspoken, it would also mean that both the teacher and students have a possibility to explicate stances, purposes and interests.

#### 11.1.2. Communicative orientation: low challenge

The teacher interferes only to a small extent during tasks and thus she puts little pressure on the students in their semiotic work. She challenges the students little to explicate their reasoning to peers or in the full class. It is thestudents’ choice to which level they want to contribute in the teaching and learning activities. This might be seen as a blurring of the teacher and students’ roles (Frønes, 2011). The teacher is very much responsible for the flow of spoken communication, but this means that the students do not need to take much responsibility. For example, the students seldom had tasks in the form of explaining subject matter to each other and questions to the teacher were never handed back to the class. Low challenge in the classroom communication can be seen as the teacher's sensitivity to the need of building students' self-esteem (Wells, 1999).

The current curriculum with its clear aims for outcome can be seen as a way of mitigating the problem of low challenge. However, when the curriculum is 'a mile wide and an inch deep', this leads to a fact focus (see e.g., Millar & Osborne, 1998). This fact focus is seen in question and answer sequences in whole class situations. The weight is put on students' recalling facts and explanations, whereas elaborations and connections are mostly left to teacher. The students perhaps did not have the required terms and scientific explanatory stories from previous schooling. In other words, the student did not have the 'knowledge' the curriculum required. Which in turn, I claim leads both the teacher and students to have an imprecise use of scientific terms in their communication. Imprecision can, however, function well as long as terms also are used more precisely alongside the 'muddled' terms (Brown & Spang, 2008). Time perhaps limited what is possible to achieve concerning enhancing firm use of scientific terms. In these cases the teacher adopts a 'wait and see' approach toward students maturity and their ability to express themselves precisely. Ellen said that she regarded it as important to use the terms precisely, but that the textbook was very 'loose' in the use of scientific terms. She also claimed that being conscious about precision was something that required maturity (comes with age) (see 3.5.3). However, I will claim that students need to practice the scientific terms over a wide range of modalities in order to get a firm grip of what the terms entail.

Ellen seldom uses verbal and mental transitivity processes when she speaks about what the students should do. Put a bit brutally, the students are not challenged to think and verbalize. However, a challenge to think and verbalize would mean that Ellen also supported the students by, e.g., giving templates, clear specifications of output as well as guidance. Students need support and structure when they are developing key ideas and opening up for differences and they need time to do this (Wells, 1999). They need to feel that they master what they do (Andersen, 2007). In interview, Ellen stated that it was very important that the students felt they mastered the science subject (see 3.5.3). However, her solution is to make the science subject simpler and more instrumental at the expense of connections between ideas. This stance, I assume, was something that she had experienced as 'working'. Moreover, it led to little resistance from the students. Nevertheless, she saw this as a dilemma in her practice.

Students choose frequently to show inattention. This inattention could be silent (e.g., students diving into the computer) or audible (e.g., students talking). Inattention undoubtedly affected the communication about the subject matter. If inattention is a sign of students falling off or that they do not understand, it is reasonable that the teacher tries to communicate the subject matter in ways that are easier. 'Easier' can be achieved through less precision and by avoiding 'noise' through exploring differences. Both these 'strategies' for 'easy' were seen in the classroom.

These students are perhaps vulnerable, they know they are 'not good at science' (whatever that might be) and class is perhaps not always a 'safe' place. According to Frønes (2011), vulnerable students need extra support and structure. In this class, this was solved by a very structured presentation of the subject matter but far less structure on how the students collaborated on their tasks. Ellen's approach to practice was not to reveal the students problems with the subject matter in front of the class. For example, this can be seen as she chose never to say 'wrong' to answers, she ignored these answers and she 'told' the subject matter to the students in the summary of the practical work. In this way, she avoids hurting the students by exposing them in class. However, there is a problem connected to this: what is not expressed as problematic might not be seen as a problem. In other words, by the teacher's choice of lowering expectations and not revealing problems, the subject matter becomes unproblematic, which in turn makes it redundant for the teacher to interfere much in the students' semiotic work.

To avoid the students' resistance, the teacher 'has to' make communication about the subject matter easy for students. It becomes important for the teacher to 'deliver' the subject matter so that students could reproduce this on a prospective exam (see 3.5.3). This gives a rhetorical framing that, to a little extent, explores differences between the students' initial ideas and scientific view of the term or phenomenon, and between different methods and results. The rhetorical framing of communication can be said to emphasize the relation to the students at the expense of subject matter. It is more important to have a good dialogue between the students and teacher than the scientific quality in this dialogue.

There is a huge BUT at the end. I do not think the students perceived this as low challenge communication. In the interview, the students did not express that science was 'easy' and none of the students in class ever raised their voice to speak up for more exploration of differences.

### 11.1.3. Orientation toward subject matter: simplification

By presenting scientific knowledge as certain, the teacher reduces 'things to think about' for the students. Scientific knowledge is not presented as models or as a particular way of understanding phenomena. By emphasizing facts through, e.g., short response questions at the expense of 'thinking questions', science in the classroom gets an air of certainty. The students need not to think so much about the knowledge – it is sufficient to remember. The subject matter is thus simplified.

Ellen exercises power as a representative of the school system, as well as her personal authority on the basis of her subject matter knowledge. The students do not contest her in the instructional domain. In the autumn, they questioned how the subject matter was dealt with, but not the teacher's 'knowledge'(see 3.4.1 and 3.4.2.4). There are no incidents where they question her subject matter statements. This might indicate that the students have a high degree of subject matter trust in their teacher. This is, I assume, a key element in why the practice works. If the students had low subject matter trust in Ellen, the communication in the instructional as well as the regulative domain would be very different, presumably with more struggles of power.

The students in the class called, in the autumn, for an approach where the textbook tasks were used more (see 3.4.2.4). The textbook tasks were mostly recall, requiring the students to copy a short phrasing or a word from the textbook for answering the question. I interpret this as if they wanted a recall approach to the subject matter. One might say that students are encultured into a school subject that is unproblematic, factual and requires little 'thinking'. Memorizing seems to be a prevalent learning strategy and a strategy that 'pays off' in the form of good grades (Elstad & Turmo, 2007). One cannot underestimate the 'value' of the shaping of this type of teaching. It probably fosters a 'habit of mind' towards learning that can be regarded as acquisition (Sfard, 1998). Further, I connect emphasis on fact recall to a stance toward teaching and an exam tradition where students are to 'cough up' standard explanations (Tobin & McRobbie, 1996). The students are concerned with acquiring facts that they can reproduce and thus they have learned. This is perhaps a not a very elaborate view of learning, but it works as reproduction often pays off in form of satisfactory grades. The teaching meets the students' expectations for recall and perhaps even strengthens it by seldom challenging the students to explicate, find alternative explanations and argue for results.

When the teacher and I discussed the subject matter, we often discussed 'truth value' of scientific models such as the much used atom model (Bohr) and talked about the limitations in this model. Regrettably, these conversations were not recorded. As I recall, we did however disagree on the point to which level one should involve students in the limitations and possibilities of models. The teacher is thus aware of limitations in scientific models. Moreover, the teacher had a more nuanced view of DNA and heritage than she presented to the students. By choosing not to discuss the 'truth value' of models with the students, the subject matter becomes simpler and certain. 'All you need to do is to remember the protein synthesis and there is no need to think about limitations of the DNA model'. I will claim that this is a way of relating to scientific knowledge that is authoritative or perhaps even authoritarian. Power is thus enforced through the teacher's subject matter positioning.

Certainty is what students expect of science as this seems to be a vital component of the teaching and learning of science (as well as other subjects) (Hodgson, Rønning, & Tomlinson, 2012). A certain factual science subject is probably what the students perceive as manageable. However, there is a problem with this. The simplification of the subject matter might require an instrumentalism that alienates students. Strong directing of subject matter might lead to instrumentalism among the students (Andersen, 2007), which in turn might lead to students' resistance. Simplifying the subject matter is perhaps making it less relevant for students, but it is manageable. The students might become marginalized insiders of the subject (Feinstein, 2011).

The pacing is often fast in the teacher's initiated question – students' answer sequences. The students have little time to interpret the question, ponder over possible answers and they are never given the opportunity to try out answers on peers before answering in full class. This can be seen in a power perspective. The students are given time to 'digest' the ideas the teacher presents, but less time to digest their own ideas. There is thus given prevalence to the knowledge presented by the teacher at the expense of student interpretations. Another aspect of giving a short response time is the form of the question. A short response time is often associated with short and factual questions. When the students have little time to think about how they might answer a question, it might lead to low involvement from many students if they do not remember 'fast enough'.

Students simplify when they have an opportunity to do so (Byhring & Knain, in progress), e.g., by simplifying procedures or not relating practical work to theory, see also Larson (1995). In my opinion, the teacher reinforces this in several ways. First, there is little emphasis on purpose and goals. There is thus little to guide the students' attention to the subject matter during introduction and the carrying out phase. By refraining from precise goals, the expected outcome of the activity becomes muddled and there is thus a lowering of expectations. Second, the teacher does not intervene directly when the students are carrying out the work. There is thus little to guide the students' attention on significant connections between 'do' and 'think'. According to Högström (2010), the guidance during practical work is vital for what students perceive as important. The combination of action (do) and reflection is crucial if students are to make scientific meaning of the task (Wells, 1999).

Ellen did, to a very small extent, link the subject matter together across time. It is implicit that the students do the connections themselves. This can also be interpreted in the view of science subject matter as isolated facts – it becomes atomised (Millar & Osborne, 1998). I relate this partly to the 'myth of efficiency' (Tobin & McRobbie, 1996). There is much subject matter to cover and it is important to 'tick off' what is done. Students making connections take time and this result in less 'efficient teaching'.

Simplification of subject matter can be related to research that indicates that teachers seem to be 'unwilling' to exceed what they believe is possible for students (Waters-Adams, 2006). Teachers may attribute students' lack of interest to their lack of motivation and/or to their lack of ability. If the students are seen as lacking in ability, there will perhaps be more emphasis on making the subject matter simpler – and reducing expectations for what the students are to do (Southerland, Gallard, & Callihan, 2011). If the teacher views the 'uninterested students' mainly as lacking motivation, this might induce a notion that science must be more 'fun' – and fun activities are chosen (Hodson, 1996).

The curriculum is an important factor for the rhetorical framing that is created in the classroom regarding subject matter positioning. I judge the curriculum as 'unobtainable' in this classroom context. There are many aims. Most of these aims deal with descriptions, elaborations and well-established explanations (see 3.1). There is thus a focus on reproduction of certain science in the curriculum. In teacher opinion this curriculum would serve its purpose in the old (elite) school system, where students had the knowledge required from previous schooling and worked hard(er) in acquiring subject matter knowledge (see 3.5.3). The teacher is loyal to the school system in the sense that she has a clear focus on covering all of the aims in the curriculum. What can the teacher and students do when there is much to be taught and learned, when the students are not very interested and have a rather weak foundation of terms as well as knowledge about practical work and inquiry. The 'obvious' choice becomes to simplify. Teachers will 'always' need to simplify the subject matter, but there are some simplifications that are less appropriate because they distort or avoid central aspects of the subject.

When the rhetorical framing is seen from a subject matter perspective, much of the power exercised in the relation is the authority of a science subject simplified to certainty. However, there is a significant BUT concerning simplification of subject matter. The students do not perceive that the subject matter is simple, quite the contrary. To meet the students' interest, the teacher as main rhetor, 'has to' simplify the subject matter. The phenomena explored in the practical work, were to a large extent, not coupled to the subject matter. Practical work and inquiry belongs to a different realm – the realm of 'do the procedure'.

#### 11.1.4. Collaborative freedom and procedure restrictions

In practical work, the students always worked in groups. Regarding division into groups, the students have their say and they choose to work with friends. When the students carry out practical work or inquiry, they divide work as they see fit. The students organize the time for tasks, e.g., they organized themselves on how much time to spend on making hypothesis (Heat pump case) or making the inquiry design (Budding researcher case). When a member of the group participated little, Ellen seldom commented on this directly, although she could make general comments such as 'all must contribute'. She does, in other words, not restrict the students' collaborative freedom. Moreover, the students decide how to use the space during the practical task. They have much more freedom to walk about, fetch things and talk informally with other students. This freedom of space, however, did not extend to walking into the teacher's preparation room that was located next to the science lab. Thus, thus the students could do pretty much as they wanted as long as they seemed to follow the given procedure.

As there was no science equipment in the lab, Ellen usually fetched the equipment and put it on a trolley before the students entered the lab. That students did not go into the preparation room can be seen in a practical light, it would be crowded if all groups were to send a representative to get what they needed. However, the (never outspoken) restriction of using the preparation room can also be seen in a power perspective. Students are not 'proper' members of 'science' – they are not – or do not regard themselves as – taking part in choosing equipment. They take the equipment they are given. I do not know the reason for the lack of equipment in the science lab. It might be purely practical. However, this might be seen as sending a message of low trust to the students concerning their ability to take care of equipment or that (proper) science is a 'restricted area'.

According to Toplis (2011) autonomy is an important reason why students like to do practical work. To me, it seems that students are content with the level of collaborative freedom. This can be coupled with Ellen's choice of low challenge of students. Although she did at times decide which students were to work together and gave explicit collaboration structures, this was not done in relation to practical activities. When the students decide themselves how to work and with whom, there is less for the student to consider. In other words, the practical activity becomes 'easier'. The aim of low resistance from the students is 'achieved' partly because they have power to decide the social aspects of the process.

Practical work is organized as lockstep procedures. There are demands for actions to be preformed or the teacher decides more tacitly (Budding researcher case). Students *do* practical work and inquiry. There is little weight on deliberations over how to carry out observations, methods for measurements and interpretations of results. In short, it is less needed to integrate theory in practical work. There is thus a reduction of things to think about, but the students need to remember procedure. The choices of providing lockstep procedures might be motivated by solidarity with the students, as there is less for the students to consider, but the result is authoritative (or even authoritarian), as there are no reasons or choices for the students to make. Ellen formulated this dilemma by saying "*if there is a procedure recipe then they follow the procedure and stop thinking. I don't know why, but it is always like this*." To 'stop thinking' is not something Ellen regards as 'good'. At the same time, Ellen wants the practical work to be easy to carry out, so she structures the practical work through lockstep procedures. This can be coupled with Ellen's statements that the students are immature and I might add their expectations of lockstep procedures. In the first practical activity in October, it seemed as many of the students wanted 'clear messages' of what to do, and 'blamed' Ellen when something was unclear. However, even if Ellen chooses not to emphasize the students' subject matter autonomy in practical work, she does so regarding literature tasks. This means that Ellen's degree of authoritative approach is coupled with what is to be worked.

The teacher had given more prominence to summaries of the practical work this year. Summing up is usually in the form of the teacher stating the results and connecting them to theory and summaries are thus the teacher's responsibility. In my interpretation, this is a way in which she shows solidarity with the students by avoiding letting the students expose subject matter problems. However, it is also sending a signal to the students that connections and overview is out of reach for the students, i.e., she is exercising subject matter power.

This gives an asymmetry between the students' social autonomy and subject matter restriction in practical work and inquiry. If Ellen had given students more subject matter autonomy, there is, however, a danger that the students had not managed to carry out the activity and that they thus would not perceive it as 'successful'. The criteria of success seem to be ‘to be able to carry out’, see Heat pump case. If the students were given more subject matter freedom or autonomy, there would probably be a need for firmer structures for how to collaborate.

In these cases, all groups of students had the same task to perform. In other words, there are no differentiation regarding task difficulty and as the ‘end’ is defined by a break there is little differentiation concerning time (Dale, Lindvig, & Wærness, 2005). The break functions as a powerful time summons, as the students not wish to work during the break. At the same time, this institutionalized time summons makes explicit time summons from the teacher redundant. The school schedule shapes the pacing of the practical work. This meant that the students did not take time to dwell upon results or how to verbalize observations. It becomes important for the students to finish on time, efficiency is thus more important than making meaning of the practical work (Larson, 1995). However, it is not necessarily so that if students had been given more time, it would have improved their work. This I base on observations of the class where the students did not start doing task immediately. If the students are given more time, they perhaps need structures for how to organize their work. In other words, the teacher will have a role to guide and ‘check up on’ the students’ progress.

The students did not necessarily see the goal of the practical work. This might lead to (will lead to?) an instrumental approach to the ‘doing’. A clear goal might have helped in these cases. Making the goal ‘understandable’ is paramount. However, it is difficult to transform the competence aims into suitable learning goals. When competence aims are reduced into learning goals, they can easily lead to another version of instrumentalism. According to Hodgson et al. (2012), it seems to be the case that Norwegian teachers are very much concerned with competence aims and making learning goals as well as assessing these. The teachers know where to go – and they can measure if the students get there. But, is it desirable? By having small goals all the time, one might lose track of the greater objective (Hodgson et al., 2012; Hodson & Bencze, 1998). This is a reason why it is so important to connect goal and purpose.

Those purposes that Ellen gave explicitly in connection to practical work were all connected to purpose of subject matter. In an educational practice, there will be many different purposes (Wells, 1999) but explicit purpose guides the students’ attention. The purposes given in these cases are vague and they are given midst or at the end of introductions. This means that the purpose does not act as a guide for the students’ attention and interpretation of the introduction. When students have no explicit purpose to guide their process it becomes harder to understand why they are doing this, as the students said in the interview (see 3.4.2.5). There are no examples where the teacher gives reasons for the internal structure in the procedure. This can be seen as there is not one recorded incident where the teacher (or the students) say ‘we do this because of…’. When the procedure itself is without a clear and explicit purpose, it becomes authoritarian – it is a ‘given’ that needs no reasons. However, it is important that the students are not overloaded with reasons or purposes (Hart et al., 2000). Too many purposes will probably give students problems with discriminating important information from unimportant, as everything becomes significant. The teacher, on the other hand, needs to know why this activity and its procedure. Perhaps if the teacher examines the steps of the procedure and not take it for granted, this will lead to a way of speaking where reasons in procedure introductions are present.

The teacher draws on a tradition of how to do practical work that seems to be a positivistic stance oriented toward doing (Hodson, 1993a; Kind, 2003). Ellen is loyal to the school system, curriculum and exam and is herself raised in an educational system where emphasis was correct explanations. In this emphasis of the science curriculum, there is no need for explicit purposes, as the science to be learned is correct (Roberts, 1988).

When the rhetorical framing is seen from a perspective of procedure, there is a strong emphasis on following stepwise procedure and little emphasis on explicit purpose and goal. This sends a message of an implicit purpose, that of getting the task done however meaningless it might be seen. Procedure in the practical work becomes authoritative or even authoritarian while the collaborative organizing is negotiated between the students. Therefore, power is exercised through the stepwise procedure and solidarity is mainly belonging to the social.

### 11.1.5. Sum up

This practice can be summed up by the following illustration where the loops indicate key elements in the practice.

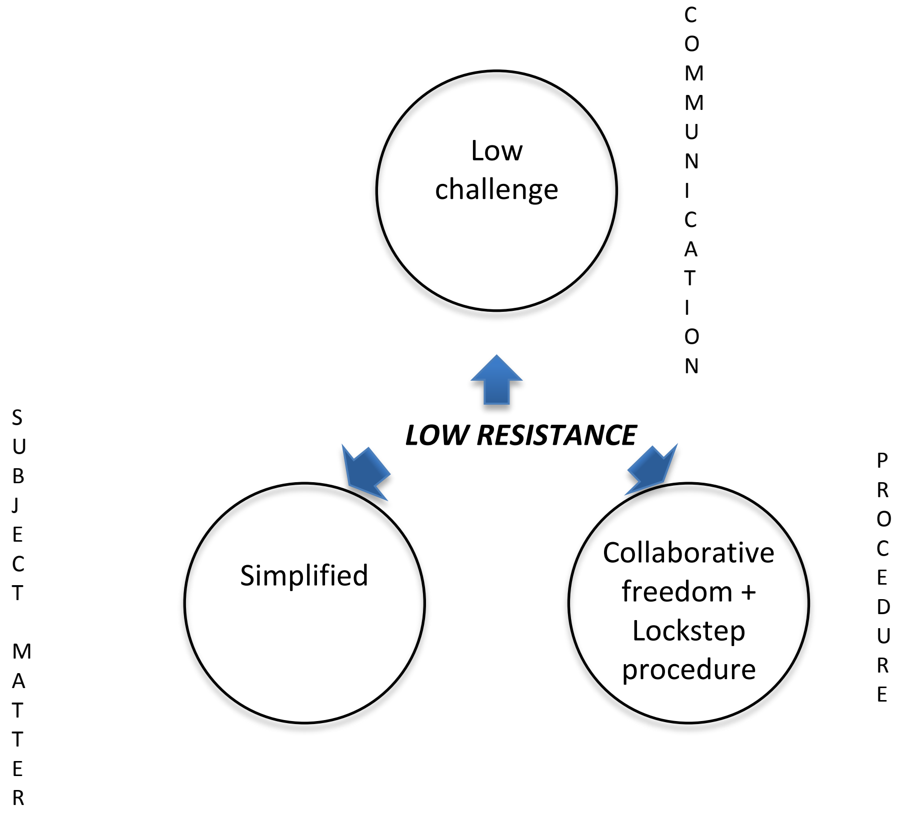


Figure 13 Key elements of practice

I have argued that the aim of low resistance from students generates a practice that simplifies the subject matter, leads to a communication with low challenge and where procedures are fixed, but how to collaborate is left for the students to decide. This gives the consequence that science subject matter becomes authoritative or even authoritarian. Students are indirectly discouraged from deliberate subject matter, exploring subject matter differences and taking a stance toward the subject matter. This can be seen as alienating students or that students become what Feinstein (2011) calls marginalized insiders. Students are supposed to learn the established science subject matter and they do so with little interest. They are not empowered to gradually take charge over the science subject matter and relate critically to it. This seems to be contradictory with 'science for all' or the democratic objective.

However, this practice might be in the interest of students if they receive passing grades without much effort – they are 'school-wise' (Brickhouse, 2011; Larson, 1995). This is a game they know how to play. The teacher has also an interest in keeping the status quo, as this approach leads to relatively good working conditions for both her and her students. Moreover, all competence aims are worked with – thus the teacher has done her job as seen from a school system perspective.

Perhaps this is also seen as satisfactory from a curricular perspective - if one chooses to overlook the objectives. These students are most likely never going to be scientists so it is perhaps good enough that they have a rudimentary insight in some scientific terms and explanatory stories? AND – students do not quit school!

To me, perhaps the most disquieting aspect in this practice is the missing question 'WHY' from students. Are students so encultured into the school system that they do not see the point of asking for a purpose? They have perhaps given up asking for reasons or perhaps (science) education is something you just have to suffer/do.

## 11.2. The practice and 'Science for all'

There are two comments before proceeding to the next part of the discussion. First, there will of course be difference between the curriculum document, teaching as an interpretation of the curriculum and students' work with subject matter as an interpretation of teaching (Goodlad, 1979; D. Roberts, 1988). In these interpretations, some information will be lost and some added according to the interests and expectations of the teacher and students. However, it is important to discuss what is seen as worthwhile in the curriculum and the science education literature on one hand and what is seen as worthwhile in this practice on the other. Second, this classroom practice with its teacher and students has some obvious shortcomings. However, communication is not breaking down, and both students and teacher are doing the best they can to make it work. When I worked together with Ellen to try to figure out good resources for supporting the students' learning (see chap 2), I did not perceive this as 'bad practice' – quite the contrary. However, by starting to dig into the details of the communication, the image of this practice became more nuanced. These details such as speech functions and transitivity processes are important as they give a 'message' that is hidden in plain sight and it influences how subject matter is perceived and dealt with.

The discussion is divided in three parts according to categories from the framework; scientific knowledge, language of science and doing science (procedure and methods).

### 11.2.1. Scientific knowledge in the classroom and 'science for all'

The scientific knowledge citizens need to deal with science-related issues does not necessarily coincide with 'traditional' school science (D. Roberts, 2007). Science-related issues in society might draw on knowledge that is beyond the scope of students and/or it might be science that is not established knowledge in the science community (in the making) (Ryder, 2001). Science-related issues also draw upon other knowledge domains (Kolstø, 2001). If one wishes that students are to take a stance in science-related issues – and possibly take action – it becomes a problem of choosing the subject matter for a school science course. What is important? What is relevant? As we do not know what issues the students will encounter in their future lives.

The Norwegian curriculum has tried to deal with this by selecting contemporary themes such as 'Energy for the future' and 'Biotechnology'. Moreover, the curriculum advocates a view that scientific knowledge is models of reality and that it is tentative. At the same time, much of the knowledge the competence aims refer to is 'certain'. It is knowledge that has withstood severe testing and has been discussed and refined over a long period of time (Chalmers, 1999). The terms and explanatory models the students needed in these cases, although of course much discussed when they were prompted, are now well established knowledge. We usually relate through language to these terms and explanatory models as things that *are*. Not as things *might be*. This makes communication about these ideas simpler as it removes precautions. School science is usually dealing with the established science that re-enforces the language of transmission at expense of interpretation (Sutton, 1998).

In the communication of 'real' science, the messiness of the research process is made redundant and not incorporated into the scientific writings (Latour & Woolgar, 1986). To understand the positions – what is regarded as certain and what claims that are proposed – one needs to see text as belonging to the context of other scientific writing (Lemke, 1998a), and this is perhaps rarely done in schools and never done in this practice. The ready-made science presented in schools is giving an image of science as value-free (Sutton, 1998). One might say that tentativeness of science is removed from school science. This is authoritative science that will most likely create a distance for contemporary students who perhaps do not see the 'greatness' and perhaps feel only estrangement toward science as practice and its products.

There are also differing ontological positions to scientific knowledge. How 'real' is science? Does science give a true image of nature? In chapter 10, I have referred to a naturalist approach to scientific knowledge. However, there are those who claim that science is objective and provides a true image of the real world. A positivist stance toward scientific knowledge is that scientific knowledge will emerge from observations in a relatively unproblematic way by induction. There is thus no need to emphasize that observations need to be interpreted – they are true. It seems to be the case that the teacher takes a positivistic stance toward the role of observation and scientific knowledge in the Heat pump case. From unaided observations, one can make explanations and moreover, the DNA-model is real. This is of course a legitimate view of science although perhaps not totally aligned with the curriculum. However, then, scrutinizing the objectives in the curriculum is not something teachers do (often) (Roberts, 1988). Perhaps this also is the case with this teacher.

Most of the science education community seems to agree that learning *about* science has to be made explicit for students. It is not enough to do science in school to gain an insight into how the 'real' (or professional) scientific enterprise works. In this practice, there are very few connections to 'real' science – and science-in-the-making. This means that school science in this practice becomes 'insulated' from deliberations in 'real' science or deliberations that might resemble 'real' science. There will of course be a deviation between what goes on in school and 'real' science because of different resources, different participants, etc. Even if school science draws upon the domain of 'real' science, it will be interpreted and communicated differently. Therefore, there will necessarily be a tension between school science and 'real' science. The question is whether school science should include more of how 'real' science is made. This view is advocated from a position that regards school science as important for participation in (a democratic) society (Kolstø, 2001; Ryder, 2001). This would involve science as a social practice, which requires creativity, perseverance, logical thinking, and an understanding of communication of and methods in science. This might provide students a more realistic impression of science, with its difficulties, choices, heated discussions as well as celebrations.

If there had been more weight on learning *about* science, would this have generated more interest among students, and would they have been more active and have seen the purpose? There is of course no way to investigate this, as learning *about* science was not made explicit in this classroom practice. However, the assumption behind more weight on learning *about* science is that it gives a better foundation to partake in debates and actions about science-related issues as a citizen (Aikenhead, Orpwood, & Fensham, 2011; Hodson, 2010). The English curriculum project – Twenty first century science – addressed the problem of school science as both a subject for those who wish further studies in science and those who need to be critical consumers of science as citizens (Millar, 2006). The core part of this curriculum was structured around themes with two features, scientific stories and ideas about science. Scientific stories are a metaphor for overall explanations where the particular details are not emphasized (Millar, 2006; Millar & Osborne, 1998). The purpose is to offer students some key ideas that can act as resources for descriptions and explanations. In this practice, the scientific ideas became perhaps only something the students thought about. The ideas became to a less extent tools for further verbalizing about phenomena, i.e., entities to think with (Ogborn et al., 1996).

Moreover, it is advocated that learning *about* science can be coupled with science inquiry. However, learning *about* science needs to be explicitly addressed (Abd-El-Khalick, 2011; Hodson, 2010; Lederman & Lederman, 2011). Science inquiry can become a unity of learning *about* science as well as subject matter. In this practice, there is a loose coupling between practical work and more theoretical deliberations *about* science.

Inquiry is also a possible starting point to encounter science in context or contextualized science (see e.g., Sperling & Benze, 2010). In contextualized science, science is but a part of what is to be addressed and science is seen as part of the everyday life of students outside school ('the real world'). The problem or phenomenon will decide what knowledge is needed. This makes the science we encounter in society in form of, e.g., socio-scientific issues complex and difficult to handle in class. In the Norwegian curriculum, there is nothing that prevents a contextualized approach, except that there is 'much to do'. In this practice, some of the literature inquiries had more emphasis on context outside school, whereas the practical inquiry – and particularly practical work – was in the context of school science.

Bryce (2010) claims that the enculturation of teachers into (traditional) science with little emphasis on the contextual aspects of science such as that science is socially embedded, makes it difficult for teachers to deal with uncertain knowledge and ethical issues in class. Managing different views and different arguments in science classrooms seem to be a problem for many science teachers (Oulton et al., 2004). In this classroom practice, discussions were very rare. When the students were to have a classroom discussion on heritage, some of the students had 'flippant' opinions. The teacher and peers do not challenge 'arguments' by, e.g., requiring backing. Arguments are not sorted and it is quite likely that the discussion becomes more 'show' than 'subject matter'. This might be related to the students' immaturity and to their insecurity as students in science. Students need not only have a desire to participate, they need the opportunity to acquire the competence for doing so (Brickhouse, 2011). They are not used to participating in more 'officially' staged debates. How should school position itself toward immaturity – should one wait until students grow up and become 'mature' or shall school actively pursue to shape students to become better in discussions, better in handling to uncertain knowledge and different views? A developmental attitude from school that might be described as 'wait and see' offers little challenge for students concerning subject matter as well as personal development.  Students are not encouraged to think about complex questions, but science in society is pursuant to definition complex, as it deals with open-ended problems where conflicting positions are prevalent (Zeidler & Sadler, 2011).

Teachers in school science rarely have the background to teach historical and philosophical topics of science. Teachers' views on science and science education are formed through their own education, work experience, science textbooks as well as colleagues. This, Roberts claims, is largely tacit knowledge for teachers (Roberts, 2011). Science-related issues in society, epistemology and ontology are usually (?) not included in teacher education. Moreover, the curriculum does not address this very explicitly (in competence aims). This means that it is up to the individual teacher. In a packed curriculum, it is easy to foretell the fate of complex science-related issues, history and philosophy in school science.

#### 11.2.2. The 'science language' in the classroom and 'science for all'

Practicing to communicate science within the context of school might help students to understand the science communicated outside of school (Ryder, 2001). The 'language of science' is, in many respects quite different from everyday language (Halliday, 2004; Zhihui, 2006). However, in all cases everyday language is prevalent. In this class, everyday language is seen as sufficient to deal with practical work and inquiry. These findings are consistent with findings in the Pisa+ project (Ødegaard & Arnesen, in progress).

Veel (2000) points out that the purpose is important when the teacher gives prominence to different sorts of meaning. If there is much emphasis on procedures and procedural recounts, this gives a focus of science as practical skills, whereas if focus is on impact of science, there will be emphasis on expositions and discussion, which also builds upon explanations. The latter is the domain where students and teacher challenge subject matter, and seek differences in the explanations in search of 'stories' with higher explanatory power. This type of challenge was not seen in this classroom where there was much emphasis on procedure and recounts.

Scientific terms are difficult, as they are connected in categorization systems and through interlocking definitions. In addition many of the 'science words' are nominalizations (Halliday, 1993, 2004). A quick count of the curriculum gave approximately 80 different terms that have a scientific 'meaning', most of these will draw on a quite substantial number of underlying terms. If one wants students to be able to use these terms in not just a superfluous manner, there is not much time to do the semiotic work that is needed. A teacher who is encountering medium to low achieving students will have to face this dilemma. What can you do and what should you do when students have but the foggiest idea of atoms and molecules? These are key ideas in science on which the explanations of heat pump and DNA hinge. The science language relies heavily on abstract terms. To learn abstract terms, there is need to spend time to link these abstract terms to the experienced world and to let the experienced world be enriched by the use of abstract terms (Vygotskij & Kozulin, 1986). When students are trying to connect verbalizing and physical phenomena, their communication is 'muddled' before they link the entities more firmly and use the entities more consistently (Roth & Lawless, 2002). It becomes thus important that the teacher makes an allowance for 'muddled', but with the goal of developing better precision. Interlocked terms require perhaps that the learning of these are not seen as a linear process but cyclical, as terms depend upon other terms, and they need to be learned not as isolated definitions but as interrelated entities. A refinement of one term will affect another term. Here, I propose, is a fundamental problem in the curriculum. There are a great number of scientific terms students 'shall be able to' use. However, connected terms are located on different stages. For example, the students had most likely been taught about atoms and energy in primary school. However, these students had not sufficiently grasped to use them for explanatory purposes.

The simplification of words and sentences makes the language 'easy' but it loose its 'scientificness' and becomes perhaps difficult to understand for instance reasons and how things are connected. Ellen avoids causal and conditional connectors in the introductions of procedure, which gives a procedure that is without explicit reasons. I do not know if this was deliberate. Students have problems with logical connectors (Wellington & Osborne, 2001) and the teacher might have adapted to this problem, as she avoided logical connectors when she could. However, it is of course also possible that her stance toward procedure was that it needs no reasons. Anyway, for the students this might make it harder to connect steps in procedure or theory with 'doing'. There is another aspect of 'simplification', and that is that the teacher acts as a model for what are appropriate ways of verbalizing science in the classroom. When the teacher chooses to 'simplify', she lowers the list of expectations to students' verbalizing. A further consequence might be that the students have little possibility to understand science, e.g., reported in media, as the students have an insufficient knowledge about 'the language of science'.

If the resources for making meaning are seen as cultural tools, it puts emphasis on learning to use the tools. To become proficient 'tool-users', the students need to interact with those who know how to handle the tools (Lidar et al., 2009). The teacher has thus an important role in interacting with the students on how to use these tools. Perhaps it is not enough that the teacher models the use of resources, probably the teacher needs to be close when the students try out meaning. In other words, it is probably very important that the teacher is (partly) present when the students are carrying out practical work and doing post-practical work.

Veel (2000) argues that procedures and recounts are simpler to do because they involve the complex grammar of science to a lesser extent than explanations. In this practice, recounts and descriptions are given prevalence. Ellen is perhaps a bit muddled in her use of the terms description versus explanation. As I recall, she did not try to clarify the distinction between these for the students. Explanation seems to be one of those words that has multiple meanings in both science and school science (Braaten & Windschitl, 2011). There are different 'traditions' within different scientific disciplines as to what a good explanation entails. This can be regarded as problematic in a general science course, where there will be different types of explanations, each with its own epistemological grounding. Sometimes Ellen asked the students to explicate their utterances. This occurred when the speaker was one of the students in the class who achieved well. Otherwise, she did most of the explications and elaborations herself. Explications are important in science classrooms as they allow for seeking reasons, without necessarily the rigour of explanation (Braaten & Windschitl, 2011).

Argumentation is central in science and it is vital importance when dealing with science-related issues (Kolstø & Ratcliffe, 2007). When doing practical work or inquiry, there is a possibility to argue on methods, results and theoretical framework and to use peers as critical friends to pose questions or make comments (Knain & Kolstø, 2011). The different arguments can thus allow for differences and new ways of understanding what one is doing. In this practice, argumentation and opening up for differences were very rare.

However, Yerrick (2000) shows that it is possible to engage low achieving students in argumentation and explanations of scientific phenomena. By establishing norms that allows for asking explicating questions to students and thus challenge them, the teacher seems to engage students in scientific reasoning. Students get and take more subject matter responsibility, i.e., they become more autonomous (ibid.). That is not to say that a transition from a 'traditional school science' to a science where inquiry and argumentation is prominent is without friction. Moreover, Brown (2006; 2008) points out that the everyday language can act as a support for the students' meaning-making if they can translate between it and the 'language of science'. The oral science language is important as it is closer to everyday language, and thus might help students' transduction from phenomena to written language.

The teacher models oral science language when she introduces the subject matter (lectures) and leads classroom 'dialogues'. In the teacher led 'dialogues', that usually were staged by the teacher so that the students were led to the right answer, can be categorized as authoritative interactive (Mortimer & Scott, 2003) and they followed a triadic pattern of teacher initiation, student response and teacher evaluation or elaboration (Lemke, 1990). Ryder (2001) claims that asking questions is an important part of relating to science as a citizen. Students asked lot of questions in the full class but very few of these questions were subject matter related. This is also reported in the PISA+ project (Ødegaard & Arnesen, in progress). The students in this class were not used to asking subject matter questions, they were used to answering questions that the teacher knew the answer to, i.e., the 'traditional' approach. Answering questions in a classroom dialogue is part of 'learning', but also asking questions can provide subject matter insight. Asking questions might provide a 'space' for meta-reflection (Mitchell, 2010). However, this requires that the teacher tries to foster an 'inquiring habit of mind' among the students by, e.g., giving praise for good questions and that the teacher is physically close so it becomes easy for students to take initiative. These students did ask subject matter questions when they had Ellen by themselves, perhaps to avoid unwanted attention from peers.

According to Norris and Phillips (2003), there is a need to emphasize reading as an important part of being 'scientifically literate'. Reading is perhaps much neglected in traditional science teaching, also findings from the evaluation of the Norwegian curriculum might indicate this, as there is little emphasis on incorporating basic skills into the teaching (Hodgson et al., 2012). To read science one might need the help from the teacher to decode the text as well as interpret the text in a wider context (Lemke, 1998a). A central aspect of interpretation is to assess the trustworthiness of the source (Kolstø, 2001). To develop competence in reading science texts can be an aid for the students' engagement in science-related issues now – or later in life. Reading science will also include interpretation of the text's multimodal assembly. In this classroom, the students did read at times, usually Internet sites, but the texts as such were not discussed. Reading was, however, rarely coupled with the practical work.

Reading is also important in order to become a better writer. Writing was, on the whole, something many of the students in this class seemed reluctant to do. Some students did not bring pen and paper to lessons and there were frequently questions such as 'must we write this?'. It also seem to me that many of the students were slow writers, as they asked questions about what was on the board some time after the teacher had written it. In this class, the students rely much on the personal computer as an aid for taking notes, but the question is whether a computer is a good tool for taking notes in school science, as science is multimodal. Written texts in science are seldom without drawings or tables. This means that the students' notes probably become more mono-modal because their text would lack the interaction between drawings and alphabetical written text.

Copying the board is a low-level writing task (Wellington & Osborne, 2001). In my interpretation, the teacher's stance toward writing is that it is important even if it is reproduction. Copying the board requires the students to be more actively engaged in the lesson. Perhaps the students did not think much about the role of writing as a means to organize the subject matter. However, learning to learn seems to have little weight in Norwegian classrooms (Hodgson et al., 2012). Another aspect of this is that contemporary students are used to visual media in their spare time, and this will influence their approach to written texts (Jewitt, 2006; Kress, 2003). When society is relying more on visual communication, the status of the alphabetical written texts is diminished. In this respect, the teacher's choice of often letting the students use images in various forms can be seen as a way of meeting the students' communicative approach. This class was very well used to using different modes and resources in their work with science. They thought working with different resources was good but harder than what they were used to using. Working with cartoons and images made science more 'fun' and the students emphasized that this meant they could put their personal imprint on subject matter (see 3.4.2.4). The teacher was very aware of the importance of using different modes of students' product because this gave a more demanding form of learning and it created variation to the teaching-learning situations. Moreover, when the students are to make an output in an entirely different mode, this requires transduction (Kress, 2010). When making a transduction from one mode to another, one needs to consider form and meaning in both modes. Therefore, in addition to being 'fun' and allowing for 'creativity', transductions involve considerations about the subject matter that are not so prevalent in 'copy and paste' tasks. Thus, transductions give the students subject matter responsibility.

Transductions might be difficult. First, to assess what is salient and how to best represent the subject matter will necessarily be a problem for the students who do not know the subject matter that well. A second problem is that it can become unclear how the product is going to be assessed, i.e., what is considered 'good' in the new mode. The teacher chose often to solve these problems by guiding students on their products. She took in preliminary products and commented (often orally) to the students what they could do to improve their product. This is a form of process 'writing' that allows students a more heuristic approach to the subject matter (cf. Knain, 2008). However, more heuristic 'writing' is time consuming for both the students and teacher. Moreover, the teacher 'has' to have a plan for assessment both during and after the product is finished. This type of process 'writing' was, however, not used in these cases – or any of the other lab reports as far as I can recall.

There are some representations in science that are important to be acquainted with, such as tables and graphs. These representations are also important to understand science communicated in media as well as school science. Tables, graphs and scientific drawings are cultural tools that get their meaning through use in social settings. These meanings must be learned (Lidar et al., 2009). Perhaps low achieving students have an even greater need for support in their transduction between resources and meaning-making through different resources. They do not easily juggle between the different resources (Lemke, 1998b). Moreover, learning to use cultural tools is time consuming and I propose that the teacher needs a long term strategy that gives students gradually more control over the resources. In this planning, the teacher needs to address the issue of how to support the students' transductions. This is probably much more important when students are medium to low achieving, like these students.

When students worked with tasks on the class wiki, they sometimes got the task of continuing and improving another student's text. Interestingly, the students in the interview said that correcting a peer's text was something that they considered impolite. This is, I claim, another form of occurrence of the norm 'low challenge'. The students do not challenge each other regarding the subject matter.

In contemporary Norwegian 'plain speaking' is much valued and difficult words seem to be avoided as often as possible. When the teacher chooses to use the 'vernacular', this might be understood in this context. However, 'real' science is far from 'plain speaking'. But the question is to what extent school science shall resemble the language of 'real' science. To this big question, there will be different answers depending upon what is seen as important. If the objective of school science is to be able to understand science well enough to partake in science-related issues in society, then perhaps some of the science grammar and modes are needed to be able to understand claims and arguments and what the 'evidence' is, etc. When students are introduced to a more 'scientific language', there is, however, the danger of alienating them. To prevent alienation, the students need to feel that they master the 'language of science' and the border crossing into science has to be explicit (Aikenhead, 1996). This has been done by the Australian 'genre school', building upon ideas from Halliday, see e.g. Macken-Horirak (2002) and Christie (2000). However, if the objective of school science is more toward affective aspects of science, then it perhaps should emphasize more on the creative forms of using different resources. The latter was emphasized in this practice.

### 11.2.3. Procedure and methods and 'science for all'

In 'real' science and the 'ideal' school inquiry, the point is to connect procedure, methods and the meaning-making, to interpret and make inferences. This means that procedure and methods play a secondary role (even if important) to meaning-making. The do-focus so often seen in school practical work (Abrahams & Millar, 2008; Kind, 2003) and in this practice show thus an opposite image of science. The goal of practical work is to carry out the lockstep procedure and there is less emphasis on whys and what the results are.

*Procedures and meaning-making*

Both the teacher and students associate practical work (and inquiry) with 'to do'. In the interview with the students, their answer to "*what do you really think about doing practical work in science?*" was that it was sometimes hard to understand what to do. They thus connect their difficulties with understanding the procedure, not with making meaning of what they have done (see section 3.4.2.5). The teacher has a clear do-focus in the introductions. When the teacher is introducing practical work, the most prominent transitivity processes are material action, and there are very few transitivity processes that are mental (e.g., think), verbal (e.g., discuss or write) or linked to making observations. This means that what is prevalent in the teacher's speech is 'do' at the expense of transduction between what is observed and the verbalising of these observations (making inferences). In other words, take the observations into the social domain to negotiate their meaning (cf., Longino, 2002). The procedure is thus disconnected from making meaning of the subject matter. These findings are consistent with other research (Abrahams & Millar, 2008; Ødegaard & Arnesen, 2010). The teacher also wants the practical work to be easy and a bit fun and something to 'investigate a bit' (see section 3.5.3). However, the teacher is concerned that it not too much or too difficult for the students. She wants them to focus on what they are doing. This, I see as a way of expressing solidarity with students by reducing 'things to think about'.

Scientific results get their meaning through the social domain (Longino, 2002). Transferred to school science, this would mean that there has to be joint assessment, discussion and meaning-making of methods, observations and measurements as well as interpretation of results. However, school science seems to emphasize the non-messy side and very simplified processes in practical work – and in inquiry too (McComas, 1998; Windschitl, 2008). One does the unproblematic procedure and in the end unproblematic results awaits (McComas, 1998). This is again contrary to 'real science', where the procedure has to be thought through, reasoned and elaborated (Chalmers, 1999). Therefore, an important question in relation to school science is if it would be possible to portray the activities in school more like 'real' science – with its messiness and social negotiations of meaning? I think yes, but this would rest upon another view of learning and knowledge production than acquisition. There would be a need to regard learning and the outcome of learning as more complex and more toward knowledge creation where the outcome is more uncertain. The complexity students experience will be challenging to handle for teacher as it is contrary to the myths of teaching (Tobin & McRobbie, 1996). The 'unproblematic' processes and results are easier for the teacher to handle as they do not challenge the traditional distribution of power in the classroom. From a 'science for all' perspective, 'lockstep do' combined with 'certain results' are problematic as this gives a situation where students do not relate critically to science.

One way of relating to messiness would be to make a clear division between inscriptions (notes, etc.) made during the practical and the transduction of these inscriptions into the finished product (article or report). This process could (or perhaps even ought to) include suspension of judgement and relating the data to theory. According to Hodson (1993b), it is important to 'keep' students in the reflection phase so there can be established connections between the 'doing' and the 'meaning'.

Typical practical work in school seems to be 'aiming' at established descriptions and explanations of phenomena. This can, of course, both be seen as a part of the school tradition of practical work (Tiberghien et al., 2001). Perhaps the current curricula can be seen as favouring lockstep procedures as it emphasizes well-established knowledge – and there is much of it.

Strong demands combined with an absence of students' explicit choice (i.e., zero degree of freedom) cannot be regarded as empowering for students' relation to science and science-related issues. However, students do not necessarily want choices. In the interview, the three students said that the teacher involved them sufficiently (this statement was however not particularly related to practical work). Møller Andersen (2007) claims that students who want choices often are mastery oriented, they want to understand not only to get the task done. In this class, the students were perhaps more oriented towards 'getting the task done'. Perhaps it is important to have a strategy for a gradual increase of choices during practical work. This might also be important in relation to preparing students for science inquiries.

*The purpose and goal of* doing *science*

I claim that there is a strong connection between vague purpose and goal and the heavy lockstep procedure, see also Ducshl and Grandy (2008). When the students do not understand what to do and why to do it, there is a need to focus on the execution of each step. The counter-question is, if the students had a clear purpose would they be able to be more self-directed in their practical work? Perhaps it would then be easier to remember and to see the necessity of steps and thus make it possible to understand why and what to do.

I assume that one of the major difficulties in education is to make long-term purposes and goals. These long-term purposes and goals would guide the teacher in choices regarding how to empower students to gradually take more charge. When students were to make their own procedure on the Budding researcher day, they had the lockstep procedures without explicit internal reasons as a model for what a procedure should look like. Seen in this light it is not so strange that students spent only a couple of minutes to make two different procedures, which they carried out. The students were not used to deliberations over procedure. Perhaps the inquiry and 'thought through' procedure the teacher required, are 'unobtainable' for students when they have no practice in assessing and discussing procedure. Developing an inquiring attitude, with all that entails, has to be implemented over time (Grandy & Duschl, 2008).

Goals are important in practical work (Hart et al., 2000). To have clear expectations to what the students are to accomplish is important, and perhaps central for improving practical work (Millar, 2010). When goals are vague, this can be understood as a way of lowering expectations to students. The teacher faces the dilemma of rising students to the level of making a 'thought through' procedure or lowering the procedure requirements so it fits the students. When students have not the skills required, a vague goal becomes the 'obvious' solution for the teacher.

However, there cannot be to many goals and purposes, as the students would have less possibility to interpret what is important (Hart et al., 2000), or if the goals are focusing on a limited outcome, it might lead to instrumentalism (Biesta, 2010).

*Guidance of practical work and inquiry*

When the students were carrying out the procedures, there was little intervention by the teacher. This is characteristic in all cases. The students use their own judgement and are not challenged. Is it enough to give students a procedure to follow and then assume it will be okay? In literature, there has been hard criticism of unguided inquiry and that it even might produce disorganized or incomplete knowledge (Kirschner, Sweller, & Clark, 2006). When there is little or no guiding of practical work and the result is known to the teacher it can be seen as discovery where students are to see the connections themselves (Gyllenpalm et al., 2010), and further that inquiry is regarded as uncomplicated both in process and outcome (Windschitl, 2004). Guiding of practical work can be seen as guiding on subject matter, procedure and methods as well as on the students' collaboration. Further, guiding is an essential feature of inquiries that works well (Hmelo-Silver, Duncan, & Chinn, 2007). Finding the correct level of guidance and assess what students need guidance on are important choices in a teaching-learning situation. If the students do not ask for guidance, these choices will belong to the teacher as main rhetor. Perhaps one strategy in the classroom would be to shape the students attitude to guidance, to make students more aware of their own learning which include asking questions and reflections on learning so that they actively seek guidance when needed. However, there might be a problem connected to guiding of students, if the students (always) seek the teacher's advice they become very dependent upon teacher. This I think calls for a considered approach from the teacher on how to deal with guiding students in order to empower them to take more charge of their own learning and the science subject matter.

If students are to learn science as well as do science activities, this will give the teacher a role where the teacher engages actively in the students' work to prevent that they are left to 'discover' by themselves. Teachers 'have to' challenge their students toward more rigour in their inquiries – and to make learning *about* science explicit – if the students do not challenge themselves. Though, it can be hard for students to deal with teachers' critiques and they might feel that the expectations are too high (Crawford, 2000). Crawford further recommends that teachers develop strategies in directing their students. These strategies will have to be (at least partly) context-dependent, as subject matter and students differ. There will of course also be a deliberation for the teacher when to intervene in students processes (doing and learning) and when not to. When a teacher chooses not to intervene the students' doing, there might be several reasons behind this decision. One of the major factors is time and how the teacher organizes time. In these cases, the teacher had other tasks to perform in addition to guiding, and this might be a contributing factor for low focus on guiding students. Another reason not to intervene is that intervention means to ask questions to students, in other words, to challenge their semiotic work.

In a practice were it was sought to keep low resistance, the teacher 'interference' would perhaps be interpreted as control (i.e., the teacher exercising power).

It is likely that the teacher and students collaborate reasoning during practical work is important for the students meaning-making of the activity (Högström et al., 2010). In the Budding researcher case, where there was ample time and few students, this could have been a good opportunity to ask the students questions about what they had planned - and why. Therefore, I surmise the low interference in students' work when they are carrying out practical activities is caused by the norm that there is to be a low degree of challenge. Students are responsible for what happens 'inside' the task, and they are not challenged or encouraged to relate critically to what they do.

*Hypothesis*

Hypotheses were used by the teacher as a teaching device to elicit students' presumptions. In other words, hypothesis was not used in the same way as it would have been in 'real' science, where hypothesis is related to a larger framework of theory and the hypothesis itself is a theoretical proposal (Ziman, 2000). Gyllenpalm and Wickman (2011) point out that students might feel insecure about making hypotheses because they are to be made within a framework where there is a correct answer. The teacher knows this answer, and the students have to try to figure out what this answer is. From a pedagogical perspective, it can be seen as useful that students connect their practical work with their presumptions, this can be seen as a way of engaging students and it can also give students a possibility to 'correct their preconceptions'. However, if the point is to 'correct preconceptions', it is necessary to address conflicting ideas explicitly. This was not done in the Heat pump case, where the students' mystery never was solved – why did isopropanol not boil? This mystery does not necessarily need to be solved immediately, as it might generate ideas and speculations. Perhaps a way of solving the mystery would be to empower the students to solve it themselves, to ask questions and make new observations?

If the point of the hypothesis is to generate interest and engagement amongst the students, it would perhaps be more appropriate to simply state that this is a 'guess' or a 'prediction' to avoid a conflation of the term hypothesis. If 'hypothesis' is used as a teaching device and not a scientific inquiry device, it needs an educational purpose, a purpose connected to the students' learning. In the inquiry (the Budding researcher), it would perhaps have been more suitable to pose 'research questions' rather than maintain emphasize on 'hypothesis'. Developing competence in asking (good) questions are important when dealing with science-related issues in society (Ryder, 2001), and should thus be encouraged.

The curriculum (Utdanningsdirektoratet, 2006) is perhaps part of the 'hypothesis problem', or does it expect that hypothesis in school science is to be used for explanatory purposes, i.e., theory generating? Interestingly, the word 'question' is not used in the curriculum at upper secondary level. Another explanation for this conflation is the low emphasis in university science courses on terms such as hypothesis and their use (Gyllenpalm & Wickman, 2011).

*Doing observations and measurements*

In the cases, there are some examples of how the teacher helps the students to observe and gives support for measurements, but there are also examples of how observations and measurements are not supported by teacher. Observations are made within a theoretical framework (Chalmers, 1999), by not establishing (at least some parts of) this framework, the students are left with their initial ideas and resources when they do the semiotic work of interpretation, verbal and physical action. Unguided or 'theory-free' observations can be connected to a naïve or empiricist stance toward observations. Observations 'without' theory can be seen as a reduction of issues the students are to concentrate on during the carry out phase (i.e., a pedagogical deliberation). A consequence of making the practical work 'easier' regarding observations is that the quality of observations become low from a scientific point of view, they are everyday observations. One explanation is that teachers tend to choose a more positivistic stance and thus give an impression that observations are directly understandable, when they are dealing with students perceived as low achieving (Hodson, 1993a). However, scientists and thus university science courses often adapt an empiricist/positivistic stance toward generating scientific knowledge (Ziman, 2000). Science teachers are to a little extent aware of the role of infer from 'pure' observations to the scientific meaning of these observations (Lederman & Lederman, 2011). Observations and measurements in this practice *simply are,* there is thus no need to deliberate, assess or discuss. Thus, the students do not need to relate critically to their observations and measurements.

Measurement seemed to be regarded as mostly unproblematic in this practice. This is contrary to 'real' science where uncertainty is vital for understanding what one can reasonably claim about the 'true' value (Evangelinos et al., 2002). This connects to the knowledge built into the measuring instrument (Baird, 2004), see also section 10.5.1. When the teacher introduced the burette and the students used it, there was no talk about the level of uncertainty, but there was talk about how to do the readings, i.e., as unproblematic values. This I surmise, has to do with 'making it easy' - less to think about. However, when removing the 'noise' of deliberation over measurement in the carrying out phase, the investigation looses much of its 'scientificness'. The instruments shape the investigation and what is possible to claim. This is however not made explicit. Moreover, the students were given the task of assessing the level of accuracy after they had carried out the inquiry. This assessment was left to the individual student group. I surmise that this is an assessment that is very hard to do when it was not part of the deliberations when making the inquiry design. If there had been deliberations over uncertainty during the carry out phase, this could more easily be picked up when the students were writing the report.

To carry out systematic observations and measurements are a part of learning 'scientificness'. In the Heat pump case, the students had measured temperature for water and isopropanol in a different order, so to be systematic was probably not something of which they had a very clear notion. In the inquiry, the students' initial procedure was carried out approximately the same way. Whereas, when they used the burette, the flow-time or the opening of the burette was different in each of the three rounds. Here is a 'problem' with the burette as a measuring instrument as it was difficult to adjust the flow-time such that it became equal in all three rounds (i.e., tacit knowledge in how to handle the measuring instrument (Baird, 2004)). This was not discussed. To enable a systematic approach and to assess the needed level of accuracy, a proper design of the inquiry is vital. However, it is perhaps not good enough to have a design, the students need to reflect on design during carry out phase, to be able to adjust their methods. This is a part of making learning *about* science explicit.

The teacher might have detected problems with measuring methods if the students had written or drawn a complete procedure that could have been used to discuss approach and methods with other students or the teacher. However, discussing and making critique of methods is a central aspect of science (Ziman, 2000), and when dealing with science-related issues in society (Ryder, 2001). This could have been done through, e.g., research meetings (Knain, Bjønness, & Kolstø, 2011). The experiences with research meetings in StudentResearch was somewhat mixed, it took some time before the students got used to this form and could act freely within the template. It is also a requirement for students sharing and discussing that they (and the teacher) believe that they can learn from each other (i.e., the teacher is not the sole provider of 'knowledge'). In this class, the form of collaboration was decided by the students as the teacher seldom provided explicit collaborative structures and seldom intervened in the students' collaborative processes. When students are collaborating in a form such as research meetings, where they are to be 'critical friends', they need to be sure that their peers are friendly-disposed and that they can feel emotional security. Students need to look at differences that are opened up as being important in the process of learning.

*Time*

Time is important when doing practical work and inquiry. Time is needed for introductions, where the activity is linked to purpose and goal, as well as giving the students the needed resources for their work. On the Budding researcher day, the teacher let the students repeat the two first smaller inquiries after a short talk. This, I propose, would have been a good strategy also in some parts of the Heat pump practical work (e.g., boiling under low pressure). I assume it would be easier for the students to have a more scientific approach to both methods and subject matter if they could repeat the activity. The repetition could give the students a new possibility to make better observations and measurements after a whole class discussion. A repetition can act as focusing attention and it is perhaps easier to link reflections on theory, methods and results. When students know they are doing a practical task twice it will probably reduce the 'do' focus if the second round is more focused on subject matter connections and methodical reflections. In this way students can first 'do' – and become acquainted with equipment and procedure before starting to think about it. However, of course, the students need to understand the purpose of doing it twice. There is a risk that some students will find this boring, especially if they continue to be in 'do modus'.

Another aspect of time is to provide specific time-slots for particular parts of the practical work, such as hypothesis or investigation plan. If time was provided for these activities, it would be possible for the teacher to discuss these with students either in small groups or the full class. Also, if explicit time was given for the making of hypothesis in the heat pump case, this would more likely have resulted in contributions from all the students in the group. When the students are rushing to finish, there will be a division of labour, which might result in that only a few students get 'ownership' of parts of the task. In connection to hypothesis as a teaching device, it is perhaps important that students talk about their preconceptions, then it is perhaps not so fortunate that making the hypotheses were done by only some of the students?

* * *

The lockstep procedures are a hindrance for the students' deliberations. However, lockstep procedures are part of the tradition of practical work in school science (Hodson, 1993b; Kind, 2003; Tiberghien et al., 2001). That practical work (and inquiry) need to be organized like this can perhaps be seen as a 'myth' that is shaping both the students and teacher's expectations of how practical work is to be carried out, made meaning of as well as its function as a teaching device. When the outcome of the work is given in advance, i.e., the practical work has a given answer, there is a need to follow the procedure meticulously to get this answer. If this view is pursued also to include practical work where the 'answers' are more open, there will be no discrimination between 'open' and 'closed' practical work. It becomes thus important for the teacher to be very clear on if, and what choices to give the students.

In the cases, one may say that the teacher gives prominence to pedagogical aspects of practical work in the sense that she makes the subject matter easy for the students by removing much of the 'scientificness'. One argument for recipe practical work is that students are 'hanging on' – but do they? Is practical work where lockstep procedures are to be followed just a way of eradicating noticeable confusion? The activity is perceived as manageable (to do) and as the connection to subject matter is weak, it becomes 'easy'. The tabloid version of this might be: Students do – and 'pretend' they are learning, whereas the teacher facilitates what they are to do – and 'pretends' that the students are learning. BUT, when there is a loose coupling to subject matter and learning *about* science, what can they learn?

* * *

BUT what if the teacher got it right? Students who are not very interested and low achieving need clear instructions and a 'closed' content. Will that mean that science educators have it all wrong?

### 11.3. Summary

This practice works well in many respects, within a school context. Students pass, get their grades and they do not show much resistance even if they are not very interested in science. Students perceive the school science they encounter as quite difficult – it is much to do and learn. The teacher tries to meet the students on their expectations to the subject, this means simplification, low challenge communication together with collaborative freedom combined with lockstep procedures.

Where the practice does not work equally well is to empower the students to participate in democratic processes where science issues are involved. This is a claim I make based upon the absence of:

- Student initiated questions to subject matter and methods
- Discussion and assessment of methods and results
- Students' freedom to make subject matter decisions
- Precision in the use of scientific terms, representations, genre and language structure in general
- The notion of science as a social and evolving enterprise
- Links between subject matter and methods

This is especially noticeable in how practical work and inquiry are dealt with, but also in more theoretical oriented tasks (although some of these tasks were more related to science in society). By not allowing for differences in the communicative approach, school science is almost irrelevant for partaking in discussion of scientific issues in society. Students are becoming marginalized insiders since they do not master science well enough to become an insider of science, and they probably have little desire to be an insider of science. However, they are not empowered to be competent outsiders. I very much doubt that students are able to use what they have learned in school science now or in future, in respect to taking stance and action in science-related issues in society. In this respect, it is doubtful if the practice meets the objective of the curriculum.

Further, I claim that the curriculum is sending a double message by being packed with many and discrete aims that mostly are concerning established scientific knowledge. This makes school science something that is worked with as simplified subject matter - to be recalled. The focus on 'do' and 'recall' at the expense of making connections and assessments, as well as asking questions, are probably well aligned with the teacher and students' expectations. Students' interest here and now for a manageable science course (i.e., a course they pass with less possible effort) is a contributing factor to the low level of challenge in communication.

This leads to the fundamental question: what is the purpose of school science? Is it enough that the subject is relevant only in a school setting – or should school system aim higher to meet the objectives in the curriculum? If the purpose is to educate students to be competent outsiders in science-related issues, what rhetorical framing is needed? This significant and difficult question I will try to give some comments to in the last section.

## 11.4. A rhetorical framing for 'Science for all'

In this practice, it became an impossible mission to ensure 'science for all', where 'science for all' is seen in a democracy perspective. However, I think it is possible to open up subject matter and transcend the lockstep procedures in science in order to acheive a science subject that can act as 'science for all'. Some of the research referred to in this and the previous chapter give some guidance as to what a 'science for all' might entail. How can a science course that is manageable and meaningful for all students be designed? I will propose an outline for a rhetorical framing that is perhaps more suitable within a 'science for all' perspective. Education is situated and complex. This gives some implications for the proposals, as there will not be a 'universal' solution to the tensions and dilemmas that the teacher and students will face.

This section is structured by the factors that influence the rhetorical framing. It starts out with norms in the regulative and instructional domain and ends with a comment on curriculum.

*Norms*

The regulative domain seems to direct much of what happens in the instructional domain (Bernstein, 2003; Christie, 2005). The norms that are established to organize and structure tasks seem to seep into how knowledge is presented, how language as a tool is used and the procedures and methods. I propose that this calls for a stronger focus on the regulative aspects when one intends to change science education. It is not enough to (only) look at subject matter. Moreover, the regulative domain is definitely situated. The norms are established by 'negotiations' between students and teacher based upon their interests and expectations. The norms are tacit – or not made explicit. It is just the practice as it is. These norms shape the teacher and students' semiotic work. To change science teaching and learning, the norms in the regulative domain need to be made more explicit, scrutinized and discussed before or as part of changing the instructional domain. This relies to a great extent on the teacher as main rhetor. The teacher will thus need reflective tools as part of identifying the norms in the actual practice and a strategy to change the norms that fall short of what is wished for. However, I see it as difficult for an individual teacher to become aware of the norms in the practice, because they are largely naturalized – it is the way we do it – and it sort of 'works'. This is one reason why teacher development should not be left entirely to the individual teacher.

*Norms in the regulative domain of communication*

One vital point is how the teacher deals with the students' resistance toward subject matter semiotic work. The teacher needs a strategy to encounter this resistance. Implementing strict rules or 'nagging' will probably not work well, as the students most likely are used to negotiate conditions in other parts of their life(world), e.g., the ideal of the democratic family (see section 3.2). As Ellen once said, she had never met a student who did not want to learn. So, how to establish norms that give prevalence to subject matter semiotic work without creating (too much) resistance from students?

The first part of an answer to this question I propose is to emphasize the role of purpose and goal. Students need to understand why they are doing this and why the teacher wants them to do it in a particular way. Why this goal is desirable and how the goal fits in the 'bigger picture'. When students see the purpose of the goal, it becomes more meaningful. In addition, when purpose and goal are made explicit it will be easier for the students to partake in a discussion of whether this is desirable or not. These students are almost adults and I see no reason why they should not partake in deciding purpose and goal. This can be connected to a democratic aspect of education where students partake in creating their learning environment. There is also an evolutionary perspective to purpose, or long-time purpose. If the students' interests and expectations are contrary to what is thought as desirable (from a school system perspective), the teacher needs to approach this stepwise. In this practice, the teacher did change the students' expectations to what a literature task in science is, but not practical tasks. The change of expectations was however done without making this explicit for the students. Some of the evolutionary perspectives are perhaps belonging to the teacher's deliberations. And thus, the teacher needs a 'plan' of how to fit purpose of each activity into the long-term purposes. Perhaps if the students are (partly) involved in this they will feel a greater autonomy both socially, but not least regarding subject matter. Their voices are given influence. A short note in the end of this paragraph: It is not my intention to make the teacher abdicate. The teacher has to lead the process of deciding purposes and goals as the teacher has an overview of the subject matter the students do not have. Nevertheless, the distribution of power in teacher-student relation will change when the students have more influence on decisions.

The second part of the answer is connected to the role of meta-reflection. When the teacher plans task structure, meta-reflection must (?) be seen as a vital part of doing the task. This is because meta-reflection is crucial for the students' own assessment of their progress and their consciousness about what they have learned (Selander & Kress, 2010). If the students perceive their learning process as diffuse, it will be harder to feel that they master what they are doing. I surmise that when students feel their 'learning' is diffuse, it might lead to alienation, they do tasks and they do not see their own progress. The task is a command, but it might not be seen as (relevant) learning from a student perspective. Connected to this, the teacher's guiding and (informal) assessment is important. If the teacher supports and challenges the students during their work on tasks by asking questions that makes it necessary for students to explicate, the students are provided with resources to think about their learning. Another aspect of meta-reflection on learning is the role of individual versus collective learning. In 'traditional teaching', the teacher is the provider of knowledge and the students do not learn from each other. If collaborate learning is to be more than 'working in parallel', then the students need to make it explicit *what* they learn together and *how* they work together. Collaborative learning is seen as an important part of the 'knowledge society' (Aikenhead et al., 2011). These cases have shown that it is not possible to take the students' collaborative skills for granted.

As part of meta-reflection, I propose it is necessary to establish norms that learning is process. The learning process takes time and it is normal not to 'get it right' at once. There needs to be a norm that even if learning is hard (semiotic) work and at times frustrating one needs to stay on task. If the last norm is to be 'implemented', then students need to see that they (finally) succeed. They need to be encouraged and challenged by the teacher and peers to stay on task and to believe they will 'get there'. Facilitating 'learning to learn' is both desirable from a perspective where students are to deal with socio-scientific issues in future, but also in a general perspective. In the 'knowledge society' 'knowledge' is rapidly changing and thus it becomes important to assess information and learn new skills (Aikenhead et al., 2011).

If the general science course is to be science for citizens, then it probably requires an approach to how students are empowered to take action and to partake in discussions about science-related issues. What this might imply for the subject matter is dealt with below, but there is a social side of citizen science. Students need a belief that what they do might influence society and their own personal lives. Their voices need to be heard. This is the opposite of the 'voiceless' and passive students that solely adapt to the conditions set by others.

*Norms in the instructional domain of communication*
I position myself along those researchers in science education that believe that school science needs to give an image of science as a social activity and that school science should empower students to relate critically to science. In other words, school science should help students have a nuanced view of science and its role in society. In relating critically to science, I do not mean 'negative', but rather that science is to be assessed and that it can be used to understand scientific issues in society. This stance gives some implications for teaching and learning.

One of the important aspects is to open up science as 'true' and 'certain'. Even if subject matter is established knowledge, there is a need to establish norms that make allowances to question subject matter. Indeed, that questioning subject matter is important to learning and that questioning is a central feature of the scientific enterprise in general. Examples of historical cases can show the different interpretations and heated discussions before it became established knowledge, and the change of language that followed. This might help students see the need of peer discussions, challenging ideas and assessing methods. School science should put more emphasis on science as tentative and that observations and measured results do not give a true or certain answer. By avoiding science as only certain, school science becomes perhaps more noisy – it becomes more to think about. However, it is possible that science as an enterprise becomes more real for students and that they understand that making science is not straightforward. The not 'straightforward' aspect can be prolonged to their own view of learning of science, see above.

Students need to ask more subject matter questions. This can be done for instance by giving prominence to inquiry.  One central aspect of inquiry is to ask questions and to establish procedures that might help in answering these questions. The teacher will however need to guide the students on what is considered good questions and there needs to be norms in the classroom that good questions are important.

As a (first) step toward a more critical school science, I think it could be feasible to make choices explicit. Students need to explicate why they choose as they did. This will of course require some practice from students. However, if the teacher has a stepwise plan and a long-term purpose, it is possible to change the students' (semiotic) work patterns. In addition, the decisions need to be made explicit and communal in accordance to the belief that learning *about* science should be made explicit.

Learning *about* science is important if students are to relate critically to science. One way of learning *about* science is to do more realistic inquiries (inquiries that are more firmly contextualized), where there is a focus on both what is to be found out and the methods for finding this out. This implies a shift from emphasizing 'do!' to emphasizing meaning. This, I claim, requires a shift of the teacher and students' expectations of inquiry to a stance where deliberations and meaning are more prominent. Probably this stance would be noticeable in shifts in transitivity processes, from material action to verbalizing and observation. Making assessments and arguments are central in the inquiry process and should thus be given more prominence.

It is difficult to introduce the students to the 'language of science'. However, if students are to relate to science in society they need a rudimentary understanding of how science is expressed. This involves genres such as descriptions, explanations, argumentations and the role of evidence as well as reports. In addition, it is vital to extract information from different modes. This will require a different approach to science texts. Reading becomes something that has to be given more prominence – and it is in this respect vital to transduct and transform texts. In this practice, there are several examples of how this worked quite well. However, students need guidance when they transduct, as the new text is so different from the starting-point. Moreover, the teacher needs a long-term plan for developing students' competence in using the cultural tools. Connected to this I think it is important to let students use different forms of visual communication, as this is a way of relating to information with which they are well acquainted. Another aspect of 'the language of science' is that the interrelated terms and abstract ideas take time to master. Students need to gain confidence that they master the science vocabulary and thus gain a larger degree of subject matter autonomy. In this process, it is, however, important that the teacher models a precise 'science language' and can translate this to everyday language, but also that the students are challenged and supported in their progress toward a more precise science language.

*Time*

The organizing of the school science schedule into longer periods might make it possible for students to connect the practical work with post-practical work. Longer stretches of science also make it possible to repeat the 'doing', which again might make it easier for students to connect and assess. In addition, there is a possibility to have 'time-outs' where aspects of the task is put forward and discussed. The call for 'time-outs' will act as a time summons that can highlight reflection about both learning (subject matter) and learning *about* science. In other words, the teacher as main rhetor has an important task in assessing when these time summons are needed. If time summons are too frequent, students' work becomes much interrupted, and if the summons are missing, the reflection might be low.

Time is important also concerning students' learning. Doing semiotic work that ends up with a desired learning outcome takes time. Perhaps even more so for students who are not encultured in the 'code of science'. This is one reason why I regarded that the process-oriented work with literature tasks were working well. The students worked over time with a task and got feedback from the teacher. They could of course also get feedback from peers. Another aspect of time and learning is connecting subject matter across time by referring to what has been done and what is going to happen.

*Resources*

When preparing for practical work and inquiry, the equipment and measuring instruments that are to be used are of great importance. Through this work, I have gained a view that equipment and instruments cannot be regarded as unproblematic. First, there is a need to assess the salient features of equipment and instruments. In other words, what they afford in respect to illuminating the phenomenon. Equipment and instruments will put something forward and make some meaning more accessible. There will thus be a need for the teacher (and students) to make a judgement if the feasible features are aligned with the phenomena.

The second aspect of equipment and measuring instruments is the effect of 'homely' vs. 'scientific'. I surmise that homely equipment can make the transduction distance too long for students. It become difficult to leave the realm of the everyday when the equipment is too 'homely' to make meaning in a 'scientific realm'. However, this must be weighed against the estrangement that might follow from the use of more scientific artefacts. Measuring instruments (e.g., data logger) might become black boxes, this is perhaps not such a big problem if the inscriptions the instruments make are explicated and discussed. The outcome (inscriptions) from black box instruments is even more important to discuss than 'transparent instruments', as the students cannot 'see' the process of making inscriptions.

These students were not much used to working with typical modes such as tables and graphs. This I would anticipate is often the case with students who are low or medium achievers in school science. Moreover, graphs and tables are much used resources for representing science and thus for students to be able to relate to science in society these representations are important to work with. I would recommend that the teacher has a (long time) plan for how the students are introduced to and gradually made more responsible for the use of these resources. When the students are made responsible for the resources, it includes to assess the affordance of the resource and to choose the most apt resource in a given situation. This can be seen as empowering the students to make their own choices.

*Physical space*

The use of the room is perhaps not what one thinks of as very important during practical work or inquiry. However, as students have more physical freedom during practical tasks, it is important that the space is adapted to the work. The room and how the students position themselves in the room can, for instance, act as a hindrance to the students' collaboration. To deal with this, the teacher will perhaps choose to observe how the students position themselves physically when they work together and discuss with the students what it is important to collaborate on – and why.

In these cases, all of the practical work was conducted inside school. However, there is perhaps no formal requirement that it should be so. Time enough to make inquiries outside school is important and if science is organized as days, it allows for inquiries in the local environment. Nevertheless, the teacher has a control function or the power to check up on the students' progress. If students with little interest for science are just 'let loose', it is highly likely that their work will be of a poor quality.

*The curriculum*

The above gives in my opinion some demands for curriculum. First, if students are to have time to master and work properly with key ideas and inquiry, including learning *about* science, then there is need for fewer aims. However, perhaps these aims should be on a higher taxonomic level. In other words, that aims that put more weight on 'assess' rather than 'describe'. Second, if science is to be more relevant it needs to connect in a larger degree to what happens in contemporary society and to usefulness. It would be feasible to be able to deal with local and global questions that interest students and where their voice can be heard. I thus advocate for a curriculum that allows for contextualized science where it is possible for students to combine with (socio-political) actions outside the classroom. This would enhance the democracy objective in the curriculum. Third, there is a tension in the current curriculum between science for future scientists and science for all. School seems to want to embrace both groups, but as Smith and Gunstone (2009) advocate, it is not unlikely that also those students who want to become students of professional science will benefit from 'science for all', where the links to society are stronger. Alternatively, there is a possibility to divide the curriculum something similar to 'Twenty first century science' (Millar, 2006).

The last point I would make is connected to knowledge and the 'knowledge society'. Contemporary modes of communication and for finding information challenge the established way of dealing with science as a school subject. Descriptions and explanations of the established body of scientific knowledge are ready to be downloaded to any computer or smart phone. It has been advocated from various positions that modern technology influences how we think and relate to knowledge (Säljö, 2006). The stance given through science education is that science is certain and unproblematic, and the myths of teaching and learning emphasize 'coughing up knowledge' on tests and exams. Perhaps it is overdue to have an informed debate about what knowledge is and what knowledge students need for future lives.

*Toward the end*

These are perhaps idealistic aspirations. How can this be possible when students are not very interested and their primary interest seems to be 'to survive' school science with as little effort as possible? In other words, it is in the students' interest that there is little subject matter challenge in the way science education works today. As I see it, there are two possible ways out of this problem. First, the subject matter has to be (made) relevant for students either by direct usefulness or by gaining competences they regard as useful later. Second, students need to see that they can succeed – that they can master what they do. This is partly connected to time. Students need time to make connections between terms and ideas and the results of inquiries. Students need time to improve inquiry design and deliberate over methods and results. However, time is not enough. The teacher is vital as a guide to support and challenge the students' views and actions. I do not think that students (or anyone else) learn best if they are left to themselves. Perhaps it would be a good idea if science teachers had fewer students in class during inquiry? This would make it simpler for the teacher to follow up with the students in a more satisfactory manner.

Teachers need more than a new curriculum document to change their science practice, a practice that works in the sense that it results in little resistance from students. If there were to be a science course that gives a more realistic image of science, it will require a shift in perspective of learning, from memorizing towards knowledge creation, in other words, to challenge myths of learning and teaching. A science course that emphasizes science for society will obviously lead to students' resistance. Teachers need to be able to tackle this resistance and to have a possibility to make realistic demands to students. I presume this will require a considerate approach to find the balance between power and solidarity. Moreover, I claim that this calls for more emphasis on long-term planning. In addition, there is of course need to support teachers and to support development of tools that can aid their teaching. These tools will involve teaching materials but also teachers' first-hand experience with inquiry, learning *about* science and use of representational resources in science.

There is (of course) at least one other way of solving the missing democracy aspect in school science. This solution is quite simple – to eradicate "*shall give one the basis for participation in democratic processes in society"* from the curriculum objectives.

Then the curriculum would appear more coherent and perhaps more aligned with school science tradition.

By this rather thorough analysis and long argument, I have sought to highlight the role of practical work and inquiry in a ‘science for all perspective’. This thesis has hopefully provided a small contribution in the debate about science education.

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