# Scientific Inquiry in Web-based Learning Environments

*Exploring technological, epistemic and institutional aspects of students' meaning making*

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Thesis submitted for the degree of PhD

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July 2009

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# Preface

One of the most important things I have learned during my PhD period is the significance of people with the capacity of making other people better at what they do. I have been fortunate to work with several of these people. First of all I would like to express my gratitude to my main-supervisor Sten Ludvigsen and co-supervisor Roger Säljö. Sten, your readings and comments, as well as our formal and informal discussions during the years have been extremely valuable to me. You are one of the few persons I know of that actually lives out sociocultural principles in your everyday work, supervision, leadership and colleagueship. Your generosity, including manners, social orientation and everlasting search for new understandings has been, and still is, an inspiration. Roger, I am grateful for your constructive and mindful comments on my work. I have learned a lot from your courses and lectures during the years, as well as enjoyed collaborating with you and your colleagues at LinCS, University of Gothenburg.

I also want to thank the research group at InterMedia. I feel privileged being part of this research community. Many thanks to present and former PhD students, Lars Opdal, Hege Renee Hansen Åsand, Louise Mifsud, Jan Dolonen, Annett Hillestad, Sturle Nes, Svein Olav Norenes, Yngve Refseth, Anders Kluge, Synne Skjulstad, Bård Engen and Dagny Stuedahl. Special thanks to my colleagues Ingvill Rasmussen, Thomas de Lange, Cecilie Flo Jahreie, Ingeborg Krange, Kathrine A. Nygård, Palmyre Pierroux, Ola Berge, Andreas Lund and Hans Christian Arnseth for all the brilliant discussions, friendships and many laughs. Hans Christian Arnseth has also contributed by co-authoring one of the articles in the thesis.

I would like to thank Thomas de Lange and Knut Qvale for their valuable help during the data collection. Also thanks to Ole Smørdal for typesetting the thesis. Furthermore I am grateful for all the administrative support from Lars Lomell, Siri Jønnum, Kari-Anne Ulfsnes and Suresh Johnpillai, and the technical support provided from the staff at InterMedia lab.

During my PhD scholarship I have been part of the Faculty of Education's research school – Learning Communication and ICT. The research school has provided the opportunity of meeting and working with leading national as well as international senior scholars. Of great importance though has been the opportunity of being part of an increasingly competent PhD group. In addition to the already mentioned colleagues from InterMedia, I would like to thank Knut Andersen, Øystein Gilje, Trond Haugerud, Oddvar Hjulstad, Kari Anne Rødnes, Håvard Skaar, Karianne Skovholt and Torunn Aanesland

Strømme. I appreciate the constructive comments, discussions and interesting seminars – and our dinners. Also thanks to the senior researchers Trond Eiliv Hauge, Leif Lahn and Jan Svennevig. Additionally I would like to thank David Middleton for reading and commenting on my work. A special thanks to Svein Østerud. Your encouragement and supervision during my work with the master thesis are important reasons for entering a PhD trajectory.

During the fall 2006, I spent five months as a visiting scholar with the L-KIT group at Graduate School of Education, University of Bristol. My scholarship was funded by the WUN-exchange program. I am grateful to Sally Barnes for including me in the L-KIT community, and for reading and commenting on my work. Furthermore, I would like to thank Arne Vines, Sarah Eagle, Lawrence Cattermole, Christina Hadjithoma-Garstka and Marta Cristina Azaola for sharing comments on academic work as well as life in general.

I am grateful to Doris Jorde for introducing me to the science education research field, and to the Norwegian Centre for Science Education for practical support. Furthermore, I want to thank all the participating students and teachers in the DoCTA project and the Viten.no project. I would like to thank the Faculty of Education for the scholarship, and also Telenor Group Business Development & Research for their co-funding. A special thanks to Birgitte Yttri, Marianne Jensen, Annita Fjuk, Kristin Thrane, Ellen Trollsaas and Lars Hafskjær for their support and understanding.

Finally, I am grateful to my parents Tone and Kjell Gunnar Avelin, my brother André Larsen Avelin and Kristina Enge for being supportive during these years. Most of all I thank you, Kai, for taking so good care of our two girls and for giving me endless support and care during these last hectic and intense months. Last, but not least, I thank Hannah and Una for constantly reminding me of the *real* important things in life. . . .

June 26, 2009

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# Contents

# Extended Abstract

# 1 Introduction

In recent years, the use of information and communication technology (ICT) in educational settings has received increased attention. A common assumption is that the use of technology can contribute to create productive learning environments supporting students' development of skills and conceptual understanding of educational subject matter. Interest in the use of ICT is also widespread within science education, where a variety of Web-based computer tools have been developed with the aim of supporting students' participation in scientific inquiry. A common feature of Web-based inquiry environments is that they are conceived with the purpose of supporting activities that are equivalent to the practices of inquiry performed by scientific researchers. The research reported in this thesis examines how students come to grips with making sense of scientific concepts while engaging with Web-based inquiry environments.

There seems to be a reasonable consensus about the distinctive processes that comprise inquiry learning (de Jong, 2006; Linn & Eylon, 2006; Quintana et al., 2004). Generally, scientific inquiry is defined as the process of asking questions, generating data through systematic investigations or experimentation, interpreting data and drawing conclusions (White & Frederiksen, 1998). Another common aspect is that the design of most of these inquiry environments is based on the assumption that communicative actions, either in textual or verbal form, have potential positive effects on students' inquiry learning (Arnseth, 2004; Edelson, Gording, & Pea, 1999).

During the last decades, several studies have reported on students' engagement with these types of Web-environments. An inspection of the conducted studies shows that it is possible to draw a distinction between studies utilising *systemic* approaches and studies utilising *dialogic* approaches (Arnseth & Ludvigsen, 2006). It can be argued that the majority of the studies of students' engagement with Web-based inquiry environments take a *systemic approach*. A fundamental tenet of research adhering to a systemic approach is their attempt to generate models of how features of a technological environment *impact* upon students'

inquiry skills or conceptual understanding. Furthermore, most Web-based inquiry environments are developed and studied by research groups conducting variations of design-based research (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004). Design-based research involves both the "engineering" of particular forms of interactions in an educational setting based on inquiry models and theories of learning, as well as the study of these forms. The objective is, among other things, to examine interaction and learning in a more naturalistic setting, but at the same time to study the impact of particular learning designs (Krange & Ludvigsen, 2009). Within this type of research, students' procedural and conceptual performances are most often measured by means of a classification and validation of their written productions within the Web-based learning environment, sometimes in combination with documenting their performances in pre- and post-tests. The classification and validation of the students' written productions are based on the idealized models of learning and scientific inquiry that also constitute the basis for the design of the Web-based inquiry environment.

In contrast to studies employing a systemic approach, studies utilizing a *dialogic* approach, as does the work within this thesis, do not have their main analytical focus on the *impact* of the Web-based environments. In research adhering to a dialogic approach, the focus is primarily to understand the very *process of learning* in settings where students engage with Web-based inquiry environments. Seen from a sociocultural perspective, learning is perceived as a social meaning making process taking place among interacting participants. Hence, students' meaning making processes can be explored by scrutinizing their interaction in settings where they engage with these types of tools. Another emphasis of dialogically oriented studies is that meanings and functions of scientific concepts and computer tools are constituted in social practices (Linell, 1998; 2009; Säljö, 2000; Wertsch, 1998). This implies seeing computer-supported inquiry as a particular practice embedded within an institutional setting with certain traditions of organising teaching and learning. Directing the analytical attention towards the process of meaning making indicates that issues other than effects are scrutinized. This means that the primary focus is on *how* the Web-based inquiry environments are integrated as structuring resources (Giddens, 1979; Lave, 1988) in the participants' meaning making processes. In order to answer these types of questions, detailed analyses of students' and teachers' interactions are needed. Such analyses are based on the assumption that the analysts' task is to account for how the participants *actually* engage in meaning making processes. This entails an emphasis on how the students orient

their talk and interaction, and what they present as significant in the Web-based learning environment under study.

This thesis includes three studies with their empirical basis in two different cases; the DoCTA[1] project and the Viten.no project. As part of the DoCTA project, a groupware system called Future Learning Environment 2 (FLE2) together with a pedagogical model of collaborative inquiry was introduced in two collaborating secondary school classrooms. The content of the learning environment was designed to be about biotechnology and ethical aspects of this knowledge domain. By communication through the FLE2 environment, the students were to formulate inquiry problems, discuss these problems with regards to relevant sources of information, and produce articles to be published on a common web-page (Wasson & Ludvigsen, 2003). The empirical analyses conducted in Study I are based on detailed examination of students' interaction during their work with genetics in the DoCTA project.

The Viten.no case represents a two-week gene technology project where the students used the Web-based inquiry environment Viten.no. Viten.no consists of programs devoted to different topics within science, of which gene technology is one. The gene technology program is designed to introduce students to various topics in genetics as well as ethical aspects. In Viten.no students are introduced to a variety of subject-matter-related resources such as text, a structured set of links to relevant sites, drag-and-drop tasks, animations, and multiple-choice tests. The empirical analyses conducted in Study II and Study III are based on students' interaction during the Viten.no project.

By virtue of being an article-based thesis which incorporates three journal articles, the conducted analytical work is in the form of three separate contributions. These separate contributions are nonetheless related in the sense that they all share a focus on students' meaning making processes in settings where they engage with Web-based environments. An important aim of the *Extended Abstract* is to discuss what constitutes the theoretical and methodological premises from which all three studies take their point of departure. The format and word limits of journal articles imply that topics such as theoretical and methodological arguments, as well as descriptions of the empirical settings cannot be the subject of extended discussion. The *Extended Abstract* provides the opportunity to present a more nuanced and elaborated argument, both on a theoretical and methodological level. Furthermore, the *Extended Abstract* also provides an opportunity for discussing relevant

[1] Design and use of Collaborative Telelearning Artefacts.

previous research and how the studies reported in this thesis contribute to the field of research. From this perspective the main purpose of the *Extended Abstract* is to create a framework of understanding for the studies presented in the thesis. In the following section I will give a more detailed account of the specific aims of the thesis.

## 1.1 Aims

This thesis has several objectives. First, it aims at clarifying how a sociocultural conceptualisation of learning as meaning making can be applied in order to explore and understand students' engagement with Web-based inquiry environments. I propose that these types of settings are best understood by taking into account technological, epistemic and institutional aspects of students' meaning making processes. Second, it aims at discussing what we know about students' engagement with Web-based inquiry environments and how studies within a sociocultural approach supplement and contribute to this existing body of research. In order to limit the number of studies as well as to ensure the relevance of the discussed findings, the focus will be on studies reporting on similar Web-environments of those that are at the centre of this thesis.

A third objective is to make a methodological contribution to the field of research on Web-based inquiry learning by analytically focusing on students' communicative actions while engaging with these types of environments. A focus on students' "accounts" – specific forms of linguistic devices such as explanations, clarifications or justifications – enables us to scrutinize what turns out to be the students' concerns during their engagement with the learning environments (Mäkitalo, 2003; Scott & Lyman, 1968; Shotter, 1984). Furthermore, turning analytic attention towards students' "interaction trajectories" makes it possible to scrutinize how students' orientations change over time (Rasmussen, 2005). A methodological approach where the focus is on students' actual interaction during their collaborative activities makes it possible to describe how students' meaning making surrounding scientific concepts relates not only to epistemic aspects, but also to technological and institutional aspects. Finally, the thesis aims to make empirical contributions to the field of Web-based inquiry learning. Based on this background, the overall focus of this thesis is:

> *to explore students' meaning making processes in settings where they engage with Web-based inquiry environments. This implies a particular focus on technological, epistemic and institutional aspects of their meaning making processes.*

## 1.2 Outline of thesis

The thesis is organised in two parts. The purpose of the first part, *Extended Abstract*, is to account for the unity of the thesis, and the second part, *The Studies*, comprises the three studies that have been produced.

In the *Extended Abstract*, following the *Introduction*, I present *Theoretical perspectives* in section 2. Here I discuss the sociocultural and dialogic perspective on students' meaning making processes as an interactional achievement between interlocutors. Furthermore, I discuss what I regard as three important aspects of students' meaning making processes in settings where they engage with Web-based inquiry environments. These aspects are referred to as technological, epistemic and institutional aspects. Studying students' talk-in-interaction makes it possible to understand how and why these aspects are invoked and made relevant by the students during their engagement with science in these types of settings. The section is concluded with a discussion where I argue for my analytical approach. Central here is the presentation of the concepts "accounts", "interaction trajectories" and "students' orientation". These concepts have served as guiding operational concepts for the analyses of student interaction conducted in the three studies.

In Section 3, *Studies on students' engagement with Web-based inquiry environments*, I review previous research. Here the focus is on studies that report on similar Web-based inquiry environments to those discussed in this thesis. I discuss the focus, methods and relevant findings of studies adhering to both a *systemic approach* and a *dialogic approach*. The main object of this section is first of all to discuss relevant findings from previous research that constitute an important context for the findings in the studies conducted in this thesis. Furthermore, this section also aims at demonstrating some of the distinctions between a systemic and a dialogic approach in regard to applied methods, how communicative actions are understood and analysed, and levels of description. Based on this background, I argue for the strengths of a dialogic and sociocultural perspective for gaining a deeper understanding of students' meaning making processes in settings where they engage with Web-based environments.

Section 4, *Empirical settings & Methods* comprises three parts. The first part gives a brief description of the empirical settings of the two empirical cases DoCTA and Viten.no, including a description of the applied Web-based inquiry environments and the data material. The second part focuses on the analytical procedures applied in the three studies. Section 4 is

concluded by reflections on research credibility and ethical considerations. Subsequently, brief summaries of Study I – III are provided in Section 5. I conclude the *Extended Abstract* with Section 6, *Discussion and concluding remarks*, in which I discuss the implications of the contributions of this research for understanding students' engagement with Web-based inquiry environments.

In the second part, *The Studies*, three articles are presented in the order in which they were written:

Furberg A., & Ludvigsen S. R. (2008). Students' meaning-making of socio-scientific issues in computer mediated settings: exploring learning through interaction trajectories. *International Journal of Science Education, 30*, 1775-1799.

Furberg A., & Arnseth H. C. (2009). Reconsidering conceptual change from a socio-cultural perspective: analyzing students' meaning making in genetics in collaborative learning activities. *Cultural Studies of Science Education, 4*, 157-191.

Furberg, A. (in press). Sociocultural aspects of prompting student reflection in Web-based inquiry learning environments. *Journal of Computer Assisted Learning*, DOI: 10.1111/j.1365-2729.2009.00320.x

# 2 Theoretical perspectives

During the years it has taken to finish my PhD, I have found it surprisingly hard to explain what I do without using abstract and complex terms. Eventually I managed to construct a version that at least was politely treated as understandable by my interlocutors: I am studying how students learn science while engaging with computer-based inquiry programs in school science. Seen from an analytical perspective, it is clear that even if this version manages to narrow down and communicate some essence of my study, it is obvious that numerous theoretical perspectives can be applied in order to help us understand students' learning in these types of settings. The theoretical perspective utilized in this study is based on a sociocultural perspective on human activity and learning (Linell, 1998; 2009; Säljö, 2000; Vygotsky, 1978; Wertsch, 1991). Expressing the everyday version of the focus of my study by means of concepts borrowed from the sociocultural research field, the focus of my study can be expressed in the following way: my focus is on students' meaning making processes, i.e. social interactions in which participants make sense of one another's actions, scientific concepts and the social settings where their actions are carried out, including the artefacts they make use of, to accomplish their tasks. Even for those familiar with sociocultural theories, it is clear that this phrasing needs some unpacking. This is what I will do in the remainder of this chapter.

I start by accounting for meaning making when seen as an *interactional achievement*. In a sociocultural perspective, learning is conceived as a social meaning making process taking place between interacting participants. This perspective emphasizes the important role of talk and joint activity, and meaning making is to be conceived as an interactional achievement (Garfinkel, 1984; Linell, 1998; Vygotsky, 1986). Consequently, studying participants' talk and interaction constitutes a possible entrance for gaining a deeper understanding of how students' learning processes emerge in these types of situations (Mercer, 2004). Subsequently I will emphasize what I regard as three essential aspects of students' meaning making in settings where they engage with Web-based inquiry

environments: *technological*, *epistemic*, and *institutional*. Focusing on these three aspects of meaning making serves two different purposes in the thesis. First, the three aspects serve to structure my theoretical argument about students' meaning making processes in these types of settings. This enables me to emphasize and reconstruct what I see as the most important premises that follow a sociocultural perspective on human activity and learning. In this sense, the three emphasized aspects of students' meaning making can be seen as theory derived, i.e. analytical. However, I would argue that these aspects are also to be conceived as empirically sensitive. This implies that *how* and *why* these aspects are invoked by or oriented to by the participants in particular educational settings remains an empirical question. This means that the focus on the three aspects has also served as analytical entrances for approaching the empirical data. Within all three studies, these aspects are implicitly or explicitly addressed, although the main focus of each of the three articles decides which of the aspects that becomes the article's topical figure and ground.

*Technological aspects* relate to the assumption that material tools, or cultural artefacts, have a fundamental position in participants' meaning making processes (Säljö, 2000; Vygotsky, 1978; Wertsch, 1991). Central in the settings analysed in the three studies within this thesis is the students' engagement with computer tools. Seeing Web-based inquiry environments as cultural artefacts focuses the inquiry on how students engage with these artefacts, and how they, in different ways, are integrated as structuring resources within students' meaning making processes. *Epistemic aspects* of students' meaning making processes orients inquiry to how students in educational settings make sense of a diversity of concepts within different knowledge domains. In this particular study, the students engaged with concepts within the knowledge domain of genetics and gene technology. Seen from a sociocultural perspective, these concepts do not come with some kind of universal or fixed meaning. Rather, scientific concepts only contain what can be seen as "meaning potentials", implying that their potential meaning must be negotiated and made sense of by participants in social interaction (Lemke, 1990; Linell, 1998; Rommetveit, 1985; 1992). To focus on epistemic aspects of meaning making, then, is to scrutinize how students grapple with making sense of scientific concepts as a communicative activity. *Institutional aspects* of meaning making relates to the assumption that students' meaning making processes are not only related to the immediate context where action is embedded. Actions and sense making are also situated in enduring institutional practices in which cultural modes of thinking and acting

are continuously produced and reproduced over time (Linell, 1998; 2009; Mehan, 1991; Säljö, 2000).

Following the outline of my theoretical argument on how to understand students' meaning making processes, I move towards arguing for an analytical approach for how to study these processes. As argued above, sociocultural analyses can be seen as partly theory driven, but also empirically grounded. In the three studies reported in this thesis, I have applied a number of operational concepts. These concepts have made it possible to display and explore how technological, epistemic and institutional aspects are invoked and realized within the interaction among the students participating within two educational settings. These analytical concepts are "accounts", "changes in orientation" and the notion of "interaction trajectories".

## 2.1 Meaning making studied as interactional achievement

In a sociocultural perspective, learning is regarded as dynamic and dialogical *meaning making processes* between interlocutors (Linell, 1998). Further, a central assumption is the emphasis on the mediating role of semiotic and cultural tools (Vygotsky, 1978; Wertsch, 1991). In their interaction, participants constantly make sense and interpretations of situations, events, and actions. At the same time, they make their own interpretations visible and observable to other participants. In this sense language is conceived as the most important tool for making sense of the world, of human practices and ideas, as well as a tool that *mediates* thinking and reasoning (Vygotsky, 1986). Talk and discourse should therefore be conceived as a "social mode of thinking" (Mercer, 2004). It does not make sense, then, to see meaning as embedded in linguistic categories that the individual succeeds or fails to decode. Meaning is dialogically constituted in specific practices, and meaning making involves complex interactions between people, resources, and the organization of the setting.

There are two closely related features of meaning making that are held as central seen from a sociocultural perspective. The first concerns the situated character of dialogues. A dialogue represents a social practice in which actors interact and communicate, and where the individual contributions cannot be understood separated from where they are produced (Linell, 1998). Seen from adjacent perspectives, such as ethnomethodology, Garfinkel refers to the term "indexicality" in order to describe the local, time-bound and situational aspects of action and language use (Garfinkel, 1984). Secondly, meaning making is deeply social and

interactional in nature in the sense that meaning making is a matter of *joint construction*. This collective construction is made possible by the mutual coordinated interactions by the different participants. Within interaction no contribution belongs only to, or is a product of, one single individual. Furthermore, every utterance, act or turn made by one of the participants in a dialogue is context-bound in the respect that its sense is dependent on the context in which it is embedded (Heritage, 1984; Linell, 1998; Wertsch, 1991). An utterance, act or turn is always a response to something; to what comes before. At the same time, each contribution in a dialogue has a context-renewing character because every current action forms the immediate context for the next contribution and by this contributes to frame how subsequent actions will be understood (Garfinkel, 1984; Linell, 1998). In other words, the context of a new action is repeatedly renewed with every current action, and hence it functions to maintain, alter or adjust the participants' orientation and activity.

As argued above, I have chosen to focus on three aspects of students' meaning making processes, which are termed technological, epistemic and institutional aspects of meaning making. The three aspects and their relevance for exploring students' meaning making processes in Web-based inquiry settings will be discussed in the subsequent sections.

## 2.2 Technological aspects of meaning making

Central in the three conducted studies within this thesis is the students' use of computer-tools during their meaning making processes. One of the core claims in this thesis is that in order to understand students' meaning making in these types of settings is the importance of explicitly scrutinizing how they engage with and make sense of these types of tools. This aspect of their meaning making processes is what I term as *technological aspects*. A sociocultural perspective on human learning and activity emphasizes the central role of semiotic and material tools in meaning making processes (Cole, 1996; Vygotsky, 1978). Two different features of tools are often emphasized. One important feature of tools is that they are resources that enable us to deal with tasks and operations that we would not been able to do without the resources. The fundamental position of not only semiotic, but also material tools, can be seen in all our daily activities where we use artefacts such as mobile phones, measuring devices, calculators, and computers in order to perform various activities during the day (Säljö, 2000; Vygotsky, 1978). Within educational settings resources such as computer mediated texts, diagrams, graphical models, or animations can be used, invoked or

referred to by students in order to make sense of scientific concepts (Schoultz, Säljö, & Wyndham, 2001).

Another feature of semiotic, as well as material tools, concerns their intermediate function by linking the past to the present. The intermediate function of tools is exactly what Cole (1994) refers to when he emphasizes the dual nature of tools:

> Artifacts exhibit a dual nature in that they are simultaneously ideal and material. Their creators and users exhibit a correspondingly duality of thought, at once grounded in the material here and now, yet simultaneously capable of entertaining the far away, the long ago, and the never-has-been. (pp. 93-94)

This implies that semiotic and material tools are conceived as *structuring resources* that become integrated into the students' meaning making processes. They are resources because they embody the knowledge of "how things are to be done" (Giddens, 1979, p. 64; Lave, 1988). Seeing cultural artefacts as mediators of historical and cultural practices is in line with Säljö's emphasis on cultural artefacts as having both a *knowledge dimension* and a *social practices dimension*. Artefacts embody knowledge and social practices developed over generations, or in other words: artefacts contain residues of prior human activity and knowledge. This knowledge and these practices are things we interact with when we use the artefacts and perform different types of activity (Säljö, 2005). In both of my two empirical settings, engagement with Web-based inquiry environments was a main activity within the science projects. As cultural artefacts, Web-based inquiry environments such as Viten.no has a knowledge dimension as well as a social practices dimension embedded within its design. Regarding the *knowledge dimension* of Web-based inquiry, the environments have science knowledge and conceptions built into them that have been developed over generations. Centuries of research, discoveries, and scientific discussions are embedded within them by means of different types of textual and visual representations. In this sense, the learning environments are designed to introduce students to a knowledge domain and scientific discourses.

Regarding the *social practices dimension*, it can be argued that two types of social practices are embedded within the design of Web-based inquiry environments. The *practices of scientific inquiry* are one type of embedded social practice. This implies that idealized understandings of epistemic activities that characterize researchers' process of scientific inquiry are embedded in the design of the Web-based learning environment. This finds

expression, for example, in how the students are instructed to engage with the scientific content in the learning environment, or with tasks designed for facilitating idealized inquiry activities. Such activities include, for instance, hypothesis generation, hypothesis testing, experimentation, or scientific argumentation. A second type of social practice that is embedded within Web-based inquiry environments is *institutional practices*. What characterizes Web-based inquiry environments is that they are not only tools for performing scientific inquiry as such. They are also tools designed with the intention of teaching students *how* to engage in scientific inquiry within a particular institutional setting: in school science. Consequently, Web-based inquiry environments also embed more or less explicit institutional practices and expectations of how to organize learning activities, the scientific content, and assessment (Crook & Light, 2002).

Even if Web-based learning resources represent knowledge and social practices dimensions, students do not necessarily employ the learning resources as intended by the designers or teachers. The meanings and functions of artefacts are (re)constructed in action. They can be used, invoked, and referred to, or misunderstood, disregarded, and ignored (Wertsch, 1991). This is to say that participants never know or manage the "real" meanings or capacities of a tool. Instead, their meaning potential is negotiable among participants, and many concerns impact upon the criteria for treating interpretations or the use of tools as appropriate in a given setting. Consequently, Web-based inquiry environments—scientific concepts as well as tasks to solve—are to be conceived as polysemic entities, and students will often have different opinions about how to understand and employ them in their work (See Study II).

## 2.3 Epistemic aspects of meaning making

Viewing language, words and concepts[2] as semiotic tools instead of inhibiting "true" and objective meanings implies that what is being meant by what is said or written cannot be pursued in terms of stipulated unequivocal literal meaning of expressions. In this respect it is possible to say that semiotic means only have a "meaning potential" (Linell, 1998; Rommetveit, 1985; Wertsch, 1991). Consequently, as semiotic tools, words and concepts

[2] As applied in this thesis, scientific concepts can be seen in relation to Vygotsky's (1987) distinction between "everyday" and "scientific" concepts. Whereas everyday concepts are related to the world of experience in a direct but relatively ad hoc manner, scientific concepts are characterized by their generality and systemic organization. This implies that they have a primary relationship to other concepts within the relevant system, and only an indirect relationship to the particular objects and events they comprise.

belonging to the field of science do not have some kind of underlying ”real” meaning. Making sense of scientific matters is, in other words, a dialogical matter taking place among interacting participants in local contexts. Words and concepts only get their meaning when seen in relation to the context in which they are used. Take, for example, a concept such as “genes”, which is a concept that could be part of a number of different discourses. One discourse could be about the how to technically perform gene modification of food. Another way of talking about this concept could be in discussion about whether or not, for instance, children’s development of characteristics is a matter of heredity or environment. This contextual (indexical) relationship between words and their meaning is what Bakhtin refers to as “heteroglossia” (Bakhtin, 1981). In this sense, talking about words and concepts in certain ways constitutes a particular form of semiotic action, or a “speech genre,” in which linguistic units are understood as abstract from individual communicative contexts (Bakhtin, 1986). These particular ways of talking do not represent objective and universal ways of understanding the topic at issue. Rather, the reason that the interpretation of words’ and concepts’ meanings *appears* shared, is that their meanings have become “frozen and fixated” (Linell, 1998, p. 122). Simply put, the words and concepts become “decontextualized mediational means” (Wertsch, 1991, p. 39).

Seen in this perspective it is not possible to obtain an identical, completely shared meaning or understanding of an issue or concept[3]. The basic achievement within such a pluralistic approach is rather how states of mutual understanding, or intersubjectivity, can be attained between the interlocutors. Rommetveit (1992) refers to what he terms “the attunement to the attunement of the other”, implying that intersubjectivity involves a reciprocally adjusted perspective within a setting and perspective taken between the interlocutors:

> Reciprocal adjustment of perspectives is achieved by an “attunement to the attunement of the other” by which states of affairs are brought into joint focus of attention, made sense of, and talked about from a position temporarily adopted by both participants in the communication. (p. 23)

[3] I will not go deeper into this issue here, but Vygotsky made a distinction between “meaning” and “sense”. The word “meaning” is referred to as the indexical meaning of a word, i.e. representing something relatively stable, generalized and precise. “Sense” on the other hand, is referred to as word meanings constructed and made relevant by participants in the particular situated contexts, implying that sense is seen as more fluid and complex (Vygotsky, 1987).

This implies that interlocutors' intersubjectivity and shared understanding of concepts or any state of affairs are negotiated, maintained and constructed within the proceeding dialogical activity. In a similar way, but seen from an ethnomethodological perspective, shared understanding and meaning making in social practices are supported by the interpretative work done by actors in talk and interaction—the participants in interaction are "doing understanding." This implies that the achievements and maintenance of understanding and shared meaning making is conceived of as "a *practical* 'problem' which is routinely 'solved' by social actors in the course of their dealings with one another" (Heritage, 1984, p. 54; Lindwall & Lymer, 2008). This way of approaching "understanding" is not to take understanding to be mental subjective matter, but rather as a practical way of dealing with how to go on in dialogic activity.

The context-bound and practical way of approaching attainment of shared meaning and understanding does not mean that students can come up with any interpretation of a scientific concept. In every scientific field, there is a range of words and concepts and ways of talking about these words and concepts that are accepted as valid. These valid ways to talk about science concepts and issues are what Lemke terms "thematic patterns." A thematic pattern is described as:

> […] a pattern of semantic relationships that describes the thematic content, the science content, of a particular topic area. It is like a network of relationships among the scientific concepts in a field, but described semantically, in terms of how language is used in that field. There is science in the dialogue exactly to the extent that the semantic relationships and the thematic pattern built up by the dialogue reproduce the thematic pattern of language use in some field of science. (Lemke, 1990, pp. 12-13)

Thematic patterns within a science field represent what we can regard as authorized versions, or decontextualized mediational means to use Wertsch's terms of science. On the one hand, these authorized versions are to be found as parts of the frequent ways of speaking about a subject that we have heard, read, and used countless times in speech and writings in settings such as lectures, textbooks, scientific articles or in popular science programs in the media (Lemke, 1990, pp. 34-35). On the other hand, more or less complex versions of thematic patterns are also to be found in dialogues among participants in educational settings, because this is where thematic patterns are reproduced and made sense of. Given that words and concepts do not have inherent meaning, it is impossible to obtain a one-to-one relationship

between the thematic pattern in a science field and the thematic pattern reproduced in a dialogue between, for instance, participants in an educational setting. Instead of searching for the perfect match between the authorized versions of science and how students reproduce these patterns in their dialogues, it is perhaps more interesting to approach their sense making of science concepts and issues as a process of appropriation. Appropriation refers to the process of "making a cultural tool one's own" and is a demanding and complex process done in interaction between individuals (Säljö, 2005; Wertsch, 1998). The notion of appropriation and how the social becomes individual is central in a sociocultural perspective on meaning making. The concept of appropriation was first coined by Bakhtin (1981) who describes the process of appropriation in the following way:

> The word in language is half someone else's. It becomes "one's own" only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. Prior to this moment of appropriation, the word does not exist in a neutral and impersonal language […], but rather it exists in other people's mouths, in other people's contexts, serving other people's intentions: it is from there that one must take the word, and make it one's own […]. Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated—overpopulated—with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process. (p. 293-294)

In most teaching and learning activities, students are exposed to new concepts. The concepts brought into the learning situation can have a more or less close connection to students' everyday language (Vygotsky, 1978). Scientific concepts that are part of the curriculum come with a history that is not explicit for the students (Lemke, 1990; Vygotsky, 1978; Wells, 1999). If there is a close connection to everyday language, the students often will start using this concept as a resource for making sense and to create some kind of social order. If the concepts are new to the students, they will need to talk them through in order for the concepts to have any meaning at all (Wertsch, 1998). Additionally, wordings must change flexibly to meet the needs of the argument, problem, use or application of the moment because words and concepts are just thematic items that are parts of thematic patterns (Lemke, 1990). In this perspective one of the most essential purposes of schooling is to socialize students to appropriate a specialized discourse in different knowledge domains, and, at a more general

level, to socialize them to a level where they become "educated citizens" (Lemke, 1990; Vygotsky, 1986; Wells, 1999).

## 2.4 Institutional aspects of meaning making

The sociocultural perspective on learning and cognition views social and cognitive processes as intertwined. This implies that the students' actions and activities are embedded in historical and institutional settings, where norms and values become central aspects in their argumentation and reasoning (Ludvigsen, in press; Mercer, 2004). Education is a dialogic process, where teachers and students interact in settings that reflect the values and social practices of schools as cultural institutions (Mehan, 1991). From this perspective students' talk and activity can be characterized by what Linell (1998; 2009) terms as "a double dialogicality", because their talk and activity stand in relation to the existing interactional context. Additionally their talk and activity are also related to sociocultural practices established over long traditions:

> [L]inguistic structures, cultural routines, norms etc. do exist prior to interactions (but only in and through the interactants' being acquainted with them). At the same time, however, these structures, routines and norms are interactionally generated, traded down and reconstructed. That is, they exist prior to individual interactions, yet would not exist without a living historical continuity of interactions. Social structures are (re)created, tried out, tested, negotiated and modified every time they are instantiated or drawn upon. (Linell, 1998, pp. 59-60)

In educational settings students orient their activities and talk towards the more or less explicit expectations, values and practices embedded in the particular educational setting. This implies that students' meaning making is not only a matter of making sense of science issues and concepts. An important part of students' meaning making processes is making sense of how to respond to a more or less explicitly expressed set of institutional practices, values, and expectations. This can be in terms of making sense of the tasks and how to solve them in a satisfactory manner, the resources in use, the teacher's instructions, and assessment criteria. This does not mean that students' activity and interaction are determined by the institutional practices and norms, but rather that institutional aspects are invoked and oriented to as structuring resources within their meaning making processes. It is the relation between

institutional aspects of the setting, and the actions performed by the students, where learning activities are created. Such activities have social complexity and forms of multi-voicedness as a starting point (Wertsch, 1991). This means that traces of the structuring impact of institutions are invoked and visualised within students' talk and activity while engaging with Web-based inquiry environments.

In two of the articles[4] in this thesis the distinction between the activity of "doing school" and "doing science" made by Jiménez-Aleixandre, Bugallo Rodríguez, and Duschl (2000) has served as a useful starting point for explicating a sociocultural approach on students' meaning making processes as well as explicating the analytical approach of the studies. Jiménez-Aleixandre et al. make a distinction between what they regard as two types of student discourse activities in science education: "doing school" and "doing science". The term "doing school" refers to the actions and activities or procedural displays that constitute the routines and rituals in educational settings. According to Jiménez-Aleixandre et al., these are often taken for granted and serve as obstacles for the activity of "doing science". The term "doing science" refers to scientific dialogues characterized by "construction, representation, evaluation of knowledge claims and investigative methods" (Jiménez-Aleixandre et al., 2000, p. 759). Several science education studies, especially those building on a socio-cognitive perspective, focus on talk and argumentation between collaborating peers and their teachers (Driver et al., 2000). However, most of these studies' analytical attention is solely focused on talk where students make written or spoken accounts of the scientific issues as such[5]. In other words the focus is on students' "doing science" activities, whereas the procedurally related talk—the "doing school" activities—is systematically left out. As demonstrated in Study I and Study II, it is often within procedural talk—"doing school activities"—that the institutional norms and practices are addressed and invoked. Consequently, it is not sufficient to exclusively focus on students' scientific talk. It is equally important to focus on students' procedural talk or the "doing school" activities.

To put it another way, this type of approach both entails a particular focus on *micro-genesis*—on how learning and reasoning develop moment-by-moment in social interaction. Simultaneously, it entails an equal emphasis on *socio-genesis*—on how specific ways of acting and using mediational means have developed historically and culturally (Linell, 2009; Ludvigsen, 2009; Säljö, 2000). Analytically, it is important to scrutinize the tensions between

[4] Study I and Study II.
[5] See e.g. the studies by Lewis and Kattmann, 2004, and Erduran, Simon and Osborne, 2004.

socio-genesis and micro-genesis, between historically developed functional, useful, or valid uses of mediational means, and participants' (re)production of these practices in interaction.

## 2.5 Arguing for an analytical approach

The three studies within this thesis take an interpretative stance, meaning that the primary analytical focus is on *socially situated meaning making*. This interpretative stance rests on the assumption that meaning making is seen in terms of a constitutive relationship between individuals' communicative actions, artefacts and the social contexts in which they are situated. More specifically, the analytical focus of the three studies is on technological, epistemic and institutional aspects of students' meaning making processes. In order to grasp this mutually constitutive relationship between these three aspects and students' meaning making the analytical focus in the three conducted studies were turned towards the students' "accounts". In the following I argue that by focusing on students' accounts over time it become possible to see how they *orient* their talk and activity towards technological, epistemic and institutional aspects in their meaning making processes. Furthermore, I argue for the importance of following the students over time, or focusing on what I term as "interaction trajectories" in order to capture how the students' orientation changes over time.

### *2.5.1 Accounts*

The three studies within the thesis focus on students' *accounts*—specific forms of language use, i.e. actions such as explanations, disagreements, or justifications. This implies that the attention has been on the participants' concerns, what they treat as relevant, as well as how they try to deal with these concerns in their talk. In an everyday sense "being accountable" originates from the metaphor of "keeping an account" of ones own conduct in social activity (Buttny, 1993). Accounts have been treated differently within different theoretical stances. Seen from an ethnomethodological perspective, accounts and accountability are seen as core features for understanding maintenance of social order. Here accountability of conduct refers to the various ways that people present their activities to render them normal, understandable and intelligible in social practices. In all types of social practices, individuals continuously account for their actions in such a way that their talk and actions are comprehended by others as "visibly-rational-and-reportable-for-all-practical-purposes" (Garfinkel, 1984, p. vii). That accounts are seen as "reportable" implies an anticipation of all individuals being seen as rational in that they are capable of giving account

for their actions and that their particular actions are always part of a contextualised activity. This means that all everyday activities are intrinsically "reflexive" because they embed procedures that justify, explain, or visualise the intention of the activity (Shotter, 1984). Examples of typical reportable and reflexive ways of accounting for social conduct could include such actions as queuing where people signal their turn by forming a line or signalling that they are waiting for a bus by standing on the side of the pavement close to a bus stop signpost.

Another way of approaching the notion of accounts lying closer to the sociocultural and dialogic perspective on social practices, as utilized in this thesis, is to treat accounts as linguistic devices[6]. Scott and Lyman (1968) describe accounts in the following way:

> An account is a linguistic device employed whenever an action is subjected to valuative inquiry. Such devises are a crucial element in the social order since they prevent conflicts from arising by verbally bridging the gap between action and expectation. (p. 46)

In this perspective there is no need to provide accounts in settings which are seen as unproblematic and intelligible such as engagement in routine. In these types of situations activities are self-explanatory and understood by interlocutors as warrantable and understandable. However, in situations characterized by a "gap between actions and expectation", or what also can be termed as "fractured social interaction", explicit accounts are required (Semin & Manstead, 1983). Accounts are either initiated spontaneously by the person that "fractured" the interaction, or by interlocutors in the form of direct inquiry of or challenge to the initiator. This means that an account is seen as "a statement made by a social actor to explain unanticipated or untoward behavior" (Scott & Lyman, 1968, p. 46). Most studies on accounting practices have been focusing on failure events and untoward behaviour where accounts have been called for or offered in terms of excuses, apologies or justifications. Many of these studies have developed detailed typologies of accounts and accounting practices (Semin & Manstead, 1983)[7].

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[6] This perspective on accounts corresponds with Goffman's generic term "facework" (Goffman, 1959; Semin & Manstead, 1983). In Goffman's view facework refers to the coping process instigated by the occurrence or some threat of some behavior which disconfirms the identity of an actor. Facework are, in other words, actions taken by the individual to render behavior in a specific situation consistent with the projected definitions of that type of situation.

[7] See e.g Schönbach, 1980 and Tedeschi and Riess, 1981. Their typologies build on and extend Scott and Lyman's taxonomy where accounts are in form of either "excuses" or "justifications". The extension consists of the addition of further categories such as "concessions" and "refusals".

However, accounts are not only circumscribed as responses to untoward behaviour or unanticipated behaviour such as conflicts or challenges. Accounts can also be in the form of descriptions, clarifications and explanations occurring in situations where there is a "gap between action and expectation". In this sense an account is seen as the practical achievement of knowing how to go on in a discussion (Mäkitalo, 2003). In some situations we might need to explain what we mean by what we say or how we understand, e.g. a particular scientific concept. In school settings where students and teachers participate in discussions about complex scientific concepts, or any type of issues for that matter, discursive gaps occur. In these types of settings, accounts can be seen as linguistic devices that participants use to deal with issues, arguments or actions that somehow require explanations, justifications or clarification because the arguments or actions might contrast with the taken for granted normative ordering of the practice or concept in question.

Seeing the previous discussion of accounts in relation to the analytical approach in this thesis, accounts, then, are to be seen as linguistic devices, where interlocutors make their interpretations and orientations visible to others, and also where they express how they want others to interpret what they are saying and doing. By focusing on accounts, we are in a position to investigate how students make sense of scientific concepts as well as the taken-for-granted character of the practice—the norms, roles and expectations structuring action. In other words, a focus on students' accounts constitutes a possible entrance into studying different aspects of students' *meaning making processes*, because it is within the accounts that these aspects are displayed, invoked, or even explicitly addressed.

### *2.5.2 Changes in orientation and the notion of interaction trajectories*

As argued, students' meaning making processes in school science is a matter of technological, epistemic and institutional concerns. How these aspects are realized in particular educational settings, however, remains an empirical question. By focusing on participants' accounts it is possible to identify how interacting participants in school science invoke and thereby *orient* to these types of aspects in their meaning making processes. Within the three studies in this thesis the notion of "orientation" is mainly used as an operational concept for being able to capture what is considered to be relevant by those who are doing the talking. Moreover, the empirical focus is on the *changes* in the students' orientations during their interaction trajectory. In the following I will first elaborate on how

to understand students' changes in orientations and then on the notion of interaction trajectories.

Goffman's concept *changes in footing* (Goffman, 1981) is applicable to how to conceive and understand the changes in students' orientation and the intertwined relationship between technological, epistemic, and institutional aspects of their meaning making processes. According to Goffman, footing is about the *grounds* for interpreting and making sense of what is said or done. In this sense footing refers to a kind of interpretative framework against which the actions of the participants get their meaning. It points to the interconnection between the normative structure of the setting and activity—for example, what constitutes an appropriate way of acting or talking about an issue within a particular setting— and what people actually say and do. Changes in footing point to how participants in and through their actions continuously change this interpretative framework during a conversation. Goffman (1981) describes the notion of changes in footing in the following way:

> A change in footing implies a change in the alignment we take up to ourselves and the others present as expressed in the way we manage the production or reception of an utterance. […] [P]articipants over the course of time of their speaking constantly change their footing, these changes being a persistent feature of natural talk. (p. 128)

During conversations speakers constantly change their footing and alignment to one another and to the content of their talk. In a school science setting, students are not only expected to engage with and make sense of specific conceptual systems. They are also expected to produce end products and perform different types of schooling activities such as discussions and solve tasks. But most importantly, the students' accomplishments and performances are to be assessed based on more or less explicit assessment criteria. Accordingly, these context specific features of schooling are most likely to be invoked in students' interaction and talk in these types of settings. Seeing the students' different orientations as changes in footing during interactional trajectories show that to be able to understand students' meaning making in genetics, it is not sufficient to exclusively focus for instance on their scientific talk. The embedded values, norms, and expectations—in other words, the context—constitutes an indivisible part of students' meaning making. Being empirically sensitive to students' changes in footing during their interaction makes possible an understanding of meaning making processes as a matter of constant shifts between

different frames for making sense of their activity and, by the same token, changes in their orientations.

A focus on changes in students' orientation during their work process is common for all three studies in this thesis. The emphasis on changes is closely related to the assumption that meaning making activities are taking place through moment-to-moment interactions, but also across longer stretches of time. A focus on what is termed students' "*interaction trajectories"* makes it possible to study how students' orientations change over time. The concept "trajectory" has been used by several scholars during the last decades (Ludvigsen, Rasmussen, Krange, Moen, & Middleton, in press). For some researchers the concept trajectory denotes a limited and restricted period of time such as a patient's course of illness (see e.g. Strauss, 1975). Another way of using the trajectory concept is within studies on individual development where trajectories are seen as individuals' participation in various contexts (Dreier, 1999). In other studies the concept of trajectory denotes the relation between various activities taking place within long term projects such as school project work (see e.g. Rasmussen, 2005 or Engle & Conant, 2002) or in relation to the lifecycle of production projects (Engeström & Escalante, 1996).

The term "interaction trajectories", as used in this thesis, denotes the relation between units of moment-by-moment interactions. Linell (1998) describes these moments as "episodes" which refer to "relatively bounded sequences" within more comprehensive speech events or encounters (p. 187). Episodes can be seen as a sequence of collective action, and most episodes are "about" something. This means that they are oriented to, attend to, and bound to some kind of topic. In this sense "interaction trajectories", as used in this thesis, is meant to capture the discursive relationship *between* episodes as well as the *changes* in participants' orientation across episodes taking place within a time—or an activity-limited educational setting. Examples of these types of settings can be activities where students interact while engaging with a particular task, interaction processes limited by recess time or a setting allocated for group discussion. Most often the analysed interaction takes place within 1 to 2 school hour sessions. On a theoretical level, the concept of interaction trajectory is important because it provides for the possibility of exploring how students orient themselves in different situations over time. In other words, it expands a moment-to-moment analysis of learning and takes into account how continuity and change are constructed in interaction (Rasmussen, 2005). In talk and interaction, topics and themes are discussed, negotiated and left behind, only to be reintroduced later (Engle & Conant, 2002). Following

students' activities through time spans might enable us to see how thematic patterns unfold. Most important, however, is that a focus on students' interaction trajectories makes it possible to identify how students' meaning making is also a process embedded in, and interdependent with, complex social and cultural contexts. The notion of interaction trajectories is not only important on a theoretical level, but also on a methodological level. I will return to the methodological implications for focusing on interaction trajectories in the methods chapter.

Returning to where I started this section, the focus in the conducted work in this thesis is on students' meaning making processes—social interactions where students make sense of one another's actions, scientific concepts and the social setting where their actions take place, including the artefacts they make use of, to accomplish their tasks. With the outline of my theoretical perspectives and analytical approach as a backdrop, I will, in the following section, present and discuss previous research on students' engagement with Web-based inquiry environments.

# 3 Research on students' engagement with Web-based inquiry environments

In the following I present and discuss some key studies on students' engagement with a) the CSILE/Knowledge Forum environment and b) KIE/WISE and Viten.no environments. The studies discussed were selected for two reasons. First, they focus on Web-based environments which are similar to the environments that are central to my own studies. Their findings on how these resources are used represent an important context for the results presented in this thesis. Second, the selected studies serve as a point of departure for positioning my own dialogic approach by means of scrutinizing some of the essential distinctions between systemic and dialogic approaches towards exploring students' engagements with Web-based inquiry environments. As mentioned in the *Introduction*, the majority of studies on students' engagement with Web-based inquiry environments take on a systemic approach. This is also the case for studies focusing on students' use of the above-mentioned Web environments. In reviewing these studies essential distinctions will be identified that are pertinent to dialogical approaches of students' engagement with Web-based inquiry environments. These essential distinctions are further elaborated on by discussing studies with a dialogic approach to students' engagement with Web-based environments.

## 3.1 Research on students' knowledge construction in Web-based discussion forums

### *3.1.1 Computer-supported knowledge-building*

Perhaps the most successful and renowned Web-based inquiry environment is the Computer-Supported Intentional Learning Environment (CSILE). This was subsequently transformed into the Knowledge Forum, developed by the research group initiated by

Marlene Scardamalia and Carl Bereiter, which is now available for professional use. The work done by this research group has influenced research on students' inquiry learning with Web-based learning environments. It has also influenced the design of several similar discourse-oriented learning environments such as the Future Learning Environment 2 which is the focus of Study I in this thesis. A common feature of this type of Web-based inquiry environment is that they are based on variations of pedagogical models of idealized inquiry processes such as the "Knowledge-building" model (Scardamalia & Bereiter, 1996). These model students' learning processes as a research activity, where the aim is joint construction of knowledge and problem solving through peer discussion. The aim for the teacher as a facilitator is to support students' awareness about the different phases of the process of scientific inquiry.

The CSILE environment can best be described as a communal database for producing, searching, classifying, and linking knowledge and ideas. The CSILE environment is designed to engage students in question-driven inquiry, help them generate and improve their own intuitive explanations, and search for scientific information (Hakkarainen, 2003a). The system facilitates sharing of information and discourse by providing students access to texts, notes and comments made by the participants in the Web-based learning community by means of different types of tools. The most central tools are an asynchronous discussion board where the students can post notes to the common workspace, a synchronous discussion tool, small-scale simulation tool and domain-specific Internet resources. The Knowledge-building board, which is perhaps the most important tool within these environments, is an asynchronous discussion board. It is considered to be a supporting module for progressive inquiry where the students post their messages to the common workspace, labelling the messages according to predefined epistemic categories, termed "thinking type tags." Some examples of tags are, for instance, "Problem", "My Theory" and "I Need to Understand." These categories are defined to reflect the different phases in the progressive inquiry process.

The CSILE environment and its like can be seen as generic environments in the sense of that the content or subject matter at issue can be accessed and produced by the users. This organisation reflects the idea of seeing the process of scientific inquiry as a generic learning model that can be applied in all settings where the aim is to construct knowledge. These types of environments are characterized by a low structuring of the scientific content. This implies that they provide access to a selection of relevant, but not necessarily systematic organised resources from the Internet, such as text extracts from textbooks, pictures, video clips, models

of scientific phenomena or news articles. Based on these information resources, the students produce their own research questions, explanations and comments within the discourse forum, sometimes in combination with writing articles to be published in the shared work space.

### *3.1.2 Research focus, methods and analytical practices*

The material forming the empirical basis for the following CSILE studies was produced over a three-year period within a design based research project taking place in a CSILE collaboration school in Toronto, Canada. Additionally, parts of the data in the comparative study conducted by Hakkarainen, Lipponen and Järvelä (2002) were produced within a Finnish school setting. In the studies the researchers from the CSILE research group followed classes of elementary school students aged ten to eleven years and their teachers over three academic years. The learning environment CSILE was used as part of the normal science education activity. Based on socio-cognitive theories, most of the studies conducted focus on identifying the *quality* and the *quantity* of students' scientific discourse within the CSILE environment as well as identifying *advancements in the students' scientific discourses* during a project trajectory (Hakkarainen, 2003a) or over longer spans of time (Hakkarainen, 2003b; Hewitt, 2002)[8]. The findings in these studies are based on systematic multiple-level analyses of students' written productions (research questions, intuitive and scientific explanations, and written comments) by means of qualitative content analysis (Chi, 1997). This type of analysis implies that students' written contributions were classified and scored in accordance with, for instance, predefined explanations levels or argumentation models. In turn, the classification and scorings served as potential indicators for explaining students' procedural or conceptual advancements.

In the CSILE environment both the students' self-produced research questions and their postings to the group discussion in Knowledge Forum were analysed. First, the students' questions were classified as being either fact seeking or explanation seeking. Second, on a general level, students' explanations and comments were partitioned into singular "*knowledge ideas*" in order to be classified according to whether their main content represented new scientific information or the student's own intuitive explanation. Third, students' knowledge ideas were classified and scored by means of either an explanation

[8] There have also been conducted cross cultural oriented studies focusing on the use of the Web-based environments in a Japanese context (Oshima and Oshima, 2002) and a comparative study including a Canadian and a Finnish school setting (Hakkarainen et al., 2002).

typology (Hakkarainen, 2004) or a five-step explanation scale where the top-end levels represented the most complex and advanced explanations (Hakkarainen, 2003a). For instance, the explanation scale included the categories level 1: "Separated Pieces of Facts", level 2: "Partially Organized Facts", level 3: "Well-organized Facts", level 4: "Partial Explanation" and level 5: "Explanation" (Hakkarainen, 2003a, pp. 1076-1077). The classification of the students' contributions was used as a basis for identifying characteristics as well as changes on class level. Some of the studies also focused on each student's individual achievement within these types of environments (Hakkarainen, 2004). Ultimately these analyses were used as a basis for exploring how a Web-based learning environment can facilitate and foster a classroom culture characterized by knowledge-building and progressive inquiry.

### *3.1.3 Findings*

The CSILE studies provide several important and interesting findings. Common positive findings within all these studies regard the identification of *advancements in the students' conceptions*. These findings are in general based on two different indicators. First, the researchers identified a change in the students' research questions from initially being *fact oriented* towards, over time, being more *explanation oriented*. This type of change has been seen both within a particular project (Hakkarainen, 2003a) and also as a more general feature developing from project to project over years of research (Hakkarainen, 2003b). A second indicator of advancements is the *development in the students' "knowledge ideas"*. The students' initial theories about concepts and issues were mostly characterized by use of intentional descriptions. However, in the course of the project, practically all students managed to overcome the intentional nature of explanations. Furthermore, the studies identified that the majority of the students during the course of time succeeded in attaining considerable deepening in the level of explanation towards more science-based explanations (Hakkarainen, 2003a). As an example of the deepening of the students' explanations, several students moved from making functional oriented explanations towards making more empirical-physical explanations. However, only a few students managed to arrive at the most advanced form of explanations; theoretical-physical explanations (Hakkarainen, 2004). The importance of teacher intervention and peer interaction is often stressed as the most important factors that contribute to explain the positive findings with regards to the students' conceptual advancements within the reported studies. However, the role of teacher intervention as well

as the role of peer interactions does not seem to be systematically analysed in the reported studies. The implication of this will be discussed in further detail later.

The studies also identify some important and challenging aspects of students' engagement with the Web-based environment. One such challenge is termed as "conceptual challenges." The analyses of students' written accounts indicate that few students were able to produce advanced theory-oriented explanations about concepts such as the function and role of cells (Hakkarainen, 2003a), and especially gravity and cosmology (Hakkarainen, 2004). Another challenging finding concerns a rather widespread use of fact-finding strategies. Fact-findings strategies refer to responses that are mainly descriptive and referencing in character in contrast to being more explanation, argumentation and scientifically oriented (Hakkarainen et al., 2002; Hewitt, 2002). However, the study of Hakkarainen et al. (2002) demonstrates how teacher intervention can have a positive impact on guiding students towards more understanding oriented approaches. In groups where teacher intervention was characterized by being indirect in terms of prompting questions and encouraging students to retrieve science-based information, the students were more likely to provide explanations instead of referring facts or giving descriptive explanations.

Summing up the presented research, some key points stand out. First, the conducted studies focus primarily on (a) identifying the quality and the quantity of the students' written explanations produced within the CSILE environment and (b) identifying advancements in the students' written explanations during a project trajectory. Second, the findings in these studies are based on classifications and scoring of students' written productions within the Web-based environment such as their research questions, discussion contributions and comments. Concerning the findings of the studies, the most unambiguous finding concerns what is termed "advancements in the students' conceptions." The finding of student advancements is primarily based on two indicators. One indicator is the changes seen in the students' research questions; from being primarily fact-oriented, the majority of the students' questions moved towards being more explanation and understanding oriented during a project or between projects (Hakkarainen et al., 2002; Hewitt, 2002). A second indicator of advancement was the increasing quality of students' explanations and knowledge ideas. The studies document a considerable deepening in the level of students' explanation towards more science based explanations during or across projects. Even though all the discussed studies emphasize the importance of collaboration and teacher intervention for these advancements, neither of these issues are systematically addressed or included in the

analyses. These studies also point to some conceptually challenging issues where students have difficulties with giving theory—and scientific explanations of issues such as the central functions of cells (Hakkarainen, 2003a), and especially gravity and cosmology (Hakkarainen, 2004).

## 3.2 Research on students' learning in scaffolded knowledge integration environments

### *3.2.1 Scaffolded knowledge integration*

The computer-based inquiry environments Knowledge Integration Environment (KIE) and its successor WISE were designed by Marcia Linn and her colleagues. The KIE and WISE environments aim to support an idealized model of scientific inquiry termed "knowledge integration" developed by Linn (1995). Knowledge integration refers to "the process of adding, distinguishing, organizing, and evaluating accounts of phenomena, situations, and abstractions" (Linn, Eylon, & Davis, 2004b, p. 30). In order to support students' knowledge integration, the Web-based learning environments build on the four broad based design principles; make science accessible, make thinking visible, help students learn from others, and promote autonomy and lifelong learning. In WISE, these design principles are realized within a variety of 50 curriculum-based science projects designed by the research group in partnership with scientists, teachers, educational researchers and technological specialists. WISE provides an Internet-based platform in which students can work collaboratively on the projects, making use of Internet resources. Typical projects engage students in, for example, designing solutions to problems, discussing socio-scientific controversies and critiquing scientific claims found in Web sites (Slotta, 2004). The students are introduced to different scientific issues, problems and concepts by navigating through specific activity steps. Central in KIE and WISE are the inbuilt tools designed with the purpose of supporting different aspects of the students' inquiry process. Examples of such tools are a tool for making sense of and organizing evidence and claims, a note tool that allows students to construct and edit their arguments using a graphical representation, and a tool for online discussion (Linn, Davis, & Bell, 2004a; Slotta, 2004). All student work is saved on central project servers.

Viten.no, the Norwegian counterpart of the KIE/WISE learning environments, is the focus in two of the conducted studies reported within this thesis. Despite some differences in

design and structuring of content and student activities, Viten.no shares many of KIE and WISE characteristics. The design of Viten.no also intends to support the idealized model of the knowledge integration process (Jorde, Strømme, Sørborg, Erlien, & Mork, 2003). By means of features such as drag-and-drop tasks, descriptive text accompanied by illustrations, animations, and multiple-choice tests, discussion tools and occasionally out-of-school activities, the students are guided step-by-step through predefined central issues within the various topics in science. The most distinctive difference between the KIE/WISE environments and Viten.no is that Viten.no only contains one inbuilt tool which is the so called notes, a generic tool designed in order to support student reflection. Viten.no is described in more detail in section 4.2.

### *3.2.2 Research focus, methods and analytical practices*

Within research on science education, scientific discourse and argumentation is a central field of interest. Accordingly, in many studies, the unit of analysis is students' talk, and talk between students and teachers (Mortimer & Scott, 2003). Within this field the majority of the studies emphasizing students' meaning making of scientific concepts and phenomena are studies with a socio-cognitive orientation. This means studies that direct their analytical attention towards a particular kind of student talk: scientific discourse. A major part of these studies is inspired by variations of argumentation models such as Toulmin's (1958) model of scientific argumentation (Newton, Driver, & Osborne, 1999; Osborne, Erduran, & Simon, 2004). Toulmin identifies four types of statements that contribute to an argument. Scientific argumentation is conceived as a process of using evidence, warrants and backings to convince others of the dependability of specific claims (Lawson, 2003; Suppe, 1998).

The emphasis on argumentation seen in research on science education in general is also prevalent in most of the research on the Scaffolded Knowledge Integration environments. Most often the unit of analysis is students' written productions within the Web-based learning environment, such as online discussions, responses to explanation prompts, or written reports. In some cases pre- and post-tests are used as well. The students' accounts within the written productions are particularised, classified and scored by means of idealized models of argumentation such as Toulmin's model or adjacent models.

Most of the studies on these types of environments are *non-experimental design* studies (Brown, 1992), where the data are produced within natural classroom settings at middle or secondary school level. There are also a few studies with an *experimental design*.

Even though students' written productions form the unit of analysis in both types of studies, the research focus differs. In the studies with a non-experimental design, the students' argumentation scores, or changes in argumentation scores during a project, become a means for measuring changes in a) the quality of students' inquiry skills, argumentation or explanations, b) the students' beliefs about science, or c) the students' conceptual understanding. Ultimately, the argumentation scores are discussed and seen in relation to the learning principles forming the base for the idealized forms of scientific inquiry (see e.g. Bell & Linn, 2000; Clark & Sampson, 2007; Mork & Jorde, 2004; Mork, 2006a; Seethaler & Linn, 2004).

A common feature of many Web-based inquiry environments is the built-in tools, also referred to as prompts, aimed at supporting specific aspects of students' inquiry processes. As described above, KIE, WISE and Viten.no contain specific tools aimed at supporting construction of scientific explanations, reflection and online discussions. Some of the research on KIE and WISE are studies that by means of an experimental design aim at measuring the effect of these prompts on students' inquiry performances and acquisition of scientific knowledge. Also within these types of studies, the findings are based on classifications and scoring of students' written productions within the Web-based environment by means of various models of idealized argumentation or types of explanations. The primary intention of most of these experimental studies focusing on the effect of prompts is to give input into how to (re)design the Web-based inquiry environment, or elements in it, in order to optimize the support of the predefined idealized activities such as knowledge integration (Davis, 2003; 2004; Davis & Linn, 2000). In the following I present the findings from some of the most central studies on the Scaffolded Knowledge Integration environments KIE, WISE and Viten.no.

### *3.2.3 Findings*

Clark and Sampson (2007) focus on the role of "personally-seeded" discussions as a way of supporting students' scientific argumentation. Personally-seeded discussions refer to discussions where students are organised in groups with other students that have different ideas or principles. The idea is to facilitate a setting where the students explain and defend their own principles by responding to and critiquing the other ideas in the discussion. In a project about thermal equilibrium, the students followed a set of given guidelines delivered to them in the WISE discussion forum in order to explain, critique, and defend each others'

principles. By means of a coding scheme developed by Erduran, Simon and Osborne (2004), based on Toulmin's argumentation model, the students' arguments produced within the Web-based environment were classified and scored. These scores were then compared and discussed in relation to argumentation scores produced within an unrelated face-to-face study conduced by Simon, Osborne and Erduran (2003). Based on this comparison, the researchers conclude that the Web-based environment effectively supported personally-seeded discussions, which in turn scaffold high structural levels of scientific argumentation. One critical and important finding was that the analysis also demonstrated that the desired argumentation structure was not always accompanied by the normative version of the scientific topic at issue, or what they term "normative conceptual content" (Clark & Sampson, 2007, p. 270).

In another study, Bell and Linn (2000) focus on changes in students' beliefs about propagation of light. The students were presented two theoretical positions in the KIE environment: one normative and one "naïve" conception. Each student team selected their position before they explored and collected evidence in order to refine their arguments. In the end the student groups presented and discussed their arguments in a classroom session. By means of pre- and post-tests related to epistemological beliefs, the students' arguments were coded and scored in relation to Toulmin's (1958) model of argumentation. The analyses show that the students' arguments moved from initially relying mostly on naïve beliefs towards asserting the normative version. In addition, the students' arguments moved from a mostly descriptive to an explanatory orientation. Based on this the researchers conclude that the activities implemented in the Web-based learning environment "elicit student arguments which offer evidence for knowledge integration" (Bell & Linn, 2000, p. 812).

In a study conducted by Seethaler and Linn (2004), the focus is on *gains in students' understanding* of the genetically modified food controversy. By coding and scoring students' written productions within the WISE environments, their positioning paper, and their responses to pre- and post-tests, the researchers found significant gains in students' conception of the gene modification controversy. The analyses indicate that the students were able to make more appropriate use of evidence to argue for their positions at the end of the project than at the outset. The majority of the students also managed to include contradictory evidences into their argumentation, indicating that their arguments reached a more advanced level. A more challenging finding, however, concerns the notion of the transferring of students' inquiry skills from one setting to another. The analyses of students' written

productions show that students rarely used evidences put forward in one discussion in other discussions where adjacent topics were debated.

Two studies are of particular interest for this review regarding the Viten.no environment[9]. The first involves secondary school students working with a socio-scientific controversy— ecological management of the wolf stock in Norway (Mork & Jorde, 2004). The focus of the study was on students' learning gains, changes in the students' views about wolves and gender differences. Students' responses to pre- and post-tests consisting of multiple-choice questions and open-ended questions were coded and scored. Based on changes in the students' scores in the pre and post-test, the researchers argue for significant learning gains. They also found large changes in the students' view on wolves. Two thirds of the students changed or modified their opinion about the danger of wolves during the project moving towards finding them less threatening. Regarding the gender issue, the girls spent more time working with the wolf program, and achieved significantly higher scores on the post-tests. In a similar pre- and post-test design study, but within the subject domain radioactivity, comparable findings are reported (Mork, 2006a). Based on the changes in pre- and post-test scores, the researcher finds that learning gains were obtained. Another finding concerns changes in students' views on radioactivity. During the project the students' focus seemed to shift from regarding radioactivity as "plain dangerous", towards a more factual and scientific description of the phenomena. The study also demonstrates that most students focused on the negative aspects of radioactivity, and that few students were able to argue for both the pros and cons of radioactivity.

As mentioned earlier, there is also a body of studies with an experimental design that focus on the effect of prompting specific aspects of students' inquiry process, such as argumentation, explanation, reflection or collaboration. Davis and Linn (2000) conducted an experimental study focusing on the effect of prompting student argumentation and explanation of scientific phenomena. Two different versions of an argument-building tool were designed and introduced to 8th grade students in a project about thermodynamics and light. The students' written responses to the prompts and their end products were classified and scored. The explanations in the groups that had received both activity and self-monitoring prompts were significantly more likely to include at least one scientific principle

[9] In addition to the two Viten.no studies in focus here, there are also some studies that focus on role-play debates where students' use of Viten.no was part of the students' preparation for the debate (Mork, 2005; Mork, 2006b). The focus of these studies are respectively students' argumentation and teacher intervention in role-play debates as such. The students' employment with Viten.no, however, was not analysed or addressed directly.

in their explanations. Furthermore, the student groups that also received self-monitoring prompts were more likely to link principles to other ideas. In a similar study, Davis (2003) contrasts the effects of two types of reflection prompts, "generic prompts" and "directed prompts", designed within the Knowledge Integration Environment. "Generic prompts" were generic in that sense that they did not provide instructions for what to elaborate. In contrast, directed prompts gave students hints about what to elaborate. First, Davis found that the students in the generic prompt condition developed more "coherent understandings" of science than the students who received directed prompts. Second, the students more often reflected "unproductively" in response to the directed prompts compared to the generic prompts (Davis, 2003, p. 129) [10]. Overall, this means that the more open-ended generic prompts were considered to have a greater effect than directed prompts.

Yet another study with a focus on the effects of prompts was conducted by Kollar, Fischer and Slotta (2007). Their analyses are based on data produced in an experimental design study where secondary school students used the German version of a WISE biology program. The main focus of the study is to explore to what degree prompts aimed at supporting students' collaboration impacted students' acquisition of argumentation skills and scientific knowledge. Groups of students were exposed to two different versions of the WISE program. By means of pre- and post-tests in the form of questionnaires assessing argumentation and domain specific knowledge, Kollar et al. draw two main conclusions from their study. Student groups exposed to the detailed collaboration script version of the WISE-program had the highest gains in the achievement of argumentation skills. However, Kollar et al. could not find significant evidence for higher gains in students' scientific content acquisition in the groups that were exposed to the detailed version. This finding corresponds with studies on other types of prompts which also show that they were more effective for enhancing students' acquisition of inquiry skills than of scientific knowledge (van Joolingen, de Jong, & Dimitrakopoulout, 2007).

After reviewing the main points from the review of scaffolded knowledge integration studies, some elements stand out. One point concerns the focus on scientific argumentation and discourse. Another point concerns the methods and analytical practices. The findings in these studies are most often based on classifications and scoring of students' written productions within the Web environment, sometimes in combination with documenting their

[10] 'Productive', in a KIE setting, refers to a "knowledge integration" processes characterized by the following: students manage to expand their repertoire of ideas, distinguish between ideas, make links between ideas and identify weaknesses in their current knowledge (Linn *et al*., 2004b; Davis, 2003).

performances in pre- and post-tests. The final point concerns what we can learn from these studies. The most documented finding concerns gains in the quality of students' inquiry skills such as argumentation and explanation (Bell & Linn, 2000; Clark & Sampson, 2007; Seethaler & Linn, 2004). Another commonly reported finding are changes in the students' beliefs about science towards more "scientific and normative" versions of issues such as radioactivity, dangers of wolves and genetically modified food (Bell & Linn, 2000; Mork, 2006a; Mork & Jorde, 2004); yet other studies report changes in the students' conceptual understanding of gene modification, ecological management of wolf stocks and radioactivity (Mork, 2006a; Mork & Jorde, 2004; Seethaler & Linn, 2004). Concerning the effects of different types of prompts, the experimental studies report positive effects especially with regard to students' inquiry skills such as explanation, reflection and collaboration. However, these studies also show a lower impact on students' knowledge acquisition (Kollar et al., 2007; Davis, 2003). These findings correspond with findings from several studies on students' engagement with a variety of Web-based inquiry environments (van Joolingen, et al., 2007). For instances as discussed above, Clark and Sampson (2007) found that even if students are capable of producing high quality argumentation, the content of the arguments does not necessarily correspond with a normative conceptual scientific content. This point will be discussed in further detail in the following discussion about the strengths and limitations of a systemic approach towards students' engagements with Web-based environments. Other reported challenges concern the notion of transfer; the students tended not to use relevant evidence in adjacent problems (Seethaler & Linn, 2004). Furthermore, gender differences were reported, showing that the girls performed better than the boys on the post-tests, as well as used more time in the Web- environment (Mork & Jorde, 2004).

Based on the account of the methods and findings of relevant research on similar Web-based environments as those in focus of this thesis, I will, in what follows, identify some essential distinctions between systemic and dialogic approaches to students' engagement with Web-based inquiry environments. Subsequently, I will discuss a selection of studies utilizing a dialogic approach. In different ways, each of these studies manages to demonstrate how an analytical focus on student interaction can enhance our knowledge about students' engagement with Web-based learning environments.

## 3.3 Dialogic approaches to students' employment of computer-based inquiry environments

In the opening of this chapter, a distinction between studies adhering to a *systemic* and a *dialogic* approach was made (Arnseth & Ludvigsen, 2006). The studies discussed so far can be categorised as studies adhering to a systemic approach. The major strength of such "systemic" studies lies in their capacity to deal with vast amounts of data as well as providing explicit criteria for systematic categorising of data sets. Ultimately, the systematic categorisations offer an opportunity for making comparisons on an individual or group level concerning students' discourse performances (Littleton, 1999; Mercer, 2004; Mercer, Littleton, & Wegerif, 2009). By means of comparing the students' performances with measures of the outcome of the collaborative activity, the researchers are able to display productive as well as challenging aspects of students' performances. These can give important input into how to optimize the design of Web-based inquiry environments and/or teacher instructions in these types of settings. Seen in relation to the reviewed studies above, the frequent findings of fact-finding strategies, for instance, is an important and relevant finding that gives valuable input into how to guide students during discourse oriented activities. Fact-finding strategies refer to the concept that the students' responses are mostly descriptive and referencing in character in contrast to being more explanation, argumentation and scientifically oriented (Hakkarainen et al., 2002; Hewitt, 2002). Furthermore, the systematic classification, scoring and quantifying of students' performances also enable the documentation of possible *changes* in the students' performances either during a project or over longer spans of time, as well as individual variances among students.

As well as acknowledging that studies with a systemic approach have contributed to our understanding of students' engagement with Web-based inquiry environments, there are some critical aspects that need to be addressed. Seen from a dialogic perspective, one critical aspect concerns the practice of analysing students' discourses. A shared aspect of the studies discussed above is that they classify and score what can be seen as isolated written speech acts instead of longer stretches of dialogue. A problem with this approach is that such categorisation practices ignore two important things. First, their categorisation of the contributions in dialogues into separate utterances and speech acts misses how meaning develops in dialogue between interlocutors. Second, they miss how the meaning of particular words or utterances is something that is at stake for the participants themselves. Instead, the

meanings and functions of words and utterances are predefined as part of the categorisation scheme employed (Arnseth, 2004; Mercer, 2004; Mercer, Littleton, & Wegerif, 2009).

Another critical aspect concerns the position of the idealized pedagogical models forming the basis for the systemic research. As argued above, there are several advantages of using these types of models. Nevertheless, a one-sided focus on what is conceived as idealized and normative productive practises can cause a "blind spot" in the research: the researchers are in danger of seeing only what they are looking for, and might overlook other important aspects of students' learning processes. A dialogic approach implies that the focus is on the students' concerns—what they address and invoke during their interactions. The students do not necessarily address or orient towards the activities within a pedagogical model and their activities around or within the Web-environment do not always fit the categories of scientific inquiry or scientific argumentation. As argued in the *Theoretical perspectives* section, however, these other kinds of activities are also important aspects of schooling. Hence, if one has a one-sided focus on talk and actions that fit the idealized model of inquiry, other important aspects of students' meaning making processes can be overlooked. A third aspect concerns the tendency to de-contextualise students' engagement with the Web-based inquiry environments. Seen from a dialogic approach, meaning making in a school science setting is also about finding out how to understand the tasks, the resources in use, and of equal importance, the institutional practices, norms and expectations. A final critical aspect concerns the tendency to make the design of the technology as the main explanatory variable for explaining students' scientific skills and conceptual advancement.

In what follows, I will readdress how some of the outlined challenges concerning a systemic approach to understanding students' engagement with Web-based inquiry environments have been met by studies adhering to a dialogic approach when exploring these types of settings.

### *3.3.1 Prompting productive talk by means of computer support*

A sociocultural and dialogic approach to exploring the role of student discourse in their engagement with science in computer-based environments does not necessarily rule out use of quantitative data, nor the reliance on or development of idealized models of scientific discourse. In their studies Mercer and his colleagues have employed methods that both attend to the joint construction of knowledge and understanding taking place during students' classroom discourses, as well as measuring the impact of specific talk-related interventions

by means of quantitative methods and pre- and post-tests (Mercer, 1994; Mercer, 2004; Mercer, Dawes, Wegerif, & Sams, 2004; Mercer, Phillips, & Somekh, 1991; Mercer & Wegerif, 1999). Based on the analyses of students' discourses in the so-called SLANT project (Mercer & Wegerif, 1999), and building on the ideas of Douglas Barnes (1976), three idealized types of talk were identified: *cumulative*, *disputational* and *exploratory* talk. In cumulative talk interlocutors uncritically build on one another's accounts. In disputational talk they disagree, but lack the means or the will to provide explanations, clarifications or other accounts that might enable them to clarify their views. In exploratory talk the individuals engage critically but constructively in each others' ideas. Claims and counter-claims are followed by justifications and explanations. Although recognising the situational appropriateness of all three types of talk, exploratory talk represents a distinctive social mode of thinking—a communicative process for reasoning through talk in the context of some specific joint activity (Mercer & Wegerif, 1999). The aim of the conducted intervention studies is to explore the success of fostering specific discourse skills combined with the use of computer-based science programs designed for prompting student discourse, seen in relation to students' understanding of science.

In a quasi-experimental study, Mercer et al. (2004) focused on students' joint construction of knowledge in a physics project about light and sound. A central activity in the project was the students' work in small groups with the computer-based program Science Explorer II providing problems and simulated experimental environments. Before the students started their work at the computer, the experimental group was introduced to what has been referred to as the "ground rules" of exploratory talk, while the control group was not. The ground rules intend to ensure that the students become able to carry out exploratory talk. Examples of these types of rules are for instance that during discussions the students should aspire to share relevant information, invite all members of the group to contribute to the discussion, and that challenges and alternatives are made explicit and negotiated (Mercer et al., 2004, p. 362). The detailed analyses of students' discourses while working with the computer tasks made it possible to identify significant differences between the experimental group and the control group. The occurrences of exploratory-related talk were much more frequent in groups that had been introduced to the discussion ground rules. Additionally, a quantification of linguistic features (expressions such as "because", "if" and "so") by means of a computer-based text analysis programme indicated changes in the talk being used over time and between conditions. Finally pre- and post-tests consisting of group reasoning tasks

indicated that the student groups that were introduced to the ground rules outperformed the students' in the control group. The researchers conclude that the software and intervention program succeeded in both expanding the amount of discourse as well as enhancing the quality of the discourse; the students talked more, and more talk was exploratory. Furthermore, the researchers conclude that there are reasons to believe that the increased use of exploratory talk was a key factor for improving the student groups' problem-solving performances (Mercer et al., 2004).

The research conducted by Mercer and his colleagues demonstrates the importance of a sociocultural and dialogic approach in order to facilitate as well as understand students' meaning making in science, or in education in general. However, one important issue needs to be addressed concerning the use of the typology of three types of talk. Despite the researchers emphasizing that the three types of talk are empirically grounded and not meant to be seen as descriptive categories to be used for coding all types of talk, the categories are nevertheless analytical in that they are generated by means of a theory of language and cognition, i.e. a sociocultural perspective emphasizing the knowledge production as a joint discursive process between interlocutors. As demonstrated by the studies referred to above, the typology of different types of talk can serve as an effective way of introducing students and teachers to productive ways of participating in scientific discourse. When the types of talk are used as analytical tools, however, they can lead to ignoring important aspects of students' interaction. Moreover, it is also difficult to pin down and identify the different types of talk. The differences between them are not always obvious. There is great value in a discussion of how teachers might intervene to help students develop analytic concepts such as those developed by Mercer and colleagues. Nonetheless, one should be careful not to turn these analytic concepts into normative labels for actions. Instead, such analytic concepts can be seen as resources that enable teachers to understand their own activities and, in that sense, to assist students in increasing their use of explorative talk.

### *3.3.2 Learning scientific reasoning in the context of open-ended Web environments*

Among the studies that utilise a dialogic approach towards students' meaning making in computer-based environments, there are several that also focus on student dialogue without the use of predefined analytical concepts. In these studies, the focus is on the students' concerns and how their construction of meaning in specific educational contexts appears through their talk. The interesting aspect of many of these studies is that they direct attention

to the challenging and complex aspects of students' meaning making. The aim of these studies is not to display the universal or general patterns of dialogue or meaning making, but rather to show the nuances and the complexity of human conduct and meaning making processes. This complexity only appears by zooming in on the sequences of dialogue and interaction taking place among interlocutors (Roth, 2005a).

Mäkitalo, Jacobsson and Säljö (2009) scrutinized the challenging aspects of students' process of learning scientific reasoning about socio-scientific issues in computer-based settings. In a science project about climate changes, students were instructed to explore and discuss different aspects of global warming and the greenhouse effects in relation to different types of Internet-based information as well as textbooks and scientific articles. Each group of students formulated their own investigative research questions. Analyses of students' talk during their problem solving constituted the main unit of analysis. By using the students' accounts as a unit of analysis, the researchers display the difficulties that the students encountered when dealing with these types of tasks and settings. In the study the difficulties that the students encountered was seen in light of Bakhtin's (1986) notion of "discourse genres" and Goffman's (1974) notion of "framing."

One of the students' main challenges was to identify and make sense of different genres presented to them by means of different sources of information in order to produce their own version of the scientific problem at issue—or as Lemke (1990) puts it, to produce a coherent thematic pattern. On the one hand, the students managed to make use and sense of the different types of discourse genres such as socio-economic, political or moral genres. On the other hand, the study shows the challenges students faced when dealing with the different types of genres on a more meta-communicative level. This implies for instance talk about *how* to collaborate, or *how* a specific scientific issue can be approached and made sense of by means of multiple speech genres. Another important finding relates to the tension between these types of learning situations and the more traditional institutional aspects of schooling. The analyses of the students' discourse display that students needed to be attentive towards not only participating in scientific reasoning and meaning making, but they also needed to address institutional expectations, such as what it means to be an "accountable student" as well as what was conceived of as an appropriate outcome or end product of their working process. As such, these institutional concerns become an important part of their meaning making processes.

### *3.3.3 The challenging relationship between procedural and conceptual understanding*

Within the learning sciences, research focusing on conceptual change has a central position (diSessa, 2006; Treagust & Duit, 2008; Vosniadou, 2008). In this perspective students' "learning" is described in terms of concept development. Among other things, this finds expression in the widespread use of the acquisition metaphor when explaining and approaching students' learning and understanding (Sfard, 1998). The central position of conceptual change also prevails in much of the systemic-oriented research on students' engagement with Web-based inquiry environments (de Jong, 2006). A common aspect of these studies is that collaboration and discourse are primarily seen as a *means* for advancing students' conceptual understanding. Additionally, many of these studies have a propensity of seeing gains in students' discourse skills, or procedural achievements, as indications of advancements in their conceptual understanding of the scientific content (cf. Hakkarainen, 2003a; Mork & Jorde, 2004; Seethaler & Linn, 2004). Seen from a dialogic and sociocultural perspective, this is methodologically a problematic inference (Mercer, 2008; Roth, 2008; Wells, 2008). This does not mean that the findings concerning advancements in students' discourse skill are contested or made irrelevant. What is problematic is taking such skills advancement as indicators for conceptual development. The key question is if "mental states" are reflected in students' talk. As emphasized by Mercer and his colleagues, the presence of advanced talk (i.e. exploratory talk) does not necessarily ensure a complex, or normatively valued, *understanding* of the talked about science (Mercer et al., 2004; Mercer & Wegerif, 1999). In a similar way, success in solving tasks, or exercise of high procedural skills, does not necessarily reflect that students have developed a robust conceptual understanding. By zooming in on students' talk, it becomes apparent that it is difficult to make strong claims about their conceptual understanding, hence the advancements in their conceptual understanding (Roth, 2005b).

In one study, Krange and Ludvigsen (2008) scrutinized the problematic relationship between students' procedural and conceptual orientation. As part of a two-week science project about gene technology, groups of students and their teacher employed a distributed 3D learning environment. This aimed at introducing them to central concepts such as DNA sequencing and protein synthesis. The Web-based environment enabled verbal communication as well as provided a shared virtual work space in the form of a 3D biological micro-world. The video recordings of the students' work within the shared virtual work place showed that all the participating groups managed to solve the tasks. On a superficial level,

this finding could be taken as an indication that the students had achieved some form of conceptual understanding of the scientific content at issue. However, a closer look at the students' interactions showed that the relationship between the students' procedural achievement and conceptual understanding was a bit more complicated. Analyses of the students' and teacher's talk while constructing a virtual model of a DNA molecule demonstrated how their collaboration was "productive" in the sense of being characterized by active argumentation. Students built on each others accounts and made use of information brought to them by their collaborating peers in order to solve the task. However, analyses of students' talk made evident that the participants' talk was mainly oriented towards procedural aspects of completing the task. The students and their teacher jointly constructed a shared understanding of procedural aspects of the tasks, however they did not manage to establish the relevance of scientific concepts within a broader conceptual system.

The finding of the procedural versus conceptual orientation is a common finding within the learning sciences in general (c.f. Anderson, 2007; Hakkarainen et al., 2002; Hewitt, 2002). However, the interesting aspect of Krange and Ludvigsen's study is that it reveals more than the students' procedural orientation towards a quick and easy way of solving a task. The analyses of the participants' dialogue also demonstrate the institutional aspects of schooling activities; i.e. that an orientation towards the procedural aspects of problem solving can be, and often is, an accepted and traditional way of "doing schooling".

### *3.3.4 The challenging aspects of making sense of the technological features*

Typical of studies representing a systemic approach is the focus on measuring the *impact* of students' employment of the Web-based environment on students' performances. Most often impact is measured by means of analyses of students' written products, or the outcome of their work in the environments such as various types of pre- and post-tests, responses to tasks within the environment or online discussions. This means that the focus is on the *result* of students' use, and not on the *actual process* of engagement with the technological environment. Furthermore, advancements in the students' performances are frequently explained by regarding technology design as the main explanatory variable. Technology as the main explanatory variable prevails in most of the studies discussed above. However, this is most explicit in studies with an experimental design where, for example, the effect of specific technological features, or designs, are compared and validated by means of measuring students' performances (cf. Davis, 2003).

Seen from a dialogic approach, emphasising technology design as the main explanatory variable for elucidating students' achievements represents a problematic issue because it implies that students' use of the technology is understood in a de-contextualised manner. This means that important sociocultural factors such as group interaction, teacher intervention, or local institutional aspects of schooling are not taken into consideration (Arnseth, 2004; Mercer & Wegerif, 1999; Rasmussen; 2005). When it comes to understanding the opportunities generated by Web-based inquiry environments, as well as how these opportunities for action are integrated as structuring resources for students' participation in scientific inquiry, detailed analyses of students' and teachers' interaction while engaging with Web-based learning environments are required. Students' engagement with scientific knowledge and scientific inquiry does not take place in a vacuum, but within a context where institutional practices, norms and expectations are embedded. Based on these assumptions, a dialogic approach towards students' engagement with the technology implies a focus on understanding *how* students actually employ the technology as structuring resources in their meaning making processes. This includes exploring how the students' employment of the technology relates to other concerns that they have to manage in the setting of school science.

Studies that demonstrate the importance of a context-sensitive approach on students' employment of technology environments include those carried out by Ludvigsen and Mørch (Ludvigsen, in press; Ludvigsen & Mørch, 2003) and Arnseth and Säljö (2007). In these studies the empirical focus is on secondary school students' interaction while discussing socio-scientific issues related to genetics using the online discussion forum FLE2. The environment is designed to support students' inquiry learning processes with a particular focus on supporting students' scientific argumentation. In FLE2 the students are prompted to label their written contributions in the learning environment by means of predefined epistemic categories such as "problem", "my working theory", "reliable knowledge" and "unreliable knowledge". This labelling procedure aims at making the students aware of different types of communicative contributions in scientific discourses. By analysing groups of students' talk during the actual writing process of their contributions to an online discussion, Arnseth and Säljö (2007) demonstrate how the students actually made sense of the categories, and how they used them in their meaning making process. First of all, the study shows that the categories are not self-explanatory, and that the students needed to put a lot of effort into making sense of the categories. Furthermore the students' activities differed

widely from the pedagogical ideas underpinning the design of the tool. It became evident that the categories did not make the procedure of an idealized science discourse visible and manageable for them. Instead the students chose the labels on their contributions on a more pragmatic level and out of local concerns as regard avoiding disagreement and in order to go on with their work (Arnseth & Säljö, 2007). However, this does not mean that the students' discussions about the categories were without any constructive elements. As the study conducted by Ludvigsen and Mørch (2003) shows, the students' explicit sense making of how to understand and make use of the epistemic categories made it possible for the teacher to discuss relevant aspects of elements in a scientific discourse with the students.

As demonstrated in this chapter, findings from a variety of systemic-oriented studies have improved our understanding of possible *effects* of students' engagement with Web-based inquiry environments. However, when it comes to understanding the opportunities generated by these types of environments, as well as how these opportunities for action are integrated as structuring resources for students' participation in scientific inquiry, detailed analyses of students' interaction while engaging with Web-based inquiry environments are needed. Students' engagement with scientific knowledge and scientific inquiry takes place within a context where institutional practices, norms and expectations are embedded. The dialogically oriented studies discussed above demonstrate how a sociocultural perspective can enhance our understanding of students' engagement with Web-based learning environments. Furthermore, the discussed dialogically oriented studies, as well as the sociocultural theories outlined above, demonstrate the importance of approaching meaning making processes by taking technological, epistemic and institutional aspects of students' meaning making processes into account.

In the following section, I give a brief description of the empirical settings forming the basis for the conducted work in this thesis, as well as providing description of the technological resources in use. Finally, I elaborate on the analytical procedures applied in my analytic work.

# 4 Empirical settings and methods

In the following I present the two cases forming the empirical basis for the three studies within the thesis: The DoCTA project and the Viten.no project. The two projects are informed by ideas from design-based research (Brown, 1992; Collins, 1992; Collins et al., 2004). Design experiments differ from both laboratory experiments and naturalistic investigations. Design experiments involve both the "engineering" of particular forms of interactions in an educational setting as well as the study of these forms. The objective is, among other things, to examine interaction and learning in a more naturalistic setting, but at the same time to study the impact of particular learning designs. Even though the DoCTA project and the Viten.no project are informed by ideas of design based research, there are some features that separate sociocultural and dialogic design based research from what can be seen as "traditional" design based research. As will be discussed later, these aspects are most of all connected to the procedures and focus of the empirical analyses (Krange & Ludvigsen, 2009). My role as a researcher differs between the two projects. Concerning the DoCTA project, I did not participate in the design or the accomplishment of the project. However, I was invited to write an article on the DoCTA data material by my supervisor, who was one of the project managers. The Viten.no project, on the other hand, was initiated by me. During this project I was in charge of initiating contact with a collaborating teacher, the research design and the data collection. As described in more detail below, I also designed specific interventions in the form of group activities taking place during the student project.

This chapter comprises three sections. In the first section, the two cases are each presented by a description of the educational setting—a brief description of the applied Web-based environment, respectively FLE2 and Viten.no, and a description of the data material. In the second section, the focus is on the analytical procedures of interaction analysis as employed in the three studies within the thesis. In addition, I address the process of selecting interactional data for further analyses by revisiting the analytical concepts "accounts" and "interaction trajectories", this time from a methodological perspective. The third section

comprises reflections on research credibility discussed with regard to the issues of reliability, validity, and generalization. The chapter is concluded by reflections on ethical considerations.

## 4.1 The DoCTA project

During the autumn of 2002, the groupware system Future Learning Environment 2 (FLE2)[11] combined with a pedagogical model of collaborative inquiry was introduced in two collaborating upper secondary school classrooms located in Bergen and Oslo. The content of the learning environment was designed to be about biotechnology (Wasson & Ludvigsen, 2003). By virtue of being a design experiment, a plan describing the goals, activities and assessment criteria were made by the research group in collaboration with the two participating teachers. During the project period, researchers and technological support personnel were present as disinterested observers.

The gene technology project was carried out during 11 school hours over two weeks. The project was divided into two periods. During the first week, the main student task was to produce scientific articles exploring different areas of gene technology. During the second week, the students produced articles about the ethical sides of gene technology. Table 1 shows the sequential plan of the project.

| **Activity** | **Session** | **Available resources** |
|---|---|---|
| Introduction to groupware system and getting acquainted | 1 – 2 | FLE2 |
| Watching TV documentary about genetics and formulation of possible problems to inquire in local groups | 3 | TV documentary, word processing software |
| Decide upon problem to inquire in the composed group | 3 | FLE2 |
| Collaborative writing of articles<br>*Empirical setting for Study I* | 4 – 8 | FLE2, newspaper database, books, popular scientific journals |
| Constructing final report in form of a web page | 9 – 11 | Web authoring software |

Table 1: The sequential plan of the project and the available resources

[11] FLE is developed by the Learning Environments for Progressive Inquiry Research Group at the UIAH Media Lab, University of Art and Design Helsinki in cooperation with Department of Communication, Journalism and Computer Science, Roskilde University, and Centre for Research on Networked Learning and Knowledge Building, Department of Psychology, University of Helsinki, Finland. See: http://fle2.uiah.fi/
DoCTA is a multidisciplinary research project hosted and co-ordinated by InterMedia, University of Bergen. The other main contributor in the project was InterMedia, University of Oslo.

The students were divided into groups of eight. Four students were located in Oslo, and four students were located in Bergen. By distributed collaboration in FLE2, the students were expected to perform joint formulation of possible problems to inquire, decide upon what problems to focus on, write articles related to their chosen problems, and finally, produce a webpage for publishing the articles.

### *4.1.1 The Future Learning Environment 2*

The progressive inquiry model is the main design principle for the groupware FLE2 (Muukkonen, Hakkarainen, & Lakkala, 1999). The model is based on viewing students' learning processes as a research activity where the main aim is joint construction of knowledge and problem solving through discussion (Hakkarainen et al., 2002; Scardemalia & Bereiter, 1994). As illustrated in Figure 1, FLE2 consists of various tools designed in order to support the distributed process of joint knowledge production within the Web-based environment.

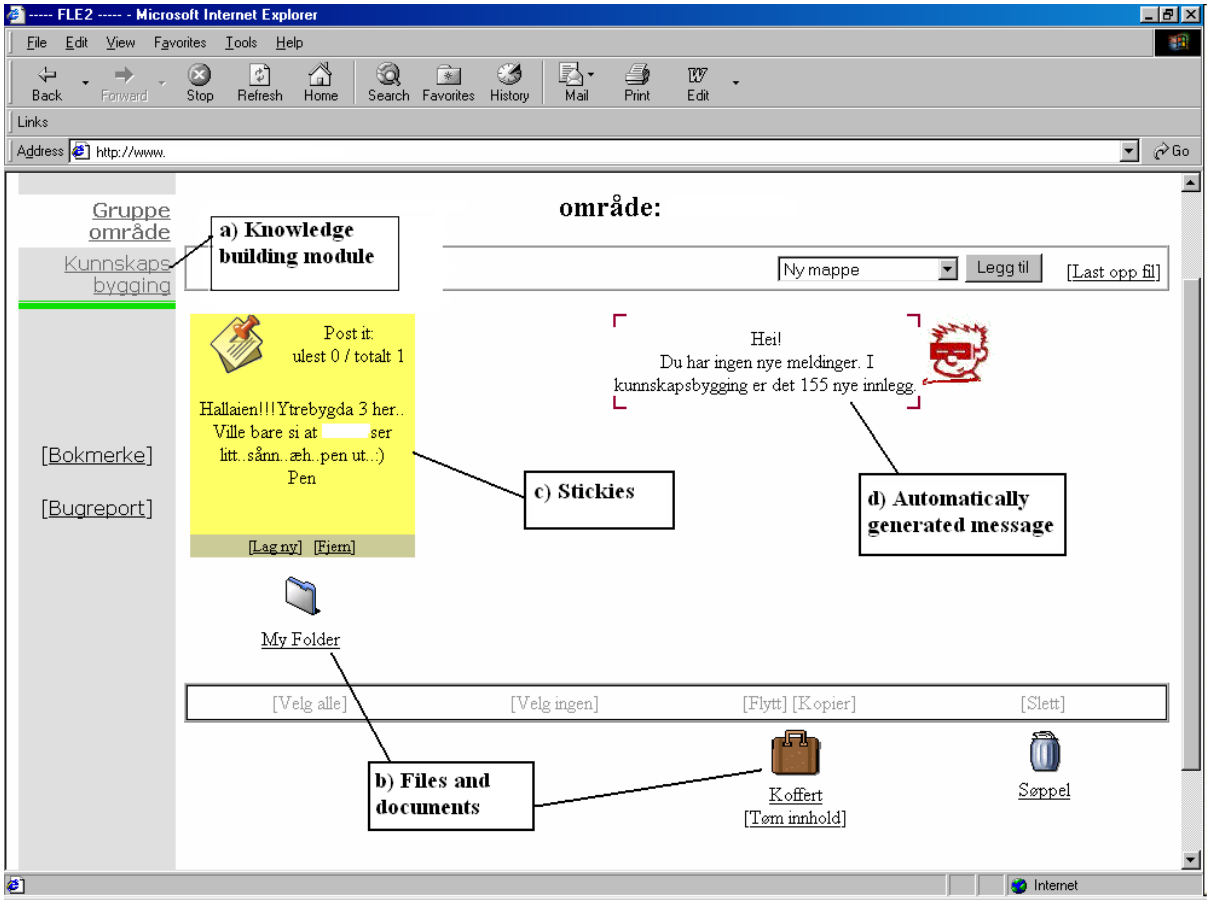


Figure 1: Screenshot of the students' Web Top area in FLE2

The Knowledge building board, which is perhaps the most important tool in FLE2, is an asynchronous discussion board. Here the students can post their notes to the common workspace. In order to support student reflection on different types of contributions to a scientific discussion, the students had to label their notes by choosing an appropriate category reflecting the nature of their contribution. Such categories included “Problem”, “My working theory”, “Deepening knowledge”, “Comment”, “Meta-comment”, and “Summary” (See Figure 2). The collection of the student groups’ discussion of different topics are organised into threaded discussions.

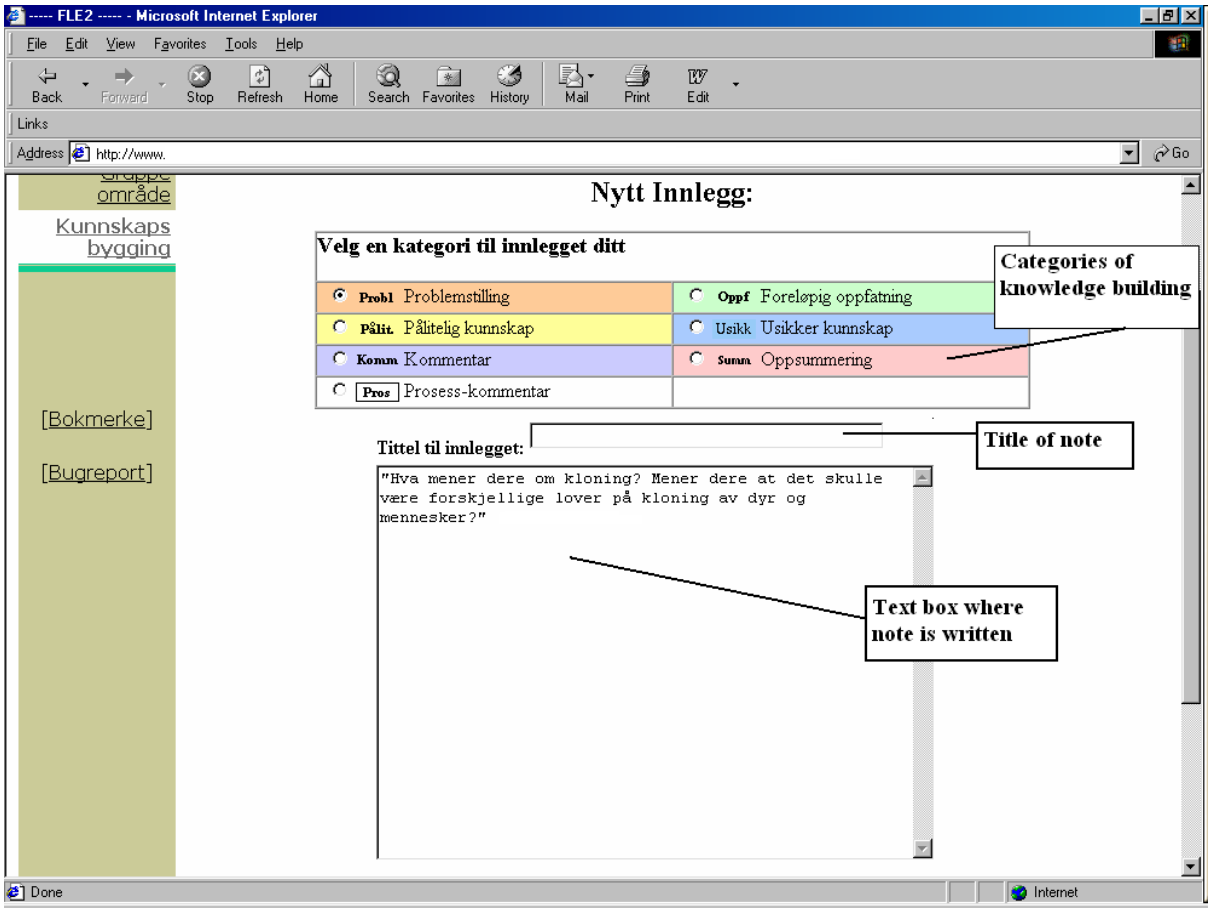


Figure 2: Screenshot of the Knowledge building module in FLE2

In addition to the asynchronous discussion module in FLE2, the students had access to technology for sharing resources, a synchronous discussion tool, a small-scale simulation tool and domain-specific Internet resources. The students could also access other relevant resources from the Internet such as text selected from their textbooks, pictures and models of scientific phenomena and newspaper articles. These recourses were made available by the integrated computer interface (see Arnseth (2004) for a more detailed description of the FLE2 environment).

### *4.1.2 Description of data*

The focus group consisted of one group of eight students and two teachers. Four of the students and a teacher were located in Oslo, and four students and the second teacher were located in Bergen. The data material from the study consists of video recordings of the participants' interactions and activities, interviews with the teacher and students, reflection notes, data logs from FLE2, and the students' textual end-products (Wasson & Ludvigsen, 2003). The *video recordings* of students' activity during the project, print-outs of the target groups' *written contributions* in the discussion forum in FLE2 and the students' *articles* published on the project Web-site represent the core data material in Study I.

The video tapes contain records of each of the two distributed collaborating groups' activities during the whole project. Both groups were video taped while sitting in front of a shared computer at their schools' computer labs. On some occasions co-located student groups split into collaborating dyads. When this happened the camera shot was on one of the dyads. The cameras were positioned on tripods capturing the students from a side angle. A microphone was placed in front of the students. As mentioned, I did not have an active role in the design or data collection during the DoCTA project. However, I had access to first-hand information of the project design and the actual accomplishment of the project through the co-author of Study I who was one of the project managers. Another important source of information was the publications produced by the DoCTA research group. See, for example, Wasson and Ludvigsen (2003) and Arnseth (2004), for a more detailed description of the project design, data collection process as well as descriptions of the data material.

## 4.2 The Viten.no project

### *4.2.1 Initiating contact*

When searching for a second case, I wanted to focus on a technology that was already used as an integrated part of science education activity. The Web-environment Viten.no provided an example of this. The main reason for choosing this particular Web-environment was that Viten.no is the most commonly used Web-based inquiry environment in Norway. In 2006, Viten.no had more than 2500 registered teachers and 70,000 registered students[12]. The

[12] In Study II the number of registered users was wrongly reported as 250,000. The correct figure should be 70,000 registered users in 2006 as reported in Study III. The figure 250,000 refers to the number of times all the programs in Viten.no have been used. This implies that this figure does not tell us anything about the number of users because one user can have employed several programs.

Viten.no research team had received a lot of attention from the media as well as from the educational sector. In order to get in contact with a school where Viten.no was used as part of normal science education activity, I contacted the Viten.no research team for some advice. One of the members of the research team had earlier worked as a teacher at a school in one of the eastern suburbs of Oslo. She put me in contact with one of the school's science teachers, Maria (pseudonym). At the time, Maria was in charge of the science lessons for three classes with about 25 students on the 10$^{th}$ level aged 15-16 years. She had not used Viten.no in these particular classes, but she had used it twice the previous year with other students. Her plan was to use the Viten.no in a two-week biology project about gene technology. Maria welcomed my participation in the project and invited me to provide input on how to practically carry out the project. As my intention was to collect data from an ordinary educational setting taking place independently of my participation, Maria was mainly in charge of planning and carrying out the project. However, I used the opportunity to initiate one intervention, which was the *follow-up activity* to the students' engagement with the Viten.no part about the basics of gene technology. I will give a more detailed account of the follow-up session later. I also provided a TV-documentary about gene technology to be used as part of the introduction session.

Maria suggested trying out the project on one of the three classes. This way she could use the first trial as a pilot, which would enable her to do some adjustments before she carried out the project with the two other classes. I was present during the pilot project, but I did not conduct any systematic data collection. However, I made reflection notes and talked to the students and the teacher in order to plan the data collection during the next two projects. Additionally, I video recorded two groups of students during the follow-up activity as well as the student plenary debate closing the project. Being present during the pilot run was very valuable for getting to know the teacher and familiarising myself with the way the school worked in these educational settings.

### *4.2.2 The organisation of the gene technology projects*

The two following student projects took place on the subsequent weeks in October 2004. Each project was allocated fifteen 45 minutes lessons in two participating classes. Table 2 shows the sequential plan for the project:

| Activity | Session | Available resources |
|---|---|---|
| Plenary session where the students were introduced to the project and topic. Group work and watching TV documentary about gene technology | 1 – 2<br>Week 1 | TV documentary of gene technology, blackboard |
| Engaging with the basics of gene technology section in Viten.no<br>*Empirical setting for Study III* | 3 – 8 | Viten.no |
| Follow-up activity. Students working in groups of four solving Viten.no related tasks<br>*Empirical setting for Study II* | 9 – 10<br>Week 2 | None, except for pen and paper |
| Preparing for role-play debate | 11 – 13 | Viten.no, Internet, textbooks, popular scientific journals |
| Role-play debate | 14 – 15 | Classroom arranged for a panel debate in front with chairs for the audience |

Table 2: The sequential plan for the project including available resources

In the plenary session (sessions 1–2), the students were introduced to the project and the topic by the teacher. As an opening activity, the students watched a TV documentary about gene technology. They then teamed up in groups of four and discussed what they found interesting in the documentary. The session ended with a plenary discussion where the teacher wrote keywords on the blackboard summing up the group discussions. The following six lessons (sessions 3 – 8) were allocated to the basic part about gene technology in Viten.no. Here the students worked in dyads, each sharing one computer in the school's data lab and library. During these sessions the teacher circulated among the students and approached them on request, but also on her own initiative. When the students had worked their way through the part about the basics of gene technology in Viten.no, they were introduced to the so-called follow-up activity.

As mentioned above, my main intervention in the project was in co-designing a *follow-up* activity. The students were introduced to this after they had finished their work on Viten.no (session 9 and 10). Because of my active role in designing the follow-up activity, and that the interactional data produced during these sessions constituted the empirical basis for one of the studies, I will give a more thorough description of the activity and its aims. In the follow-up activity, two student dyads combined to form groups of four seated around a table. The students were given three reasoning tasks and were instructed to solve the problems by discussing them among themselves without using any resources such as computers or textbooks. The reasoning assignments corresponded with the topics they had been working with in Viten.no and asked the students to account for issues such as the

relationship between the concepts gene, DNA, protein and amino acids and inheritance of characteristics. Two lessons were allocated for the follow-up activity. In advance, the teacher informed the students that the discussion should be the main outcome of the exercise. However, the students were also instructed to write down their answers and to make related drawings. These were to be handed in to the teacher at the end of the session. The main idea informing the intervention was to design a situation where students' talk, (re)construction of claims, explanations, and arguing were explicitly in focus. Strengthening and emphasizing student discussion as a goal in itself, and at the same time not allowing for use of resources such as computers and textbooks, is not a revolutionary way of designing a learning activity. However, the hope was that it might contribute to more explicit and elaborate talk about the assignments, the concepts, and the scientific content. As shown in Study II, the data produced during these sessions turned out to be rich in the sense that several student groups used the opportunity to engage in complex and extended discussions about scientific concepts.

After the follow-up activity, the students started their work with the second main activity in Viten.no. This was a plenary role-play debate about gene modification of food. By means of Viten.no, students in groups of four prepared for their participation in the debate by making pro and con arguments mainly based on information provided to them through URL links in Viten.no and textbooks (session 11–13). Finally, the gene technology project ended with a student-lead role-play debate in the classroom. One representative from each student group participated in the panel discussion lead by two student moderators. The students sitting in the audience were instructed to ask questions to the panel. The teacher was sitting in the audience mainly participating as an observer, occasionally asking questions to participants in the panel.

### *4.2.3 The Viten.no environment*

Viten.no [13] consists of curriculum-based programs devoted to different science topics such as gene technology, which is at the centre of Study II and Study III. The gene technology program is sectioned into two parts. In the first part, students are introduced to basic topics within genetics such as "cell construction", "the genetic code" and "protein synthesis." During these activities the students work their way through a set of organised web-pages containing texts, illustrations, drag-and-drop tasks, animations and multiple-choice tests (see screenshot from Viten.no in Figure 3).

[13] http://Viten.no/

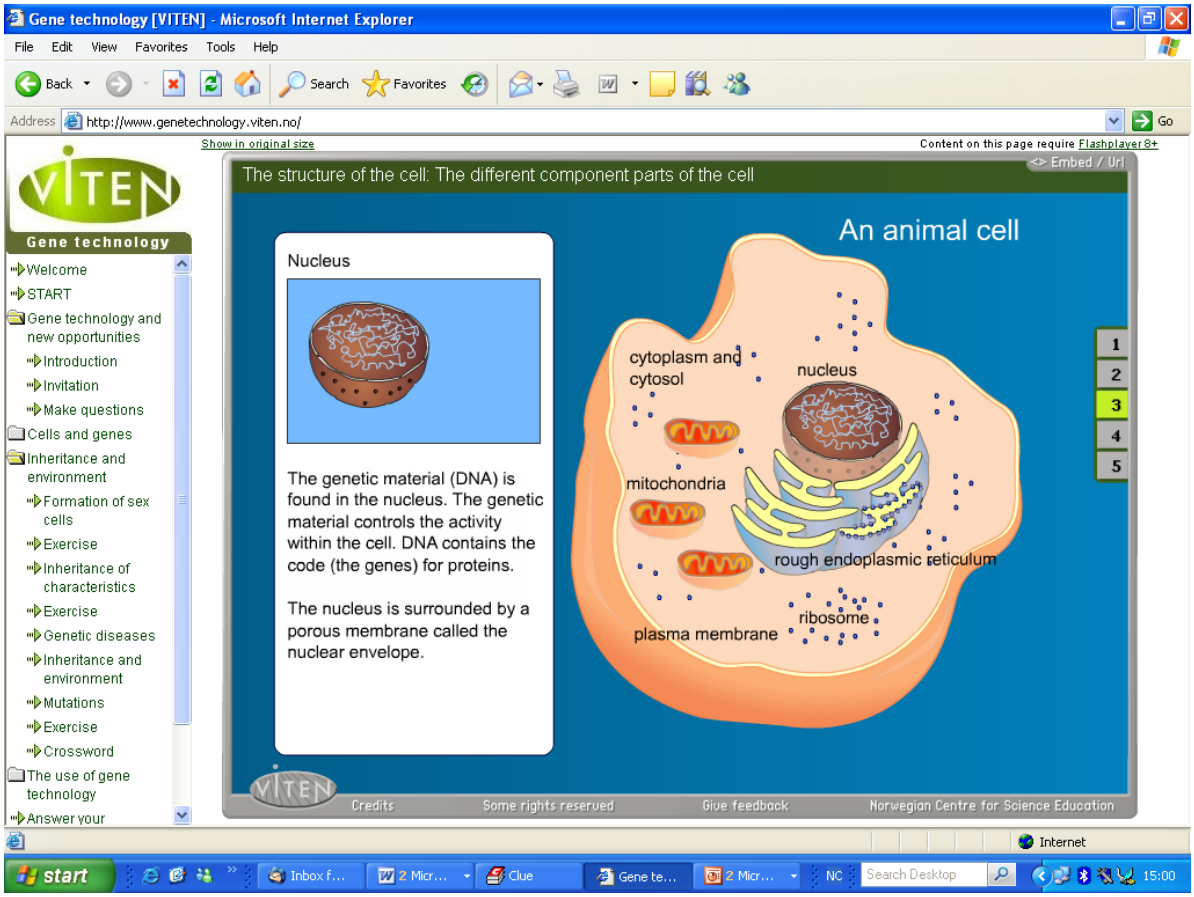


Figure 3: Screenshot from the gene technology program in Viten.no

An important feature of the Viten.no environment are the prompts (referred to in Viten.no as "notes") designed to elicit reflection on central aspects of the scientific content (Jorde et al., 2003). After each main topic, students are exposed to pop-up prompts containing open-ended questions about the topic with which they have just engaged. The students are asked to write their responses in a designated column in the pop-up window, and the responses are then saved in a so-called "workbook". The teacher has online access to the students' workbooks and can evaluate and add comments to the students' work.

The second part of the gene technology program is focused on the ethical aspects of gene modification. Here students have access to texts and a structured set of links to relevant sites in order to prepare for a plenary role-play debate about gene modification of food. The Viten.no gene technology project ends with a plenary role-play debate (See Figure 4).


Figure 4: Screenshot from the gene technology program in Viten.no

In addition to the student-oriented web-pages, there are separate teacher oriented Web-pages containing guidelines and suggestions on how to plan and carry out science projects with use of Viten.no.

### *4.2.4 Description of data*

Two student dyads in each class were selected as target groups. After the students had finished the first part of the project, two student dyads combined to form groups of four. This means that in the last part of the project there was one target group of four students in each class. All student groups were organized by the teacher, who also suggested possible target groups. Concerning the target groups, the teacher was requested not to point out students with the highest grade levels, but rather to consider how the individual students normally participated in collaborative work and how they normally contributed verbally in these types of settings.

As shown in Table 3, the total data set consists of video recordings of student target groups' activity, a set of documents such as planning notes, a project overview and out prints

of the students' workbooks in Viten.no, reflection notes and audio taped interviews with the teacher and target group students. The core data are the video recordings, the students' written and illustrated response to the reasoning tasks and the out prints of the students' workbooks in Viten.no. Other material gathered in the school was used to contextualise the analyses of this core data. During data collection I was fortunate to be assisted by a colleague who operated one of the two cameras and participated in the interview sessions. His participation was also valuable as a reflection partner with regard to ad hoc challenges, impressions and data collection strategies.

| **Type of data** | **Descriptions** | **Status of data** |
|---|---|---|
| Video recordings | 40 hours in total. Capturing student target groups' activity during the whole project | Core data |
| Documents | 12 written and illustrated student group responses to the reasoning tasks in the follow-up activity | Core data |
| | Print outs of 25 students' workbooks in Viten.no | Core data |
| | The teachers' activity planning document | Ethnographic contextualising data |
| | Handouts to students; project plan | Ethnographic contextualising data |
| Reflection notes | From plenary sessions, Viten.no sessions, follow-up sessions, preparation for debate sessions and plenary role-play debates | Ethnographic contextualising data |
| Audio-taped interviews | Teacher: Semi-structured pre- and post-interviews<br>Students: Individual semi-structured pre- and post-interviews with 8 target group students | Ethnographic contextualising data |

Table 3: List of data and their status

The forty hours of *video recordings* of students' interaction constitute the core data for the analyses in Study II and Study III. These are records of the student target groups' interaction during the whole project. In sessions where the students worked in dyads in front of the computers, two cameras were used; one on each target student dyad. The cameras were placed on tripods behind the students to capture the computer screen. Microphones were placed in front of the students in order to optimize the sound. I decided to place the camera behind the students, because I found it important to follow their navigation within the Viten.no environment. In the follow-up sessions, the students were seated around a table in a way that all four students faced the camera (see Figure 5). A microphone was placed in the middle. In the session where the students worked in groups of four preparing for the role-play debate, video recording the whole group was challenging. In this session the student groups

often parted, as some of the students shared one computer, while others read books in the classroom or in the library. In these settings I chose to video tape the students' activity in front of their originally designated computer. Finally, the plenary role-play debate was video-recorded using a tripod that enabled an alternating focus between the panel and the audience.

Figure 5: Students working with Viten.no and follow-up activity

All forty hours of video recordings of the interactional data were transcribed. However, some segments of the material were transcribed in more detail. Analytical work was an iterative and cyclic process where the transcriptions of the interactional data were written and re-written. The video tapes were subjected to repeated viewing. The process of transcription most often began with writing content logs while I watched the tapes. During the second viewing, the logs were expanded into more detailed transcripts primarily containing talk-oriented activities; some sporadic records of the participants' use of resources and bodily expressions were also included. Subsequently, key analytically relevant episodes or longer sequences of interactional data were identified for translation into English. These episodes were then discussed in research groups and seminars internally in my own department, but also in international research seminars. Finally, short sequences were selected and transcribed in detail in preparation for the final analysis conducted in the articles. In section 4.3 I elaborate on the rationale behind the selection of specific interaction extracts and the analytical procedures.

The data material also consisted of different types of *documents*. For example, twelve written and illustrated responses to the reasoning tasks produced by groups of four students during the follow-up activity were used. Other documents were the out prints of the student dyads' electronic workbooks in Viten.no. These workbooks stored all the students' written responses to the tasks about the basics on gene technology as well as their preparation notes

for the role-play debate. Finally, there were documents such as the teacher's activity plans and the handouts given to the students describing the gene technology project and the timetable. In between handling the video-cameras, I acted as a non-participant observer making *reflection notes*. The notes were not systematic field notes, but rather recordings of reflections and thoughts to follow up when subsequently transcribing and analysing the data. It did not feel natural to look over the students' shoulders while they worked with the Viten.no environment. This notes a more general level of comment and observation of student activity.

A final source of data was the audio-taped semi-structured interviews with the eight students in the target groups and the teacher before and after the project (Hammersley & Atkinson, 1995; Kvale & Brinkmann, 2009). The students were asked about social aspects of schooling and their experience with technology as well as gene technology. During the interviews following the project, the students were asked to describe their collaboration experiences during the project, their thoughts about the Viten.no environment, and what they personally saw as the most productive and interesting part of the project. The teacher interviews focused on her thoughts about teacher intervention during the project, and her reflections on the project and the students' performances.

## 4.3 Analytical procedures

### *4.3.1 Interaction Analysis as an analytic frame*

Earlier, I indicated how my interventions can be seen as a variant of design-based research. When accounting for the analytical procedure however, I will elaborate on how my approach can be seen as distinct from the more "traditional" design-based research. A common feature of design-based research is the focus on computer-tools or instructional interventions whose design is informed by *idealized models of productive learning*. As discussed in the review chapter, the majority of design based research does not only apply these idealized models in the process of designing productive learning environments or technology. They also apply the models as intentional outcome standards for students' performances when evaluating the impact and success of the conducted interventions. It can be argued though, that a critical side of having a one-sided focus on idealized models of learning, or other types of idealized practices, are that the analysts' interests become the main research priority. This often implies that the emergent concerns, interests and understandings

of the actual participants are overlooked or neglected (Krange & Ludvigsen, 2009). The analytical procedure applied in this thesis however, is based on the assumption that the analysts' task is to account for how the participants *actually* engage in meaning making processes. This entails an emphasis on how they orient their talk and interaction to what they present as significant in the Web-based learning environment under study. The methodological implications of this will be discussed in more detail later. The issue here is that by making the participants' interaction the analytical starting point, it was possible to understand how they made sense of the scientific concepts, how they employed and made sense of the technological features and how they solved the tasks. Consequently, this type of analyses provide valuable input on how to (re)design educational settings and technology.

The analytical procedure employed within the three studies in this thesis can best be described as a form of "Interaction Analysis" (Jordan & Henderson, 1995). Interaction Analysis can be seen as an interdisciplinary method with roots in research fields such as ethnography, sociolinguistics, ethnomethodology, conversation analysis, and sociocultural theories:

> [A]n interdisciplinary method for empirical investigation of the interaction of human beings with each other and with objects of their environments. It investigates human activities, such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution. (Jordan & Henderson, 1995, pp. 39)

There are two significant aspects of Interaction Analysis as described by Jordan and Henderson. First, the focus is not only on talk-in-interaction but also participants' engagement with objects and artefacts is an important part of the analyses. Second, Interaction Analysis combines micro-level analysis and use of ethnographic data. Ethnographic data constitute the basis for providing "thick descriptions" of the observed activity that are necessary for an understanding of social interactions (Geertz, 1973, Roth, 2005a). In other words, ethnographic data make it possible to understand how the micro-level activities are part of locally situated contexts and institutional practices (Linell, 1998; 2009; Mercer, 2004).

In the three studies presented here, the focus is on how meaning is constructed during interaction. An important practical guideline informing the analytical procedures in the three studies is "bracketing out" the analyst's pre-existing theories and interpretations while

constructing the analyses of participants' interaction (Schegloff, 1991; Silverman, 2001). In many studies, context information or types of predefined categories are added and used by the researcher in order to understand an interaction occurring in a specific setting, yet these context elements or categories are not necessarily what the participants themselves relate to and find relevant (Sacks, 1984). The conducted analyses in the three studies aim at making the interaction between the participants the starting point for exploring what turns out to be *their* orientation during interaction and *their* way of invoking and making sense of categories. Another guideline concerns the notion of indexicality. This implies that the meaning of utterances and actions crucially depend upon the context within which they are performed (Koschmann, Stahl, & Zemel, 2007). According to Linell (1998):

> [D]ialogism regards every cognitive and/or communicative act as an "answer," as responsive to something (often only implicit) in the contexts. A contribution to dialogue, whether a single utterance or a lengthy spate of talk, is made coherent by being related to some (often implicit) issue ("quaestio") of current relevance; the contribution must be rendered accountable (by the actor or the analyst) in relation to the ubiquitous meta-question "why that now (to me etc.)." (pp. 35–36)

In this sense, interactional data are analysed by focusing on what is going on then and there, aiming to construct the past and current context wherein the interaction takes place by means of what the participants make topical through their conversation and interaction. On a practical analytical level, this emphasis implies that each utterance or act is seen as a response to something that has been before. This practical guideline for analysis secures the idea that the analytical descriptions are oriented towards the interactional achievements instead of what might take place in the individuals' minds (Garfinkel, 1984; Schegloff, 1991).

In line with a sociocultural and dialogical approach, Interaction Analysis-oriented studies combine analyses of interactional data with ethnographic data. The primary reason for including these types of data is the emphasis on the relation between micro-genesis and socio-genesis: students' interaction and engagement with scientific concepts and Web-based environments takes place within a context where institutional demands, historically developed practices and norms are embedded (Linell, 2009; Ludvigsen, 2009). Use of ethnographic data makes it possible to understand how participants' meaning making processes are situated in historically developed institutional practices.

### *4.3.2 Selection of data: revisiting the analytical concepts accounts and trajectories*

In interaction analytic work, the focus is not strongly determined by theory or an analytical scheme. Instead, activity patterns emerge as the analysis proceeds and the analyst gets a deeper understanding of the orderliness of the studied practice. However, in order to explore students' meaning making processes, there is a need for empirically sensitive operational concepts (Hammersley & Atkinson, 1995). In section 2.5 I discussed the theoretical relevance of the concepts "accounts" and "students' interaction trajectories" with regard to students' meaning making processes. In the following I revisit these concepts and discuss their methodological relevance.

The concept *interaction trajectories* captures how students participate in meaning making activities over time (Dreier, 1999; Rasmussen, 2005). Meaning making activities are taking place through moment-to-moment interactions but also across longer stretches of time. A sociocultural oriented approach implies that meaning making is seen as a context-embedded process. On a theoretical level, the concept of trajectory is important because it provides for the possibility of exploring how students orient themselves in different situations over time. In other words, it expands a moment-to-moment analysis of meaning making and takes into account how continuity and change are constructed in interaction. Consequently, the notion of interaction trajectories becomes important on a methodological level. In talk and interaction, topics and themes are discussed, negotiated and left behind, sometimes to be reintroduced later. In order to focus on *changes* in the students' orientations during a trajectory, analyses of chronological extracts are conducted in the three studies. By following this procedure, the three studies visualise how different characteristics or thematic patterns unfold over time (Study I and Study II) or between different types of activities (Study III).

However, the analysed sequences are not only selected in order to reconstruct a *sequential course of events*. All the extracts analysed in the three studies are selected because the interaction taking place is in form of *accounts*—specific linguistic actions such as explanations, justifications or clarifications concerning issues that the participants invoke (Mäkitalo, 2003). Furthermore, the selected sequences represent important interactional events—*episodes* in the students' work, or where their orientations towards one another and the task changed (Linell, 1998).

First of all, on a micro genetic level, these episodes are interesting because they enable the scrutiny of what turns out to be participants' concerns during their meaning

making processes. Detailed analyses of the participants' interactions make it possible to identify how different aspects of students' meaning making processes intersect, i.e. how technological, epistemic and institutional aspects embedded within the educational setting are invoked and oriented to by the participants. Practically, this means that I searched for episodes of interactional data where the participants addressed issues such as how to make sense of the scientific concepts, how to practically solve the task at hand, how to make sense of the technological and conceptual features in the Web-based learning environments, and the teachers' instructions. Further, these episodes were interesting because they also enabled the scrutiny of tensions between *socio-genesis* and *micro-genesis*. That is to say, the tension between historically developed institutional practices and participants' (re)production of these practices in interaction (Ludvigsen, 2009; Mäkitalo, 2003; Säljö, 2000). Additionally, focusing on participants' accounts made it possible to direct the analytical attention towards what is conceived of as valued, acceptable and normal practices within the context of schooling (Ludvigsen, in press; Mehan, 1991; Mäkitalo et al. 2009; Rasmussen, 2005).

## 4.4 Reflection on research credibility

### *4.4.1 Reliability*

A quantitative research framing a test's reliability concerns to what extent a repeated measurement using the same test under the same conditions produce the same results (Abercrombie, Hill, & Turner, 1984; Silverman, 2001). Relevant to qualitative studies, strengthening the reliability of a study can be done by thorough documentation of the research procedures (Kirk & Miller, 1986). Here I will focus on one of the most important reliability aspects with regards to interactional analysis, which is how data are presented and made available for analysis.

Several efforts have been made in order to strengthen the reliability of the studies within this thesis. One effort concerne the transcriptions of video recorded interactions. Compared to field notes and different forms of recollection of past events, transcripts of video records have a stronger position concerning reliability. The video recordings of the participants' interaction were transcribed according to standardized transcripts conventions. The applied transcript notations are shown in Table 4. For most talk and interactional-oriented studies, this most often implies applying variations of Jefferson's transcription conventions (Jefferson, 2004).

| | |
|---|---|
| [ ] | Text in square brackets represents clarifying information |
| ⌈ ⌊ | Simultaneous/overlapping talk |
| = | Indicates the break and subsequent continuation of a single utterance |
| ? | Rising intonation |
| : | Indicates prolongation of a sound |
| Underlined | Emphasis in talk |
| (.) | Short pause in the speech |
| - | Single dash in the middle of a word denotes that the speaker interrupts herself |
| -- | Double dash at the end of an utterance indicates that the speaker's utterance is incomplete |
| CAPITALS | Loud speak |
| *Italics* | Context descriptions |
| <text> | Indicates that the enclosed speech was delivered more slowly than usual for the speaker |
| `Courier New` | Students' reading from the screen is typed in `Courier New` |

Table 4: Transcript notations applied in the analyses of interaction extracts in the three studies

The uses of standardized transcript notations provide readers with a more in-depth description of the activity at issue. Furthermore, the notations make it possible to consider the trustworthiness of the data analysed. Another effort that strengthens the studies' reliability is the display of the analysed data as well as the actual analyses. This transparency enables the readers to follow the analyses step-by-step and make their own opinions about how the analysis is carried out, as well as deciding whether or not they find the inferences trustworthy. Finally, the reliability of the studies was strengthened by joint analytic efforts and feedback on transcriptions in internal research seminars within research groups of which I was a member as well as at international seminars with external researchers and research groups.

### *4.4.2 Validity*

The origin of the term "validity" refers to "the success of a test in measuring correctly what it is designed to measure" (Abercrombie, Hill, & Turner, 1984). Concerning qualitative research however, a study's validity can be seen in relation to whether the analytic claims that are being made about any piece of data can be regarded as convincing, as well as the strategies we can make use of in order to come up with valid conclusions (Kvale & Brinkmann, 2009; Silverman, 2001). A negative aspect of writing articles for journals is that most journals have a very strict word limit. This often implies that the restricted amount of

words is more likely to be used on the actual analyses of data instead of reflecting on the applied methods. Seen against this background, a thesis' *Extended Abstract* facilitates a more detailed examination of methodological issues and, as a consequence, strengthens the studies' validity. A positive side of studies based on interaction analysis is the issue of transparency. By providing moment-by-moment analyses, the readers are able to follow the researcher's analytical steps along the way. This means that the readers are allowed to reach other conclusions, as well as to question the evidences on which findings are based (Heritage & Atkinson, 1984; Peräkylä, 2004). A positive side of being part of a research community is that you share your data and analyses with other researchers. During my PhD period, I have participated in several research seminars where I have presented data extracts. Critical comments and joint analysis efforts have contributed to strengthen the validity of the three presented studies.

A positive element of studies that include the use of ethnographic data is that they provide rich descriptions of social settings. Such descriptions invite the reader into a research setting and give a broader basis on which to make decisions with regard to the study's credibility (Kvale & Brinkmann, 2009; Silverman, 2001). Nevertheless, as noted by Mehan, the rich descriptions of ethnographic studies can also turn out to be a potential weakness (Mehan, 1979 in Silverman, 2005). By using the term "anecdotalism", Mehan refers to qualitative researchers' problem of convincing themselves and others that their findings are based on critical examination of the whole data corpus, not only on a couple of well-chosen extracts that fit their theory based assumptions. In the following I address this important validity aspect with regard to my own analytical procedures. I do this by discussing how I responded to a critical comment made by the reviewers on the first version of Study III.

When receiving reviews from journals, a common critique from reviewers concerns the typicality of the interaction patterns indicated by analyses of a few selected extracts. This is what happened in the review process of Study III. In this study a typical pattern concerning how students engage with the prompts in Viten.no was described. In the first submitted version, I displayed detailed analyses of interaction extracts from *one* group of students engaging with a prompt. The reviewers argued that I had to be more persuasive in order to convince them that the students' activity pattern as identified through the analyses represented a *typical* way of engaging with the prompts. In order to show the validity of my claims about the typical pattern, I did three things. In the revised version, I first explicitly accounted for the meticulous process of transcription and selecting the specific extracts; all

the extracts in the studies were selected on basis of the total data corpus. This can be seen as what Mehan terms a "comprehensive data treatment" referring to that "all cases of data [are] incorporated in the analysis" (Mehan, 1979 in Silverman, 2005, p. 215). The focus on typical patterns does not imply that all students do the exact same things or have the exact same work trajectories. It refers to that when zooming out and taking the whole data corpus into account there are some patterns that appear to be more typical than others. As such the selected extracts can be seen as "condensed exemplifications" that make it possible to zoom in on and explore the typical patterns.

Secondly, I responded to the critique by bringing in another type of data, namely the students' written responses to the prompts in Viten.no. A comparison of all the students' prompt responses showed that most of the students dealt with the prompts by employing a "copy and paste" strategy. I used this finding as an argument for supporting my claims about the relevance and typicality of the pattern identified through the interaction analysis. A third initiative for meeting the reviewers' critique was to display the analysis of an additional interaction extract. This extract was selected from another student dyads' interaction trajectory. The analysis of this extract showed some of the nuances between the student groups, but most importantly it made visible the similarities between the groups' ways of dealing with the prompts. In the re-review both reviewers reported that they were satisfied with the way I had responded to their validity critique. Seen in hindsight, an interesting lesson learned was that a study's trustworthiness, and hence validity, is closely related to how you disclose your analysis procedures as well as your reasons for selecting the specific data extracts.

A final issue regarding the studies' validity that I will address concerns ecological validity, i.e. the degree to which the activity observed and recorded in a study reflect the activity that actually occur in natural settings (Silverman, 2001). The issue of ecological validity is associated with "generalizability" which is another important aspect of qualitative studies.

### *4.4.3 Generalization*

In quantitative-oriented studies, the issue of generalizability is related to the possibility of transferring the findings within a sample to the population at large. For qualitative studies however, the analytical focus on a few non-randomised cases makes it difficult to discuss generalizability on the premises of quantitative research (Silverman,

2001). This does not imply that the issue of generalizsability is an irrelevant aspect of qualitative studies. The generalizability of interaction analytic studies can better be addressed by focusing on to what extent the findings within one educational setting are applicable to other educational settings (Ercikan & Roth, 2006).

For studies utilizing a sociocultural and dialogic perspective, the issue of situatedness is fundamental. If students' meaning making processes are locally situated, how then is it possible to make general claims based on analyses of interactions taking place within a particular setting? The generic claims raised in the conclusions in the three studies can be seen in as *analytical generalizations* (Kvale & Brinkmann, 2009; Miles & Huberman, 1994). This implies that the proposed generic claims are based on a combination of the theoretical point of departure, the inductive generated findings from the empirical analyses and findings of related studies. Seen in relation to the work conducted in this thesis, the overall focus has been to explore technological, epistemic and institutional aspects of students' meaning making processes while engaging with Web-based inquiry environments. These aspects are mainly theoretically derived, implying that they can be conceived as generalized aspects of students' meaning making processes within these types of settings. However, *how* the students invoke and orient towards these aspects during their meaning making processes is something that is realized in practice by the participants. This implies that insight into how this is realized in practice is only available through inductive empirical analyses of the situated practice.

Finally, the findings of the studies are discussed in relation to findings in previous studies of students' meaning making in Web-based inquiry environments. Over time, empirical studies from similar educational settings generate robustness and nuances in the analytic generalizations that can be made from one study alone. This means that over time, we become more and more sensitive to students' meaning making in various knowledge domains.

### *4.4.4 Reflections on research ethics*

In the following section I discuss some of the ethical considerations concerning the research undertaken. Since I did not take part of the planning and accomplishment of the DoCTA project, I primarily focus on my research conducted on the Viten.no project. The reflections made on data analyses process, however, concerns both projects.

Before the start-up of the Viten.no project, I wrote a notification request to the Norwegian Social Science Data Services (NSD). NSD is the Privacy Ombudsman for all the Norwegian universities, university colleges and several hospitals and research institutes. Staff members offered me advice on different ethical aspects to consider, especially regarding protection of participants' privacy. My notification request was approved. Since the project involved minors (aged 15-16 years), a written approval from the students' parents was necessary. In the information letter, I described my focus, data collection methods, and how the video records would be used. All the student guardians and the students themselves had to give me their written approval before I could video record them. Only three of the seventy five students declined, and those three were not videotaped. During transcription of the video recordings, all names were replaced by pseudonyms. Additionally, the name and location of the schools has not been used in any of the published material. Clips from video recordings have been shown for analysis purposes in small research groups, but these clips have not been published outside the research community. I have undertaken to make anonymous the whole data corpus after the project is finished and to ensure that the data material will be securely stored.

When the research project started, I decided not to hide the research process and interests from the students and teachers. Even though this might have affected the participants' behaviour in my presence, I believe that an approach based on openness gives a basis for mutual trust between the researchers and the participants. Being a participant-observer raised a number of ethical issues that extend beyond formal consent to the research. As a closing comment, I would add that I have found it important to take account of the participants' privacy during all phases of the research.

# 5 Summary of the studies

## Study I

Furberg A., & Ludvigsen S. R. (2008) Students' meaning-making of socio-scientific issues in computer mediated settings: exploring learning through interaction trajectories. *International Journal of Science Education, (30)*, 1775-1799.

This article reports on a study concerning secondary school students' meaning making of socio-scientific issues in settings where they engage with open-ended Web-based inquiry environments. In recent years there has been an increasing emphasis on socio-scientific issues in school science (Driver, Newton, & Osborne, 2000; Mortimer & Scott, 2003). The emphasis on socio-scientific issues science involves bringing socially relevant issues into the classroom. The overall aim is to bridge the gap between the students' everyday experiences and ongoing scientific discourses in society (Lemke, 1990; Vygotsky, 1978). Furthermore, the focus on socio-scientific issues also incorporates an emphasis on the importance of collaboration and student talk for students' learning processes (Wells, 1999). When it comes to how to organize students' learning activities, open-ended tasks that are to be solved through project work, discussions and the use of Web-based inquiry environments are often put forward as productive strategies.

During the last decades, several Web-environments aimed at supporting student collaboration and discussion have been developed. Many of these Web-environments provide students with various types of content-based resources such as online textbooks, popular science articles, news articles, and overview of URL links. How students and teachers grapple with making sense of socio-scientific issues when engaging with these types of open-ended environments is what is scrutinized in this article. A sociocultural perspective on learning, as utilized in this study, views social and cognitive processes as intertwined. This implies that students' actions and activities are embedded in historical and institutional settings where norms and values are part of students' argumentation in particular knowledge

domains. It is in the relations between institutional aspects of the setting and the actions performed by the students where learning activities are created (Linell, 1998; Mäkitalo, et al., 2009; Wertsch, 1991).

The empirical focus of the study is on the interaction of two secondary school students while working with socio-scientific issues related to genetics using different information resources provided to them through the groupware system FLE2 (Wasson & Ludvigsen, 2003). In this setting the students worked with responding to a set of predefined scientific questions about gene modification of food. By analysing sequences of the two students' interaction, the study explores how they grappled to make sense of scientific concepts at issue. The analyses of the students' interaction were guided by the following research questions:

- *What characterizes the students' accounts of how to deal with the socio-scientific task?*
- *How are institutional aspects displayed in the students' talk and activities?*

The analyses of the students' accounts show that the two students oriented their accounts differently. One of the students oriented towards finding *scientific explanations*, whereas the other student oriented towards *the consequences* of gene modification. The students' different orientations contributed to an ambivalent tension, which, on the one hand, was productive because it urged them into ongoing discussions and explicit sense making. On the other hand, the tension elucidated how complex and challenging it is for students to relate to different types of perspectives and information sources. Towards the end of their working process, the students' orientation changed again. When writing up their response to their guiding questions, their orientation turned towards being *fact-oriented* (Hakkarainen et al., 2002). The analyses of their interaction during their production of the end product show their uncertainty of how to respond to the task. As a solution they turned towards what can be seen as a traditional textbook procedure: They ended up copying text from the articles they found in the FLE2 environment. The findings suggest that in order to obtain a deeper understanding of students' meaning making of socio-scientific issues in settings where they engage with open-ended Web-based inquiry environments, it is important not only to address how students make sense of the scientific concepts. It is equally important to be sensitive with respect to how students orient their talk and activity towards more or less explicit values, demands, and expectations embedded in the educational setting. In other words, how students perform the activity of "doing school."

## Study II

Furberg A., & Arnseth H. C. (2009). Reconsidering conceptual change from a socio-cultural perspective: analyzing students' meaning making in genetics in collaborative learning activities. *Cultural Studies of Science Education (4)*, 157-191.

In the learning sciences, students' understanding of scientific concepts has often been approached in terms of conceptual change. These studies are grounded in a cognitive or a socio-cognitive approach on students' understanding, and imply a focus on the individuals' mental representations of scientific concepts and ideas (Kindfield, 1993/1994; diSessa, 2006; Stewart & Hafner, 1994). In this study students' conceptual change is approached from a sociocultural perspective as they make new meaning in genetics (Linell, 1998; Säljö, 2000; Wertsch, 1991). Adhering to a sociocultural perspective, interactional and institutional aspects of human learning and understanding are emphasized. This is demonstrated by replacing the term "students' conception of" with the term "students' meaning making of" genetics. Further, it is argued that students' interpretations of genetics concepts are produced as part of specific types of *meaning making practices*, practices that are perceived as emergent properties of social interaction (Linell, 1998). This view implies that participants in various practices, and analysts of such practices, need to be sensitive to the normative organization of settings.

The empirical basis for this study is the Viten.no project where secondary school students and their teacher conducted a two week school project about gene technology. The central resource for introducing students to the gene technology curriculum was the Web-based inquiry environment Viten.no. The analytical focus of the study is on a group of four students' interaction trajectory taking place during a so-called *follow-up activity*. In the follow-up setting, the students were instructed to engage with reasoning tasks related to the content in Viten.no by discussing among themselves without using any resources such as computers or textbooks.

In the study detailed analyses of sequences of students' interaction trajectory were conducted. In order to emphasize the multiple aspects of students' meaning making processes, four research questions were addressed:

- *How do students use resources in discursive collaborative learning activities, and what are the consequences for students' participation?*

- *How do teachers in and through their talk facilitate students' meaning making?*
- *What characterizes students' dialogue in collaborative learning activities, and what are the consequences for students' participation?*
- *How do institutional concerns impact students' meaning making in genetics?*

Four findings of the study can be summarised. First, the study demonstrates how the Viten.no was integrated as an important structuring resource in the students' discussion. Invoking representations in Viten.no, such as explanations, practical tasks, depictions and animations, helped the students recall details and visualizations of an authorized version of the science content. Furthermore, the integrated resources seemed to constitute mediational means that made this complex domain tangible for the students. In this sense the resources extended the students' possibilities of managing to talk about the scientific content as well as their divergent perspectives. Second, the study demonstrates the importance of *teacher intervention* in students' meaning making processes. Three important sides of teacher intervention in situations characterized by collaborative classrooms activities were identified: a) guiding the students in their process of making sense of the relevant scientific concepts, b) facilitating the students' discussion, and c) guiding them in how to solve the task.

Third, the focus on students' interaction trajectories made it possible to grasp changes in the students' *interactional accomplishments* during their discussion. In the initial phase of their interaction trajectory, the students oriented towards exploring and explaining the scientific concepts at issue. Over time, however, the students' orientation changed towards being position-driven, implying that their talk became characterized by short unjustified claims and tricky arguments. Towards the end of their discussion trajectory, the students' orientation changed again. In this setting the students' attention became oriented towards how they could produce an end product that was in accordance with the institutional expectations and assessment criteria. Finally, emphasizing the changes in the students' way of accounting during their interaction trajectory show that students' meaning making in genetics not only relates to an epistemic concern, but also relates to interactional and institutional concerns.

## Study III

Furberg, A. (in press). Sociocultural aspects of prompting student reflection in Web-based inquiry learning environments. *Journal of Computer Assisted Learning*. DOI: 10.1111/j.1365-2729.2009.00320.x

This article reports on a study of students' engagement with a collaborative Web-based inquiry environment aimed at supporting student reflection during scientific inquiry. Within the learning sciences, there seems to be a fair consensus that reflection has a positive impact on students' acquisition of knowledge as well as on their inquiry skills (Brown, Bransford, Ferrara, & Campione, 1983). Over the past few decades, several Web-based computer tools have been developed with the aim of engaging and scaffolding students in scientific inquiry (de Jong, 2006; Linn & Eylon, 2006). A common feature for many of these Web-based inquiry environments is the built-in tools aimed at supporting specific aspects of students' inquiry processes, which include sense making, process management, articulation and reflection (de Jong, 2006; Quintana et al., 2004). In the research literature, such tools have been referred to as "scaffolds" (Quintana et al., 2004), "support tools" (Manlove, Lazonder, & de Jong, 2006), or "prompts" (Davis, 2004; Davis & Linn, 2000). Research on students' employment with prompts in Web-based learning environments shows divergent findings. Common findings are that students often tend to ignore prompts, or that students do not benefit from the support that the prompts are intended to give. Additionally, there are few studies that demonstrate positive effects of prompts with regard to student performance (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003; Clarebout & Elen, 2006).

In order to gain a deeper understanding of these discouraging findings, a sociocultural approach is taken. Seen from a sociocultural perspective, Web-based learning environments such as Viten.no can be regarded as a cultural artefact (Cole, 1996) embodying *opportunities* to engage with embedded *knowledge* and *social practices* developed over generations. This knowledge and these practices are what students potentially interact with when they employ artefacts and perform different types of activities (Säljö, 2000). The interesting aspect then becomes the exploration of if and how the students make use of these opportunities for action during their engagement with the learning environment.

In this article, the empirical focus is on secondary school students' interaction while engaging with gene technology in Viten.no. A central feature in Viten.no is the prompts

designed to support students in their process of reflecting on the scientific concepts by means of content-related questions. In the study, detailed analyses of students' interaction while engaging with the Viten.no environment are conducted. Additionally, the students' written responses to the prompts in Viten.no represent important supplementing contextual data for understanding the analyses of the students' interaction. In order to understand how the students engaged with the Web-based learning environment, the following research questions were addressed:

- *What opportunities for action are embedded within the Web-based learning environment Viten.no, and how do these opportunities for action become structuring resources in the students' participation in scientific inquiry?*
    - (a) *in non-prompting situations?*
    - (b) *in prompting situations?*

One important finding is that the examination of the students' written responses to the reflection prompts demonstrated a widespread use of a "copy and paste" strategy. Furthermore, the analyses of student interaction shed light on this finding. These analyses show that the students made use of these "copy and paste" strategies in order to come up with "correct" answers to the prompts. Moreover, the analyses demonstrate how the students' employment of these strategies can be seen as a response to their interpretations of the institutional practices, expectations and norms embedded within the design of the prompts and the general learning environment. These findings are discussed and explored in accordance with findings from previous studies on prompting students' reflection in Web-based inquiry environments. Overall, the study demonstrates the value of a sociocultural perspective for gaining a deeper understanding of students' engagement with Web-based inquiry environments. Such a perspective can give valuable insight into how to (re)design prompts, and how prompts can be productive parts of students' meaning making processes.

# 6 Discussion and concluding remarks

## 6.1 Web-based inquiry environments as structuring resources

Several systemic oriented studies have demonstrated that students' engagement with Web-based inquiry environments has a potential positive effect, particularly on students' inquiry performances, but also, to some extent, on students' acquisition of scientific knowledge (see for example: Clark & Sampson, 2007; Hakkarainen, 2003b; 2004; van Joolingen et al., 2007; Seethaler & Linn, 2004). Seen from a sociocultural perspective, these findings are of important value. The overall aim of this thesis, however, has not been to focus on the impact of Web-based inquiry environments, but rather to explore the very process of students' meaning construction and how Web-based environments are integrated as structuring resources in this process. Two types of Web-based inquiry environments have been at the centre of the conducted studies. In Study I the focus was on students' engagement with the discussion facilitating open-ended environment FLE2. In Study II and Study III, the focus was on students' engagement with the structured and curriculum-based Viten.no environment.

An overall finding across all three studies is that there are constructive as well as challenging sides of how Web-based environments are integrated as structuring resources in students' meaning making processes. Previous studies have shown that using multiple information sources, as students do in environments like FLE2, is rather challenging. One reason for this is that the students come across different kinds of information reflecting different discourses and types of texts. Navigating in these kinds of environments is distinctly different than, for instance, engaging with textbooks. In textbooks the facts are often more or less given and tightly connected to the assignments in the textbook (Mäkitalo et al., 2009). When dealing with multiple information sources, it becomes a challenge for the students to make sense of different kinds of content mediated through various information sources

(Lemke, 1990). When managing these open-ended environments, the students need certain types of qualifications: the students' problem-solving must move from the general picture towards finding ways to particularize their argumentation and to make sense of scientific concepts (Mäkitalo et al., 2009).

The findings in Study I confirm as well as add new perspectives to such findings. The analyses of students' interaction trajectory while engaging with socio-scientific issues when using FLE2 showed constructive, but also more challenging sides of dealing with these types of educational settings. The tension between these constructive and challenging sides is most explicitly demonstrated by the obvious distinction between the quality of the students' discussion during their working processes and the quality of their written end product. The analysis of the students' interaction during their work process showed how the students' constructed complex and relevant arguments when accounting for the concepts at issue. By using texts they found on the Internet as a starting point for their discussions, the students became able to discuss gene modification of food seen from various perspectives such as ethical, economical and scientific perspectives. The examination of the students' written end product and the analyses of the students' discussion towards the end of their trajectory however, showed that they ended up copying text from the web pages they had been discussing. The students' use of a "copy and paste" strategy was not only a typical pattern for this group, but also a typical pattern for most of the student groups in this project.

The finding of a "copy and paste" strategy confirms the finding of other studies showing frequent use of fact-orientation strategies (Hakkarainen, 2003b; Rasmussen, 2005). The distinction between the students' discussion and their end product can be explained in different ways. One plausible explanation is that their fact-orientation strategy indicates that they did not see their accounts and reasoning as an important part of their inquiry process. Their focus was on passing authorized "facts" presented to them by means of the links in the FLE2 environment. Consequently, they did not see the relevance of documenting their own rather complex and advanced reasoning process. Another plausible explanation is that they did not know *how to document* their argumentative efforts in their end products. Either way, it is obvious that the students in this situation had to find out for themselves how to write up their end product. In this setting, they chose to reuse extracts of texts found on the Internet.

Based on this background, it is possible to see how the FLE2 environment on the one hand became integrated as a constructive resource in the students' meaning making process. Their access to different types of information sources made it possible for them to discuss

different aspects of gene modification. However, it is also possible to see that the Web-environment did not explicitly become a constructive resource in their process of documenting their findings. Without explicit support structures facilitating documentation of their reasoning, it became hard for the students to find out how to deal with this important part of their inquiry process.

The analyses of students' interaction trajectories while engaging with Viten.no in Study II and Study III also show the tension between the constructive and the challenging sides of students' engagement with Web-based inquiry environments. Concerning the constructive sides, the analyses of students' interaction trajectories during their engagement with Viten.no and their interaction trajectory in the follow-up activity show how the elements from the Web-based environments became resources for structuring their meaning making processes.

As demonstrated in Study III, the students used the tasks, text based explanations, depictions and animations within Viten.no as a starting point for discussing central scientific concepts. Furthermore, the analyses show how the visualization of the scientific content enabled them to talk about complex concepts as well as constructing complex arguments. In other words, they used the engagement with the Web-environment as an opportunity for talking science (Lemke, 1990). A further interesting finding concerning how the Web-environment constituted a constructive resource in the students' meaning making processes was demonstrated during the follow-up activity as documented in Study II. In this setting the students were introduced to a set of reasoning tasks following their engagement with the Viten.no environment. The analyses show how the students invoked and used features from the Viten.no environment, such as written explanations, drawings, and depictions of the cellular processes, in order to collaboratively construct complex and detailed accounts of the concepts at issue. First, these findings demonstrate how textual and visual features in Web-environments can help the students recall details and visualizations of the standard, or normative, versions of the science content. Second, it demonstrates that Web-based resources have an intermediate dimension. This means that the resources invoked represent one possible portrayal of the subject matter domain, and the resources constitute mediational means that make this complex domain accessible to the students. Furthermore, the resources extend the students' possibilities for managing talk about the scientific content as well as their divergent perspectives on scientific topics.

However, there are also more challenging sides to students' engagement with Viten.no. These challenges were most explicitly demonstrated by examining their written responses to the prompted questions in Viten.no and their interaction during the process where they produced these responses. The examination of the students' written responses to the prompts revealed that their constructive way of accounting for and exploring the scientific concepts was not reflected in their written responses. Just like the students' written productions within the FLE2 environment, these students' written responses were characterized by a "copy and paste" strategy. This implies that in settings where the students were required to document their findings, their orientation turned towards being fact-oriented and reproducing the standard versions of the concepts at issue. Once more, this confirms the assumption that one of the most challenging features in the students' inquiry processes is to figure out how to document findings and make reasoning visible for themselves and others.

These initial findings have implications for the design of Web-environments designed to support students' inquiry processes. The two studied environments were included as a constructive support in the students' process of exploring and discussing complex and abstract concepts. Nevertheless, in the setting where the students were about to document their inquiry, the Web-environments do not provide explicit guidance on how to approach the documentation process, and few explicit references to the procedures of scientific inquiry are given. Without any guiding principles about how to deal with the documenting process, it became up to the students to figure out how to deal with this part of the inquiry process. The discussed findings call for a technology design that not only facilitates student discussions and their engagement with a scientific content, but also for a design that explicitly facilitates the students' process of documenting their inquiry.

The main emphasis of this thesis has been to argue for the importance of focusing on *technological*, *epistemic* and *institutional aspects* of students' meaning making in order to understand how they come to grips with making sense of science while engaging with Web-based inquiry environments. This implies that technological aspects, such as features of the design of the technology in use, are only one aspect that should be considered in order to understand these types of processes and settings. In the following section, I will discuss how the tension between the constructive and challenging sides of the students' way of engaging with the Web-based environments also must be considered in relation to institutional aspects.

## 6.2 Engaging with science in institutional settings

A central aim in this thesis has been to focus on epistemic aspects of students' meaning making processes while engaging with Web-based inquiry environments, i.e. how they grapple with making sense of scientific concepts. Several studies have demonstrated the challenges of designing educational settings and Web-based learning environments that facilitate not only an orientation towards procedural aspects of solving a task, but also an orientation towards conceptual understanding (Clark & Sampson, 2007; Hewitt, 2002; Krange & Ludvigsen, 2008). As argued, students' fact-orientation is a frequent finding in studies on students' engagement with Web-based learning environments (Hakkarainen et al., 2002; Hewitt, 2002; Rasmussen, 2005). Fact-orientation practices have been described as one of the main challenges following the use of ICT in education (Collins, 2001; Hewitt, 2002). However, seen in relation to classroom research in general, this practice has been part of schooling long before ICT became a part of the learning environments (Scardamalia & Bereiter, 1994; Wray, 1985).

The analyses of students' interaction while engaging with the Web-based inquiry environments FLE2 and Viten.no, as well as the examination of their written contributions, confirm the frequent findings of fact-orientation practices. However, the analyses of the students' interaction trajectories also show another pattern that can better be described as explanation oriented practices. The most interesting point is not that it is possible to document different types of student orientations. Rather it is that by scrutinizing the students' interaction over time, the studies have demonstrated how their orientation changes over time. The students' interaction trajectories in these types of settings often contain an initiation phase characterized by exploring the Web-environment and the scientific concepts they are introduced to. It is in these settings where the most complex and advanced arguments are constructed. However, as discussed above, the students' orientation changed direction when they entered the phase where they were about to document their findings. From engaging with explaining and exploring scientific concepts, their orientation changed toward how to practically solve the task. In other words, as already indicated, they ended up with using a "copy and paste" strategy. In this sense it is possible to say that the students' accounts changed from being explanation-oriented toward being fact-oriented.

How can the students' fact-orientation be explained? One overarching emphasis in this thesis is that students' successes or challenges during their meaning making processes

cannot be explained either as a singular result of individual capacities, social relations, teacher instruction or features of the technology design. Students' meaning making processes take place in an institutional setting. Institutions comprise historically developed practices, norms and socio-material structures that have an impact on the meanings and functions of the students' communicative actions (Linell, 1998; 2009). Viewed in a historic perspective, the students' fact-orientation may also represent acquiescence to institutional practice in a specific, yet typical, school setting (Wray, 1985). Referring to and knowing the exact content of textbooks, have played – and still plays – an important role in teaching and education. Students' activities have traditionally been oriented towards responding to ready-made questions by using resources such as textbooks and other written texts. Furthermore, seen as cultural artefacts (Cole, 1996; Säljö, 2000), Web-based inquiry environments such as FLE2 and Viten.no embody opportunities to engage with embedded knowledge and social practices developed over generations of scientific inquiry. Consequently, Web-based environments as educational environments in general embed residues of more or less explicit institutional practices reflecting specific ways of organizing, for instance, instruction, learning activities and assessment.

In this sense the students' fact-orientation can be seen as a strategy for dealing with what they interpret as institutional practices, demands, and expectations. The changes in the students' orientation, from being explanation-oriented toward being fact-oriented, can thus be explained by that responding to their anticipation of institutional practices and expectations become their primary concern. When writing up their end products (Study I and Study II) or in settings where they engage with the reflection prompts (Study III), the students' orientations towards institutional practices seem to take precedence, whereas exploring and explaining scientific concepts and procedural aspects of scientific inquiry recede into the background. With no guiding principles about how to deal with documenting their arguments and findings, it becomes the students' responsibility to figure out how they can manage their accomplishment of the given tasks. Without explicit guidance as well as explication of expectations and assessment guidelines, it is possible to assume that the students were attuned toward how they would be assessed and what the teacher expected from them. Above all the three studies demonstrate the importance of a concerned teacher that can guide the students in the different stages in their meaning making processes. The issue of teacher intervention is what will be discussed in the following section.

## 6.3 The importance of teacher intervention

A shared feature of all the three conducted studies is that they show the importance of the teacher in orchestrating and facilitating students' learning processes in settings where they engage with Web-based inquiry environments. For example, the study conducted by Hakkarainen et al. (2002) demonstrates how teacher intervention can have positive impact on guiding students towards more understanding-oriented approaches as opposed to more fact-orienting strategies. In settings where the teacher intervention was characterized by open ended questions and encouraging search for scientific information, the students were more likely to provide attempts of explanations instead of referring to facts or descriptive information. Despite the general acknowledgement of the importance of teacher intervention, several studies have shown that, in many cases, the teacher serves mainly as an administrative facilitator. Often the interaction between the teacher and the students is characterized by talk about the practical side of how to complete a task (Arnseth, 2004; Krange & Ludvigsen, 2008; Ludvigsen, in press; Rasmussen, 2005). Seen together these findings illustrate the ambiguity of "doing" teaching in these types of settings. On the one hand they illustrate the absolute importance of a concerned participating teacher. On the other hand the findings demonstrate the challenges of facilitating students' meaning making processes in these types of settings.

All three studies in this thesis demonstrate the importance of teacher intervention; however, in Study II the interaction between the students and the teacher is given analytical attention. The teacher in the Viten.no case went way beyond being an administrative facilitator. Even so, the study demonstrates challenging aspects of teacher intervention in these types of settings. First, the analyses show that teacher interventions in these types of settings were not, and should not be, restricted to guiding students in their process of making sense of scientific concepts. Of equal importance is procedurally oriented guidance, as well as guiding students in their process of engaging with and making sense of the Web-based learning environment. This includes explicating institutional practices, norms and expectations. Furthermore, the analyses showed the importance of teaching interventions for the development of the students' reasoning. By asking probing questions, the teacher can direct the students to dig deeper into the subject matter. Or in Lemke's words, teachers' questions guide the students towards constructing a more complex thematic pattern (Lemke, 1990). However, the analyses also demonstrate the difficulty of guiding the students too much and too little. As the shown in Study II, the teacher's constructive way of probing

open-ended questions was productive up to a point. At a point, however, the students' discussion stalled into to what became fixed opposing positions, and the students were left to themselves to come up with a solution of how to make sense of a particular concept as well as how to settle their disagreement. As a consequence their productive and advanced reasoning process ended in an unsettled incongruity.

A final remark with regards to teacher intervention concerns how Web-based resources can be used in educational settings in order to facilitate joint construction of meaning. The follow-up session in the Viten.no project, where the students engaged with the reasoning tasks, points out as the situation where the most advanced and complex content oriented accounts were constructed. This setting was carefully designed in order to initiate content-related talk by putting reasoning tasks at centre. The reasoning tasks were to be discussed without the use of resources like ICT or textbooks. The analyses of the students' interaction during such sessions show that they used this opportunity for constructing their version of the concepts at issue. The analyses also show that each of the students was only partially able to account for the concept. However, during the discussion they subsequently managed to construct a complex and detailed thematic pattern (Lemke, 1990). Research has shown that these types of situations do not come into being by themselves. More often than not they must be planned and nurtured over longer periods of time in order to become more than sporadic incidents (Hakkarainen et al., 2002; Hewitt, 2002). However, the analyses of the sessions in the Viten.no project demonstrate that it is possible to facilitate this type of situation where the focus primarily is on reasoning about scientific concepts. Such situations however, must be planned, organised and orchestrated by a concerned teacher.

Web-based environments such as Viten.no are rich on illustrations, animations and illustrative examples. These resources can be used as resources in teacher instruction settings or classroom discussions. In a study Gillen, Littleton, Twiner, Staarman and Mercer (2008) demonstrate how interactive whiteboards in primary science education was used as an instructional resource for facilitating students' meaning making processes. In one of the study's analysed cases, a teacher used the multimodal possibilities of an interactive whiteboard to introduce the students to the phenomenon of evaporation. By using self produced video clips and video stills showing how water evaporates in a hot frying pan, the teacher invited the students into a discussion of the process taking place. In the study analyses of sequences of interaction taking place at different stages during the students' "meaning making" trajectory are conducted. The analyses of the participants' interaction

demonstrate that the use of multimodal presentation of the evaporation process served three interrelated purposes: to create continuity between lessons, to establish shared experience and understanding, and to bridge the gap between everyday and scientific explanations of the phenomenon (Gillen et al., 2008, p. 354). In the Viten.no project, the Viten.no environment was not explicitly used in plenary classroom settings. However, as the interactive whiteboard study demonstrates, these types of environments can be used in instructional settings as a complementary way of facilitating shared meaning construction. Using the multimodal presentations of the scientific content in Viten.no could be a productive starting point for creating engaging and productive classroom discussions.

## 6.4 The intersecting aspects of students' meaning making

The main methodological contribution of this thesis relates to approaching students' meaning making processes and engagement with Web-based inquiry environments through analyses of their interaction trajectories. As already discussed in section *2.5.2,* the notion of trajectories has been central in several previous studies (Ludvigsen et al., in press). The term trajectories has been used to denote different types of processes of limited duration, such as a patient's course of illness (Strauss, 1975), individuals' participation in different contexts (Dreier, 1999), or the lifecycle of production projects (Engeström & Escalante, 1996).

The term interaction trajectories as used in this thesis denotes the relation between units of moment-by-moment interaction taking place within time or task limited school activities. Theoretically, focusing on interaction trajectories is important because the construction of knowledge and meaning making are considered to be aspects of interaction that develop over time. Methodologically, emphasizing interaction trajectories has implied an analytical focus on chronologically selected extracts from sequences of students' interaction. First, the analytical emphasis on students' interaction trajectories has made it possible to study the unfolding of activities regarding how students construct knowledge and meaning as a moment-to-moment achievement over time. Second, being sensitive of students' orientation during their interaction trajectories makes possible an understanding of meaning making processes as a matter of constant shifts between different orientations.

Several times within the thesis I have referred to Jiménez-Aleixandre et al.'s distinction between what they regard as two types of student discourse activities in science education: "Doing school" and "doing science" (Jiménez-Aleixandre et al., 2000). "Doing

school" refers to the procedural displays, which constitutes the routines and rituals in a school setting. These are often taken for granted and serve as obstacles for the activity of "doing science". Science education does not imply a simple transfer of knowledge from scientific practices to school practices (Chinn & Malhotra, 2002). Doing scientific inquiry as a researcher is another type of activity than performing scientific inquiry as a student. In a school setting, students have to deal with concerns other than making sense of how to do inquiry learning. Seen from an analyst's perspective, this thesis demonstrates the need for being sensitive towards how students orient themselves and how institutional aspects are displayed in interactions, in other words, how the students are "doing school". In this way, we will be able to gain a deeper understanding of students' meaning making in Web-based educational settings.

Seen from an instructional perspective, the findings from the three studies reported in this thesis demonstrate that "doing school" activities cannot be seen as obstacles for "doing science" activities. On the contrary, these types of communicative actions must be seen as intertwined and a central part of students' meaning making processes. Instead of taking these activities for granted, or aiming at reducing these types of activities, educators should use opportunities to explicate and discuss with the students' procedural aspects of scientific inquiry and schooling in general. This includes elements such as how to deal with specific tasks, what is expected from the students and their end products, and how they will be assessed. These types of discussions must not be seen as obstacles for learning or a waste of time. On the contrary this type of talk is the very essence of guiding students in their processes of scientific inquiry in an educational setting. The analytical findings in this thesis suggest that students move between different orientations during their interaction trajectory. If we are able to use the students' orientation as an analytic starting point, we will achieve a richer understanding of the intersecting relationship between technological, epistemic and institutional aspects of students' meaning making in Web-based inquiry settings.

# References


Abercrombie, N., Hill, S., & Turner, B. S. (1984). *Dictionary of sociology*. London: Penguin Group.

Aleven, V., Stahl, E., Schworm, S., Fischer, F., & Wallace, R. (2003). Help seeking and help design in interactive learning environments. *Review of Educational Research, 73*(3), 277-320.

Anderson, C. (2007). Perspectives on science learning. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 3-30). London: Erlbaum.

Arnseth, H. C. (2004). Discourse and artifacts in learning to argue. Analyzing the practical management of computer supported collaborative learning. PhD thesis. Institute for Educational Research. University of Oslo.

Arnseth, H. C., & Ludvigsen, S. (2006). Approaching institutional contexts: systemic versus dialogic research in CSCL. *International Journal of Computer-Supported Collaborative Learning, 1*(2).

Arnseth, A., & Säljö, R. (2007). Making sense of epistemic categories: analysing students' use of categories of progressive inquiry in computer mediated collaborative activities. *Journal of Computer Assisted Learning, 23*(5), 425-439.

Bakhtin, M. M. (1981). In M. Holquist (Ed.), *The dialogic imagination: Four essays*. Austin: University of Texas Press.

Bakhtin, M. M. (1986). The problem of speech genres. In C. Emerson & M. Holquist (Eds.), *Speech genres and other later essays* (pp.61-102). Austin: University of Texas Press.

Barnes, D. (1976). *From communication to curriculum*. Harmondsworth: Penguin Books.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8).

Brown, A. L. (1992). Design experiments: theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, *2*(2), 141-178.

Brown, A. L., Bransford, J. D., Ferrara, R. A., & Campione, J.C. (1983) Learning, remembering, and understanding. In P. H. Mussen (Ed.), *The Handbook of Child Psychology: Cognitive Development, Vol. III* (pp. 77-166). New York: Wiley.

Buttny, R. (1993). Social accountability in communication. London: Sage.

Chi, M. T. H. (1997). Quantifying qualitative analyses of verbal data: a practical guide. *Journal of the Learning Sciences, 6*, 271-315.

Chinn, C.A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: a theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175-218.

Clarebout, G., & Elen, J. (2006) Tool use in computer-based learning environments: towards a research framework. *Computers in Human Behaviour, 22*, 389-411.

Clark, D. B., & Sampson, V. D. (2007). Personally-seeded discussions to scaffold online argumentation. *International Journal of Science Education, 29*(3), 253-277.

Cole, M. (1994). A conception of culture for a communication theory of mind. In D. R. Vocate (Ed.), *Intrapersonal communication: different voices, different minds*. Hillsdale, NJ: Lawrence Erlbaum.

Cole, M. (1996). *Cultural psychology: a once and future discipline*. Cambridge, MA: The Belknap Press of Harvard University Press.

Collins, A. (1992). Towards a design science of education. In E. Scanlon & T. O. O'Shea (Eds.), *New directions in educational technology* (pp. 15-22). New York: Springer-Verlag.

Collins, A. (2001). The balance between task focus and understanding focus: education as apprenticeship versus education as research. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL 2: carrying forward the conversation.* Mahwah, N. J.: Lawrence Erlbaum.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: theoretical and methodological issues. *The Journal of the Learning Sciences, 13*(1), 15-42.

Crook, C., & Light, P. (2002). Virtual society and the cultural practice of study. In S. Woolgar (Ed.), *Virtual society? Technology, cyberbole, reality* (pp. 153-175). Oxford: Oxford University Press.

Davis, E. A. (2003). Prompting middle school science students for productive reflection: generic and directed prompts. *The Journal of the Learning Sciences 12*(1), 91-142.

Davis, E. A. (2004). Creating critique projects. In M. C. Linn, E. A. Davis & P. Bell (Eds.), *Internet environments for science education* (pp. 215-229). Cambridge: Cambridge University Press.

Davis, E. A., & Linn, M. C. (2000). Scaffolding students' knowledge integration: prompts for reflection in KIE. *International Journal of Science Education, 22*, 819-837.

diSessa, A. A. (2006). A history of conceptual change research: threads and fault lines. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences.* New York: Cambridge University Press.

Dreier, O. (1999). Personal trajectories of participation across contexts of social practice. *Outlines. Critical Social Studies, 1*, 5-32.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84* (3), 287-312.

Edelson, D. C., Gording, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry based learning through technology and curriculum design. *Journal of the Learning Sciences*, *8*, 391-450.

Engeström, Y., & Escalante, V. (1996). Mundane tool or object of affection? The rise and fall of the postal buddy. In B. A. Nardi (Ed.), *Context and consciousness: activity theory and human-computer interaction* (pp. 325–374). Cambridge, MA: MIT Press.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: explaining an emergent argument in a community of learners' classroom. *Cognition and Instruction, 20*(4), 399-483.

Ercikan, K., & Roth, W.-M. (2006). What good is polarizing research into qualitative and quantitative? *Educational Researcher, 35*(5), 14-23.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*(6), 915-933.

Garfinkel, H. (1984). *Studies in ethnomethodology.* Cambridge: Polity Press.

Geertz, C. (1973). The interpretation of cultures: selected essays. New York: Basic Books.

Giddens, A. (1979). Central problems in social theory. Action, structure and contradiction in social analysis. London: Macmillan Education LTD.

Gillen, J., Littleton, K., Twiner, A., Staarman, J. K., & Mercer, N. (2008). Using the interactive whiteboard to resource continuity and support multimodal teaching in a primary science classroom. *Journal of Computer Assisted learning, 24*, 348-358.

Goffman, E. (1959). *The presentation of self in everyday life*. New York: Doubleday Anchor Books.

Goffman, E. (1974). *Frame analysis*. New York: Harper and Row.

Goffman, E. (1981). *Forms of talk*. Philadelphia: University of Pennsylvania Press.

Hakkarainen, K. (2003a). Progressive inquiry in a computer-supported biology class. *Journal of Research in Science Teaching, 40*(10), 1072-1088.

Hakkarainen, K. (2003b). Emergence of progressive-inquiry culture in computer-supported collaborative learning. *Learning Environments Research*, *6*, 199-220.

Hakkarainen, K. (2004). Pursuit of explanation within a computer-supported classroom. *International Journal of Science Education, 26*, 979-996.

Hakkarainen, K., Lipponen, L., & Järvelä, S. (2002). Epistemology of inquiry and computer-supported collaborative learning. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL 2: carrying forward the conversation* (pp. 129-156). Mahwah, NJ: Lawrence Erlbaum Ass.

Hammersley, M., & Atkinson, P. (1995). *Ethnography. Principles in practice (2nd ed.)*. London and NY: Routledge.

Heritage, J. (1984). *Garfinkel and ethnomethodology*. Oxford: Polity Press.

Heritage, J., & Atkinson, J. M. J. (1984). Introduction. In J. M. J. Atkinson & J. Heritage (Eds.), *Structures of social action. Studies in conversation analysis* (pp. 1-17). Cambridge, MA: Cambridge University Press.

Hewitt, J. (2002). From a focus on task to a focus on understanding: the cultural transformation of a Toronto classroom. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL 2: Carrying forward the conversation*. Mahwah, NJ: Lawrence Erlbaum Associates.

Jefferson, G. (2004). Glossary of transcript symbols with an introduction. In G. H. Lerner (Ed.), *Conversation analysis: studies from the first generation*. Amsterdam/Philadelphia: John Benjamins.

Jiménez-Aleixandre, M. P., Bugallo Rodríguez, A., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": argument in high school genetics. *Science Education*, *84*(6), 757-792.

de Jong T. (2006). Scaffolds for computer simulation based scientific discovery learning. In J. Elen & R.E. Clark (Eds.), *Dealing with Complexity in Learning Environments* (pp. 107-128). London: Elsevier Science Publishers.

van Joolingen, W.R., de Jong, T., & Dimitrakopoulout, A. (2007). Issues in computer supported inquiry learning in science. *Journal of Computer Assisted Learning, 23*, 111-119.

Jordan, B., & Henderson, K. (1995). Interaction analysis: foundations and practice. *The Journal of the Learning Sciences, 4*(1), 39-103.

Jorde, D., Strømme, A., Sørborg, Ø., Erlien, W., & Mork, S. (2003). *Virtual environments in science. Viten.no* (No. 17). Oslo:Unipub

Kindfield, A. C. H. (1993/1994). Biology diagrams: tools to think with. *The Journal of Learning Sciences, 3*(1), 1-36.

Kirk, J., & Miller, M. (1986). Reliability and validity in qualitative research. London: Sage.

Kollar, I., Fischer, F., & Slotta, J. D. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning and Instruction, 17*, 708-721.

Koschmann, T., Stahl, G., & Zemel, A. (2007). The video analyst's manifesto (or the implications of Garfinkel's policies for studying instructional practice in design-based research). In R. Goldman, R. Pea, B. Barron & J. D. Sharon (Eds.), *Video research in the learning sciences* (pp. 133-143). Mahwah: Lawrence Erlbaum Associates.

Krange, I., & Ludvigsen, S. (2008). What does it mean? Students' procedural and conceptual problem solving in a CSCL environment designed within the field of science education. *International Journal of Computer Supported Collaborative Learning, 3*, 25-51.

Krange, I., & Ludvigsen, S. (2009). The historical and situated nature of design experiments – implications for data analysis. *Journal of Computer Assisted Learning*, *25*, 268-279.

Kvale, S., & Brinkmann, S. (2009). InterWiews. Learning in the craft of qualitative research interviewing (2nd ed). Los Angeles: Sage.

Lave, J. (1988). *Cognition in practice*. Cambridge: Cambridge University Press.

Lawson, A. E. (2003). The nature and development of hypothetico-predictive argumentation with implications for science reaching. *International Journal of Science Education*, *25* (11), 1387-1408.

Lemke, J. L. (1990). Talking science. Language, learning, and values. Norwood, NJ: Ablex.

Lewis, J., & Kattmann, U. (2004). Traits, genes, particles and information: re-visiting students' understandings of genetics. *International Journal of Science Education, 26*(2), 195-206.

Lindwall, O., & Lymer, G. (2008). The dark matter of lab work: illuminating the negotiation of disciplined perception in mechanics. *The Journal of the Learning Sciences, 17*(2), 180-224.

Linell, P. (1998). *Approaching dialogue: talk, interaction and contexts in dialogical perspectives*. Amsterdam, The Netherlands: John Benjamins Publishing Company.

Linell, P. (2009). Rethinking language, mind and world dialogically: interactional and contextual theories of human sense-making. Charlotte, NC: Information Age Publishing Inc.

Linn, M. C. (1995). Designing computer learning environments for engineering and computer science: the scaffolded knowledge integration framework. *Journal of Science Education and Technology, 4*(2), 103-126.

Linn, M. C., Davis, E. A., & Bell, P. (2004a). Inquiry and technology. In M. C. Linn, E. A. Davis & P. Bell (Eds.), *Internet environments for science education* (pp. 3-28). Cambridge: Cambridge University Press.

Linn, M. C., Eylon, B-S., & Davis, E. A. (2004b). The knowledge integration perspective on learning. In M.C. Linn, E.A. Davis & P. Bell (Eds.), *Internet environments for science education* (pp. 29-46). Cambridge: Cambridge University Press.

Linn, M., & Eylon, B.-S. (2006). Science education: integrating views of learning and instruction. In P.A. Alexander & P.H. Winne (Eds.), *The handbook of educational psychology, 2nd ed*. Mahwah, NJ: Lawrence Erlbaum Associates.

Littleton, K. (1999). Productivity through interaction: an overview. In K. Littleton & P. Light (Eds.), *Learning with computers. Analysing productive interaction* (pp. 179-194). London: Routledge.

Ludvigsen, S. (2009). Sociogenesis and cognition: the struggle between social and cognitive activities. In B. Schwarz, T. Dreyfus & R. Hershkowitz (Eds.), *Transformation of knowledge through classroom interaction* (pp. 302-318). London: Routledge.

Ludvigsen, S. (in press). What counts as knowledge: learning to use categories in computer environments. In R. Säljö (Ed.), *ICT and transformation of learning practices*. Amsterdam: Pergamon Press

Ludvigsen, S. R., & Mørch, A. (2003). Categorization in knowledge building: task specific argumentation in a co-located CSCL environment. In B. Wasson, S. R. Ludvigsen & U. Hoppe (Eds.), *Designing for change in networked learning environments. Proceedings of the international conference on computer support for collaborative learning* (pp. 67-76). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ludvigsen, S., Rasmussen, I., Krange, I., Moen, A., & Middleton, D. (in press). Multiplicity and intersecting trajectories of participation: temporality and learning. In S. Ludvigsen, A. Lund, I. Rasmussen & R. Säljö (Eds.), *Learning across sites: new tools, infrastructures and practices*. Amsterdam: Pergamon.

Manlove, S., Lazonder, A. W., & de Jong, T. (2006). Regulative support for collaborative scientific inquiry learning. *Journal of Computer Assisted Learning 22*, 87-98.

Mehan, H. (1991). The school's work of sorting students. In D. Zimmerman & D. Boden (Eds.), *Talk and social structure.* Cambridge: Polity Press.

Mercer, N. (1994). The quality of talk in children's joint activity at the computer. *Journal of Computer Assisted Learning, 10*, 24-32.

Mercer, N. (2004). Sociocultural discourse analysis: analysing classroom talk as s social mode of thinking. *Journal of Applied Linguistics, 1*(2).

Mercer, N. (2008). Changing our minds: a commentary on 'Conceptual change: a discussion of theoretical, methodological and practical challenges for science education.' *Cultural Studies of Science Education, 3*(2), 351-362.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359-377.

Mercer, N., Littleton, K., & Wegerif, R. (2009). Methods for studying the process of interaction and collaborative activity in computer-based educational activities. In K. Kumpulainen & M. César (Eds.), *Investigating classroom interaction: methodological choices and challenges* (pp. 27-42). Rotterdam: Sense Publishers.

Mercer, N., Phillips, T., & Somekh, B. (1991). Spoken language and new technology (SLANT). *Journal of Computer Assisted Learning, 7*, 195-202.

Mercer, N., & Wegerif, R. (1999). Is 'exploratory talk' productive talk? In K. Littleton & P. Light (Eds.), *Learning with computers. analysing productive interaction* (pp. 79-101). London: Routledge.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis (2nd ed)*. Thousand Oaks, CA: Sage Publications.

Mork, S. M. (2005). Argumentation in science lessons: focusing on the teacher role. *Nordic Studies in Science Education, 1*(1), 16-29.

Mork, S. M. (2006a). A case study of design and implementation of the Web-based Viten program radioactivity. In S. M. Mork. *ICT in science education. Exploring the digital learning materials at viten.no*. PhD thesis. Department for Teacher Education and School development, University of Oslo, Norway.

Mork, S. M. (2006b). A dual approach to analysing student argumentation in classroom debates. In S. M. Mork. *ICT in science education. Exploring the digital learning materials at viten.no*. In S. M. Mork. PhD thesis. Department for Teacher Education and School development, University of Oslo, Norway.

Mork, S. M., & Jorde, D. (2004). We know they love computers, but do they learn science? A study about the use of information technology and controversy in science instruction. *Themes in Education, 5*(1), 69-100.

Mortimer, E. F., & Scott, P. H. (2003). *Meaning Making in Secondary Science Classrooms*. Philadelphia: Open University Press.

Muukkonen, H., Hakkarainen, K., & Lakkala, M. (1999). Collaborative technology for facilitating progressive inquiry: future learning environment tools. In C. Hoadley & J. Roschelle (Eds.), *Proceedings for: computer support for collaborative learning. Designing new media for a new millennium: collaborative technology for learning* (pp. 406-415). Education and Training. Stanford University.

Mäkitalo. Å. (2003). Accounting practices as situated knowing: dilemmas and dynamics in institutional categorization. *Discourse Studies, 5*(4), 495-516.

Mäkitalo, Å., Jakobsson, A., & Säljö, R. (2009). Learning to reason in the context of socioscientific problems: exploring the demands on students in "new" classroom activities. In K. Kumpulainen & M. César (Eds.), *Investigating classroom interaction: methodological choices and challenges* (pp. 7-26). Rotterdam: Sense Publishers.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, *21*(5), 553–576.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Oshima, J., & Oshima, R. (2002). Coordination of asynchronous and synchronous communication: differences in qualities of knowledge advancements discourse between experts and novices. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL 2: Carrying forward the conversation* (pp. 99-109). Mahwah, NJ: Lawrence Erlbaum Ass.

Peräkylä, A. (2004). Reliability and validity in research based on naturally occurring social interaction. In D. Silverman (Ed.), *Qualitative research. Theory, method and practice (2nd ed)*. London: Sage.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*(3), 337-386.

Rasmussen, I. (2005). *Learning Trajectories and the use of multimedia in group work*. PhD thesis. InterMedia. University of Oslo

Rommetveit, R. (1985). Language acquisition as increasing linguistic structuring of experience and symbolic behavior control. In J. V. Wertsch (Ed.), *Culture, communication and cognition – Vygotskian perspectives* (pp. 183-204). New York: Cambridge University Press.

Rommetveit, R. (1992). Outlines of a dialogically based social-cognitive approach to human cognition and communication. In A. H. Wold (Ed.), *The dialogical alternative. Towards a theory of language and mind* (pp. 19-44). Oslo: Scandinavian University Press.

Roth, W.-M. (2005a). *Doing qualitative research. Praxis of method*. Rotterdam: Sense Publishers.

Roth, W.-M. (2005b). *Talking Science. Language and learning in science classrooms*. Lanham: Rowman & Littlefield Publishers.

Roth, W.-M. (2008). A question of competing paradigms? *Cultural Studies of Science Education, 3*(2), 373-385.

Sacks, H. (1984). Notes on methodology. In J. M. J. Atkinson & J. Heritage (Eds.), *Structures of social action. Studies in conversation analysis* (pp. 21-27). Cambridge, MA: Cambridge University Press.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge building communities. *The Journal of the Learning Sciences*, *3*(3), 265-283.

Scardamalia, M., & Bereiter, C. (1996). Computer support for knowledge-building communities. In T. Koschmann (Ed.), *CSCL: theory and practice of an emerging paradigm*. Mahwah, NJ: Lawrence Erlbaum.

Schegloff, E. A. (1991). Reflections on talk and social structure. In D. Boden & D. Zimmerman (Eds.), *Talk and social structure: studies in ethnomethodology and conversation analysis* (pp. 44-70). Cambridge: Polity.

Schoultz, J., Säljö, R., & Wyndhamn, J. (2001). Heavenly talk: discourse, artifacts, and children's understanding of elementary astronomy. *Human Development, 44*, 103-118.

Schönbach, P. (1980). A category system for account phases. *European Journal of Social Psychology, 10*, 195-200.

Scott, M., & Lyman, S. (1968). Accounts. *American Sociological Review, 33*(1), 46-62.

Seethaler, S., & Linn, M. C. (2004). Genetically modified food in perspective: an inquiry-based curriculum to help middle school students make sense of tradeoffs. *International Journal of Science Education*, *26* (14).

Semin, G. R., & Manstead, A. S. R. (1983). *The accountability of conduct: a social psychological analysis*. London: Academic Press.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher, 27*(2), 4-13.

Shotter, J. (1984). *Social accountability and selfhood*. Oxford, UK: Basil Blackwell.

Silverman, D. (2001). Interpreting qualitative data. Methods for analyzing talk, text and interaction. London: Sage.

Silverman, D. (2005). *Doing qualitative research (2nd ed)*. London: Sage.

Simon, S., Osborne, J., & Erduran, S. (2003). Systemic teacher development to enhance the use of argumentation in school science activities. In J. Wallace & J. Loughran (Eds.), *Leadership and professional development in science education: new possibilities for enhancing teacher learning* (pp. 198-217). London & New York: Routledge Falmer.

Slotta, J. D. (2004). The web-based inquiry science environment (WISE): scaffolding knowledge integration in the science classroom. In M. C. Linn, E. A. Davis & P. Bell (Eds.), *Internet environments for science education* (pp. 203-232). Cambridge University Press, Cambridge.

Stewart, J., & Hafner, R. (1994). Research on problem solving: genetics. In D. L. Gabel. (Ed). *Handbook on science teaching and learning project*. New York: MacMillan.

Strauss, A. (1975). *Chronic illness and the quality of life*. St. Louis: The C. V. Mosby Company.

Suppe, F. (1998). The structure of a scientific article. *Philosophy of Science, 65*, 381-405.

Säljö, R. (2000). *Lärande i praktiken: ett sociokulturellt perspektiv* [Learning in practice: a sociocultural perspective]. Stockholm: Prisma.

Säljö, R. (2005). Lärande & kulturella redskap: om lärprocesser och det kollektiva minnet. Stockholm: Norstedts Akademiska Förlag.

Tedeschi, J. T., & Riess, M. (1981). Verbal strategies in impression management. In C. Antaki (Ed.), *The psychology of Ordinary Explanations of social behaviour.* London: Academic Press.

Toulmin, S. (1958). *The uses of argument*. Cambridge, UK: Cambridge University Press.

Treagust, D. F, & Duit, R. (2008). Conceptual change: a discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education, 3*(2), 297-328.

Vosniadou, S. (2008). Conceptual change research: an introduction. In S. Vosniadou (Ed.), *International handbook of research on conceptual change*. New York: Routledge.

Vygotsky, L. S. (1978). *Mind in society: the development of higher social processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge: The MIT Press.

Vygotsky, L. S. (1987). The collected works of L. S. Vygotsky: Vol. 1. Problems of general psychology. New York: Plenum.

Wasson, B., & Ludvigsen, S. (2003). *Designing for knowledge building*. (No. 19). Oslo:Unipub.

Wells, G. (1999). Dialogic inquiry. Towards a sociocultural practice and theory of education. Cambridge: Cambridge University Press.

Wells, G. (2008). Learning to use scientific concepts. *Cultural Studies of Science Education, 3*(2), 329-350.

Wertsch, J. V. (1991). *Voices of the mind: a sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

White, B. Y., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: making science accessible to all students. *Cognition and Instruction, 16*, 3-118.

Wray, D. (1985). *Teaching Information Skills through Project Work.* Newcastle upon Tyne: Hodder and Stoughton.

# The Studies

# Study I

Furberg A., & Ludvigsen S. R. (2008)
Students' meaning-making of socio-scientific issues in computer mediated settings: exploring learning through interaction trajectories.
*International Journal of Science Education 30*, 1775-1799

# Study II

Furberg A., & Arnseth H. C. (2009)
Reconsidering conceptual change from a socio-cultural perspective:
analyzing students' meaning making in genetics in collaborative learning activities.
*Cultural Studies of Science Education 4*, 157-191.

# Study III

Furberg, A. (in press)
Sociocultural aspects of prompting student reflection
in Web-based inquiry learning environments.
*Journal of Computer Assisted Learning*.
DOI: 10.1111/j.1365-2729.2009.00320.x