Lab work in science education:
Instruction, inscription, and the practical achievement of understanding
LAB WORK IN SCIENCE EDUCATION

Instruction, inscription, and the practical achievement of understanding

OSKAR LINDWALL
At the faculty of Arts and Science at Linköping University, research and doctoral studies are carried out within broad problem areas. Research is organized in interdisciplinary research environments and doctoral studies mainly in graduate schools. Jointly, they publish the series Linköping Studies in Arts and Science. This thesis comes from the Department of Theme Research, Program of Communication Studies.

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ABSTRACT

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Taking an analytical perspective founded on ethnomethodology and conversation analysis, the four studies presented in this thesis provide detailed analyses of video recorded lab work in mechanics at secondary and university level. The investigated activities all build on educational designs afforded by a technology called probeware. The aim of the thesis is to investigate how teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical achievement of understanding in the setting. The first study investigates how students use the technology in the interpretation and production of graphs: how they produce increasingly precise interpretations, how they fluently switch between different modes of meaning, and how the interpretations are both prospectively and retrospectively oriented. With a starting point in the analysis, the relevance of technology and task structure for the students’ interaction and learning are discussed. In the second study, the use of probeware is contrasted with the use of a simulation software. The study shows that some important differences between the local enactments of the two technologies are to be found in the practical work of the students; more specifically, in the ways that students orient to the subject matter content. The third study demonstrates an intimate interplay between how students display their problems and understandings and how instructors try to make the subject matter content visible and learnable. The analyzed episodes are illuminating with regard to the analytical notion of disciplined perception as applied to graph interpretation, the cognitive and practical competencies involved in producing, recognizing, and understanding graphs in mechanics, and the interactive work by which these competencies are made into objects of learning and instruction. The fourth study investigates episodes where explicit references to students’ understanding are made through formulations such as, “I don’t understand” or “do you get it?” The analysis focuses on the use, reference, interactional significance, and positioning of these formulations, and is followed by a discussion on the relation between the many and varied ways references to understanding are used and the concrete conditions of lab work. In sum, all four studies contribute to a detailed understanding of lab work as an educational practice and how learning and instruction are practically achieved.
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Part One

LAB WORK IN SCIENCE EDUCATION
CHAPTER 1

INTRODUCTION

The aim of this thesis is to explicate and discuss some ways in which lab work, Newtonian mechanics, and student understanding become “visibly-rational-and-reportable-for-all-practical-purposes” (Garfinkel, 1967, p. vii). Four empirical studies provide detailed analyses of video-recorded lab work in science education, with a focus on how teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical achievement of understanding in the setting. In the studies, a number of research questions related to the overarching aim are addressed, including: What does it take to see a conceptual construct such as Newtonian force in a graph? What counts as having understood a lab task? What are the differences between claims and displays of understanding? What is the relation between the ways a teacher makes the conceptual realm of physics visible and learnable and the ways students present their problems and understandings?

The formulation visibly-rational-and-reportable-for-all-practical-purposes is taken from ethnomethodology, which is the tradition that provides the thesis with its analytical approach. In order to clarify the aim of the thesis and the sense of this formulation, the chapter begins with a short explication of some ideas, insights, and research policies taken from this tradition. As stated by Lynch, Livingston and Garfinkel, an “overriding preoccupation in ethnomethodological studies is with the detailed and ob-

1 While this section focuses on what the notion of visibly-rational-and-reportable-for-all-practical-purposes might mean when applied to science and science education, the next chapter provides a general outline of ethnomethodology.
servable practices which make up the incarnate production of social facts, for example, order of service in a queue, sequential order in conversation, and the order of skillfully embodied improvised conduct” (Lynch, Livingston, & Garfinkel, 1983, p. 206). What these studies repeatedly show is that social activities—including those commonly treated as intellectual—are produced so as to display their recognizable orderliness. One consequence of this, central to this thesis, is pointed out by Edwards, “It is an intrinsic feature of cultures that the way they work is learnable. This requires that discursive and other cultural practices are, in the ethnomethodological sense I have been using, ‘visible’” (1997, p. 297). An initial example of social activities’ exhibited and recognized orderliness can be found in the formatted queue.

The members of a queue position themselves, enter the queue at its exhibited end, witnessably inspect the order of the queue, distance themselves from each other, advance in observably regular ways, and orient their bodies therein to show, and showing, who is after whom, where the queue is going, where the end of the line is, who is in the queue, who is not, and who may just be visiting. (Livingston, 1987, p. 12)

How the queue is produced, that is, how the order of the service becomes “ongoingly coherent and certain” (Garfinkel & Livingston, 2003, p. 21), is also how the queue becomes recognizable as a queue. Queue members produce the order of the service in and through the ways in which they witnessably position themselves in the line. They are therefore able to answer numerous inquiries about the queue—who is next in line, where the line starts, and so on—by examining the embodied positions of the queue’s members. Being able to answer such inquiries is in fact to be able to produce the order of the queue.

Even when someone acts in seemingly disorderly ways, for instance, by butting in line, it is “disorderly in that it is done against the background of witnessed orderliness of a queue as that orderliness is recognized by all the participants involved.” (Livingston, 1987, p. 15) Since the disconcerting person is seen just as one that butts in line, this display of deviant behavior

2 Formatted queues and their *phenomenal field properties of order* are a recurrent topic in ethnomethodological texts (e.g., Francis & Hester, 2004, pp. 91-95; Garfinkel, 2002, chapter 8; Garfinkel & Livingston, 2003; Laurier, Whyte, & Buckner, 2001; Livingston, 1987, chapter 4; Lynch & Sharrock, 2003, pp. XXVI-XXVIII).
is nevertheless recognizable as a queue-relevant and queue-specific action and therefore as part of the orderliness of the queue. Standing in line, like any other social activity, is reliant on an array of visual, interactional, and embodied competencies. Commonly, these order-productive competencies are taken for granted—they are “seen but unnoticed” (Garfinkel, 1967, p. 41). When someone butts in line, however, the competencies are brought to the surface.3 The butting witnessably calls for a remedial action—it makes it relevant to further highlight the orderliness of the queue and to topicalize and show the competencies involved in producing this order.

Notwithstanding the occasional person butting in line, most adults know how to stand in line and know how to recognize, acknowledge, and report the order of a formatted queue. In contrast, the competencies involved in doing science—in producing a mathematical proof (Livingston, 1986, 1999, 2000), discovering an optical pulsar (Garfinkel, Lynch, & Livingston, 1981; Koschmann & Zemel, 2006), or excavating an archaeological field site (Goodwin, 1994, 2000a, 2000b)—are only mastered by a few. Discovering an optical pulsar or unearthing a pre-historical village necessitates competencies in the proper use of certain technologies, techniques, and languages—competencies that are not readily available or easily accessible to people outside specialized scientific communities. Without such competencies, one is not only incapable of partaking in the scientific practices, but also unable to see and say what members are mathematically, astrophysically, and archeologically doing.

Still, these practices are no less produced so as to display their recognizable orderliness for competent members than are service lines or other mundane activities. Just as the queue must be formed and recognized as

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3 When someone deliberately disrupts a situation like this for research purposes, it is sometimes referred to as a breaching experiment (Garfinkel, 1967, pp. 38-47). As Crabtree (2004) points out, a common misunderstanding is that breaching experiments are used by ethnomethodologists to create uncertainty or anxiety in order to question the everyday structures of practical action for ideological purposes. The ethnomethodological use of breaching experiments should rather be seen as “aids to a sluggish imagination” (Garfinkel, 1967, p. 38), which “make whatever accountable structures of practical action are at work in a setting visible and available to reflection, and so raise them as essential topics of inquiry (essential in the sense that whatever the topics turn out to be, they are endogenous to the setting, they belong to it, are constitutive features of it and so, are indispensable).” (Crabtree, 2004, p. 203)
a queue in order to get its legitimacy as that queue, so must the scientific
discovery be done as an adequate demonstration and be recognized as
such by a scientific community in order for it to gain legitimacy as that
discovery. One way of expressing this—how findings as well as activities
are produced so as to display their recognizable orderliness—is in terms of
accountability. In the day-to-day activities of scientists, accountability works
on many levels.

Persons can be accountable to external institutions, such as government
agencies or scientific disciplines, at the same time that they are account-
able to the expectations of their colleagues with regard to normal work-
place procedures. Persons are constantly accountable for their produc-
tion of recognizable talk and movements, even while they are managing
institutional levels of accountability. Finally, they can also, and at the
same time, be accountable to the properties of natural phenomena (as
in scientific experiments), which may refuse to cooperate in produc-
ing an accountable display for colleagues. (Rawls, 2003, pp. 38-39)

In relation to the accountability of the formatted queue, the work of scien-
tists is considerably more complex: it includes a “network of contexts of ac-
countability at various levels of social organization” (ibid, p. 38), all requir-
ing a wide range of specialized competencies that commonly take years to
master. As the social existence of scientific phenomena are “essentially tied
to the professionally accountable methods of producing its accountably de-
monstrable features” (Livingston, 1987, p. 63), many of these competencies
are directly related to the issue of how to produce facts and findings so that
they display their recognizable orderliness. In order to render phenomena
recognizable as phenomena of a specific sort, inscriptive practices have to
be matched against “socially organized ways of seeing and understanding”

4 Proponents of traditions focusing on cultural practices—including pragmatist philoso-
phers (e.g., Rorty, 1979) and social constructivists (e.g., Shotter, 1993)—have problema-
tized the term representations because of its connotations associated with representationalist, picture theories of language (e.g., Wittgenstein, 1922/1961) and mentalist theories of learning and cognition (e.g., Chomsky, 1988; Fodor, 1975; Larkin & Simon, 1987; Marr, 1982). Related to this, alternative terms such as renderings (e.g., Garfinkel, 2002; Ivarsson, 2004) and inscriptions (e.g., Latour & Woolgar, 1986; Roth & McGinn, 1998) have been adopted as alternatives to the term representations, where the latter refer to “any set-up, no matter what its size, nature and cost, that provides a visual display of any sort in a scientific text.” (Latour, 1987, p. 68)
(Goodwin, 1994, p. 606). Since the optical pulsar and the historical village are not there to be seen with one’s naked eye, scientists are constantly faced with the "problems of how to transform 'invisible' phenomena and 'noisy' data into diagrams, graphs, photographs, micrographs, maps, charts, and related visual representations" (Lynch, 1991, p. 2). Both the production and interpretation of inscriptions, moreover, are contingent on the competent use and understanding of specialized tools. The interpretation of an X-ray image, for instance, "involves not only knowing anatomy, pathology, and so forth but also having an awareness of what is visible and invisible to the device and how idiosyncratic limitations of the tool produce visual traits to be ignored" (Nemirovsky, Tierney, & Wright, 1998, p. 125). In addition—and despite "the popular belief of this past century that scientific language is simply a transparent transmitter of natural facts" (Bazerman, 1988, p. 14)—the adequate writing of experimental reports requires a high degree of discursive and rhetorical competencies. Thus, in the day-to-day work of scientists, an assortment of inscriptive, technological, discursive, and visual competencies are required for making the work and potential findings accountable, or, to recapitulate the expression found in the introducing section, for making activities, facts, and phenomena visibly-rational-and-reportable-for-all-practical-purposes.

While it is generally agreed that the production, interpretation, and use of models, graphs, diagrams, and other renderings are constitutive for scientific activities, such visual and inscriptive practices "are also among the fundamental elements of scientific learning underlying the science education standards" (Wu & Krajcik, 2006, p. 64). There are many parallels between the work conducted by scientists and that done in the school science laboratory. Students too have to write reports, transform “invisible”

5 In recent decades, sociocultural approaches to learning and development (e.g., Säljö, 1999, 2005; Vygotsky, 1978, 1986; Wertsch, 1991, 1998) have gained increased recognition within the educational research community. As a result, there has been a growing interest in the role of tools—sometimes referred to as artefacts or mediational means—in human development, both socio- and ontogenetically. In these traditions, the terms are used very broadly and usually include both visual inscriptions—graphs, maps, and tables—and the inscription devices (Latour, 1987, p. 68) that produce them. In this thesis, graphs, tables, maps, and so on are alternately referred to as inscriptions, visual representations, and renderings, while the terms tools and artefacts are reserved for inscription devices and other apparatus.
phenomena and “noisy” data into various inscriptions, and in this process discern what is relevant data from the visual traits to be ignored. In fact, these similarities—and the related potential of providing students with practical experiences of scientific practice, including scientific inquiry—are often referred to as the main merits of lab work in science education (cf. Lunetta, 1998; Lunetta, Hofstein, & Clough, 2007; Trumper, 2003).

Of course, there are also central differences between the production and interpretation of inscriptions as part of scientific work practices and the production and interpretation of inscriptions in the lab work of science education. In the discovery of an optical pulsar, for instance, the astronomers have to make sense of what the instruments are showing, determine if there is in fact something there to be seen, decide what adjustments should be made in order to make this potential something less vague, and coordinate their perceptions so as to witness the same thing—all the time without really knowing if the outcome of their work will turn out to be a finding at all (cf. Garfinkel et al., 1981; Koschmann & Zemel, 2006). In contrast, when students are doing a lab assignment and are unable to see anything relevant in the visual inscriptions they have produced, they can generally take a number of things for granted: that they are supposed to see something, that this something is supposed to be recognizable and understandable, that the instructor knows the answer, and that they may ask him or her for help and guidance.

Sometimes, the differences between the practices of science and education have been brought up in order to criticize classroom science for being mock-ups (e.g., Atkinson & Delamont, 1976) or lacking authenticity (e.g., Brown, Collins, & Duguid, 1989; Roth, 1995, 1997). Although this critique of education might be grounded in sound and progressive efforts to improve education, it is important to note that the science taught and demonstrated in classrooms is necessarily different from that of “authentic” science, since it “is designed to be demonstrated on occasions built of the various organizational contingencies inhabiting the school setting” (Lynch & Macbeth, 1998, p. 273), making it problematic to “presume that a correct or authentic version of physics can provide a backdrop for characterizing the classroom situation.” (ibid.) If social activities are produced so as to be visibly-rational-and-reportable-for-all-practical-purposes, moreover, the practical purposes clearly differ between the tasks and practices of scien-
tists, teachers, and students. Even though students, by being involved in some sort of inquiry, might make discoveries for themselves and thereby learn something new, their findings do not qualify as scientific discoveries and they are not published for scientists to read. Thus, whereas students and teachers are involved in activities where the use, interpretation, and production of scientific inscriptions are central, these practices are necessarily different from those found in “real” science labs; in particular, they are not aimed at the production of scientific facts so much as towards the achievement of understanding among students.6

As stated at the beginning of this chapter, the aim of the thesis is to investigate how teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical accomplishment of understanding in the setting. While scientists have to produce inscriptions that are recognizable and intelligible to fellow scientists, it is the “distinctive task and competence of teachers to produce the coherence of their lessons as public coherences, coherences that can be found from any chair in the room.” (Macbeth, 1994, p. 320) Teachers have to design lectures, experiments, and demonstrations in ways that make it possible for the students to see and discern relevant phenomena, despite these students’ limited mastery of the proper use of relevant technologies, techniques, and languages. In these activities, there is a “teleological orientation to a progressive cultivation of a scientific way of seeing and speaking” (Lynch & Macbeth, 1998, p. 270), which is “evident both in the progression of exercises from one grade to the next and in the teacher’s efforts to correct the students’ ordinarily adequate ways of explaining what they see in situ.” (ibid.) This orientation can also be seen among students, who are accountable for actively participating in these activities—by listening to lectures, completing lab assignments, and doing exams—and for developing, displaying, and sustaining an understanding of both activities and subject matter content. Exactly how lab-work and student understanding become visibly-rational-and-reportable-for-all-practical-purposes, and how teachers and students orient towards the progressive cultivation of a scientific way of seeing and speaking, are shaped by the specific technologies, techniques, and subject matter knowledge involved.

6 Other unavoidable differences include issues of scale, timing, division of labor, witnessability, competence, equipment, cost, and safety (cf. Lynch & Macbeth, 1998).
MECHANICS AND EDUCATIONAL TECHNOLOGY

In the four empirical studies reported in this thesis, educational activities in which students use a technology called probeware to carry out lab assignments in mechanics are investigated. Whereas the previous section explicates a background to the analytical interest of the thesis, it does not provide a motive for investigating this particular kind of setting. The reasons for the selection can be traced to another tradition with a different literature, aim, and agenda. More specifically, they emanate from research on science education, an interest in students’ problems when trying to learn mechanics, and the different pedagogical innovations designed and employed to address these problems. By presenting an overview of a small part of this research, this section provides an alternate background to the thesis.

Mechanics is a branch of physics concerned with the motion, as well as the interactions causing motion, of physical objects. The scientific roots of mechanics can be traced back to Aristotle’s (384-322 BC) writings about natural and unnatural motion. Among the important historical contributors, one also finds the medieval philosopher Buridan (1300-1358) who founded the so-called impetus theory. According to this theory, the act of setting an object in motion creates an internal force or impetus that maintains the motion of the object until it gradually fades away and the object comes to a stop. The theory was popular for several centuries and was supported by Galileo (1564-1642) in his earlier work. After Newton (1643-1727), however, the medieval impetus theory has lost ground in the scientific community. As the well-known philosopher and historian of science Thomas Kuhn points out:

The vocabulary in which the phenomena of a field like mechanics is described and explained is itself a historical product, developed over time, and repeatedly transmitted, in its then-current state, from one generation to its successor. In the case of Newtonian mechanics, the required cluster of terms has been stable for some time and transmission techniques are relatively standard. (2000, p. 11)

Although Newtonian mechanics might seem like a stable and unproblematic conceptual domain from the vantage point of an historian of science, this does not necessarily mean that it is uncomplicated to teach and learn the subject. Both science educators and researchers of science education generally treat mechanics as an important, basic, but challenging subject. A vast number of studies have demonstrated students’ difficulties with central concepts in mechanics, such as force, velocity, acceleration, and impulse. In the literature, these difficulties are often related to students’ prior understandings of the concepts; for instance, it is claimed that our everyday experience of force and motion “is of little help in coming to an understanding of what Newton meant by the laws of motion” (Lindström, Marton, Ottosson, & Laurillard, 1993, p. 12). A common argument is that students’ “surprisingly extensive theories about how the natural world works” (Resnick, 1983, p. 477) can be compared to the theories found in the history of science, since “the real world, that is to say, the practical world of everyday experience, is, to a large extent, an Aristotelian world” (Garrison & Bentley, 1990, p. 20). The historical analogy is also used when students are held to reason in ways parallel with the medieval impetus theory (Clement, 1982, 1983; Fischbein, Stavy, & Ma-Naim, 1989; Halloun & Hestenes, 1985) and when parallels are drawn between students’ learning and the paradigmatic shifts found in the history of science (cf. Driver & Easley, 1978; Garrison & Bentley, 1990; Vosniadou & Brewer, 1987).

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8 Newtonian mechanics are sometimes referred to as classical mechanics and, as the term indicates, there are more recent versions. Using Newtonian mechanics, it is possible to produce adequate approximations of the behaviour of objects in a rather wide range of situations—from molecules to planets. For systems moving at high velocities, however, relativistic mechanics has taken its place, and for phenomena at atomic and sub-atomic level quantum mechanics is used. In this thesis, and if not explicitly stated otherwise, the term mechanics is used for the Newtonian version.

9 An all-encompassing review of this literature would have to cover hundreds of studies (for reviews of some of the more influential studies, see: Driver, 1989; Hestenes, Wells, & Swackhamer, 1992; McDermott, 1984; McDermott & Redish, 1999; Smith, diSessa, & Roschelle, 1993). There is also the associated literature that focuses on students’ problems in interpreting and producing graphs representing force and motion (e.g., Beichner, 1994; Leinhardt, Zaslavsky, & Stein, 1990; McDermott, Rosenquist, & van Zee, 1987; Roth & McGinn, 1997).

10 Greiffenhagen and Sherman point out that some uses of this analogy suggest “that pupils are akin to scientists (engaged in building explanations of the natural world) and
It could hardly be expected of students that they should know mechanics before they have been instructed—that would make the education superfluous. What is considered problematic, however, are the numerous studies showing that traditional instruction does not help students to acquire a sufficient understanding of the subject (e.g., Hestenes et al., 1992; Thornton & Sokoloff, 1990). The conjectured reasons for this are manifold. Some researchers hold that concepts in mechanics are hard to learn because students’ initial understandings are deeply rooted in practices outside school where the concepts have different meanings (e.g., Clement, 1983; Kuhn, 2000; Resnick, 1983; Ueno, 1993). Another common argument is that the abstract and formal nature of science, as it is presented in lectures and textbooks, makes it hard to connect phenomena with representations (Confrey, 1990; Roth, McRobbie, Lucas, & Boutonne, 1997). It is also claimed that teachers are unaware the extent of students’ difficulties and the lack of impact of their own teaching. Based on a vast number of empirical cases, Hestenes concludes that there is a huge gap between what teachers think they are teaching and what students are actually learning about mechanics, “not only is physics instruction frequently failing to address student misconceptions, it often inadvertently strengthens them and induces new ones.” (1998, p. 466)

In order to address this problematic situation, several educational innovations have been designed, employed, and evaluated (e.g., Laws, 1997b; McDermott, 1998; Sokoloff, Thornton, & Laws, 1997, 1998; Thornton, 1995; Thornton & Sokoloff, 1990). Among these, one finds probeware, the technology that is used in the labs investigated in the empirical studies. While the term probeware is rather new, the use of this technology in science classrooms began shortly after the introduction of computers into schools. The first probe to be used was a motion sensor that collected data concerning the position and motion of objects. The motion sensor was connected via an interface to a computer, and the interface registered the time interval between transmission of pulses and reception of echo, making

that what pupils know, their common-sense knowledge of the natural world, has the same ‘purpose’ or ‘aim’ as a scientific theory.” (2008, p. 3) They consider this highly misleading, since what scientists do is very different from what students do, which is something “no curriculum or pedagogy can change.” (ibid.) As indicated in the previous section, this is also the position taken in this thesis.
it possible for the software to calculate the position, velocity, and acceleration of the object causing the echo. Any of the calculated quantities could then be displayed immediately in the form of a graph on the computer screen. Nowadays, more than forty different probes exist for measuring light, force, temperature, and so on.

Probeware has garnered a great deal of attention since it is frequently shown that participation in activities afforded by the technology results in better gains on post-tests than participation in other activities, including traditional labs, lessons, and simulations (e.g., Laws, 1997a; Thornton, 1997; Tinker, 1996). Some authors even claim that probeware is the only technology used in science instruction with proven educational effects (Euler & Müller, 1999). Others similarly hold that it is the “single most important educational innovation enabled by microcomputers” (Gobert & Tinker, 2004, p. 2), or “the most promising of all educational computing tools” (Weller, 1996, p. 472). Of course, the technology in itself does not provide an adequate learning environment. As several researchers point out, the use of probeware needs to be combined with “curriculum design and careful considerations of instructional strategies” (Nakhleh, 1994, p. 376) in order to obtain good learning results. This issue has also been addressed in empirical research. By administrating pre- and post-tests in several introductory level mechanics courses, Bernhard (2003) found significant differences between labs where probeware was employed as “interactive-engagement activities,” which guided students through inquiry focused on conceptual issues, compared to labs where the technology was used in more “traditional” ways, in which students were instructed to verify textbook equations by following a “step-by-step recipe.”

According to Bernhard, it was primarily different teachers’ conceptions of learning and teaching, embodied in instructions and task design, that explained the difference between the labs. Exactly how instructions and task design influenced the students’ ways of working in the lab, and how this connected to the increased learning outcomes, was not reported in the study. In fact, given the methodological approach, these issues could not be investigated. As Berger et al. put it: “even the best pre-post and randomized designs” cannot provide an “understanding of what is going on while students are learning using instructional technology” (1994, p. 476). In a similar way, Goldman notes that “quantitative studies often provide
researchers with assessments and global predictions, but do not aim to explain the inside story—the meaning that people ascribe to the events they experience in learning environments.” (2007, p. 25)

Thus, when educational interventions are examined by means of standardized tests before and after instruction, what is going on inside the walls of the classroom laboratories often becomes black boxed\textsuperscript{11}. In order to gain a further understanding of the activity, addressing some of the differences that make a difference between probeware and other activities, it is thus rewarding to open the black box and to examine what is going on in activities were students use the technology. The metaphor of opening the black box is used by Roschelle (1991) to characterize an approach where detailed analyses of video recordings are used in order to investigate the “nature of qualitative understanding and associated learning processes in the context of a computer simulation” (p. 2). At the time of its publication, this was a rather new approach to the study of computer use in science education. Since then, however, the use of video to examine learning environments has increased dramatically (cf. Goldman, Pea, Barron, & Derry, 2007; Kelly, 2007; Roth, 2005), and includes studies of lab work (Ford, 1999; Roth, 1999; Roth, McRobbie, Lucas, & Boutonné, 1997), the production and interpretation of graphs and other inscriptions (Cobb, Yackel, & McClain, 2000; Roth & McGinn, 1997), and the use of probeware (Nemirovsky, 1994; Nemirovsky & Noble, 1997; Nemirovsky et al., 1998; Russell, Lucas, & McRobbie, 2003). The empirical studies in this thesis—in their attempts to open the black box and answer questions about “what is going on” while students use probeware—are contributions to this literature.

By investigating students’ collaborative use of educational technology, the thesis can also be seen as a contribution to the field of computer supported collaborative learning, usually referred to by its acronym CSCL. This field is commonly seen as a reaction to the individualistic tendencies associated with early efforts to use computers in education, although the background to this reaction and what it implies in terms of research vary between different accounts of CSCL (cf. Arnseth & Ludvigsen, 2006; Jones, Dirckinck-

\textsuperscript{11} According to Latour, the word black box was initially used in cybernetics “when-ever a piece of machinery or a set of commands is too complex. In its place they draw a little box about which they need to know nothing but its input and output” (Latour, 1987, pp. 2–3).
Holmfeld, & Lindström, 2006; Koschmann, 1996b; Koschmann, Hall, & Miyake, 2002; Stahl, Koschmann, & Suthers, 2006). Koschmann (1996a), for instance, points to the influence of disciplines outside psychology—such as anthropology, sociology, linguistics, and communication—and identifies socially oriented constructivist theories, sociocultural theories, and theories of situated cognition as particularly important for the “paradigmatic” shift of CSCL. Even though he also discusses the increased interest in the educational implications of students collaborating with technology, the emphasis is placed on theoretical, analytical, and methodological developments. Lehtinen et al. (1999), on the other hand, focus on the strengths of collaborative group work—as has been shown in cooperative learning research, which is primarily conducted with methods taken from social and developmental psychology (cf. Slavin, 1995)—and how the use of technological applications can be used to facilitate collaboration and distributed teaching. Taken as descriptive accounts of the research presented at conferences and journals, the two reviews are complementary and point to the heterogeneous character of the field. With its specific aims and methods, this thesis belongs to a branch of CSCL research that take ethnomethodology to be “a useful disciplinary foundation for building a systematic and rigorous program of video-analytic research related to design experiments.” (Koschmann, Stahl, & Zemel, 2007, p. 135)

ETHNOMETHODOLOGY AND DESIGN–BASED RESEARCH

Commenting on innovation in educational research, Macbeth notes that this field has traditionally “borrowed its methods from the disciplines (from psychology, history, linguistics, anthropology, and sociology)” (2003, p. 241). In the last few years, methods and metaphors taken from additional disciplines have been brought to bear on educational contexts and problems. Using insights from design and engineering, proponents of design-based research commonly emphasize the complexity of educational activities and the need for both theory and tinkering for educational designs to work.12 Whereas educational theory and design have informed each other

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12 Design–based research can be seen as one side in a debate on evidence–based education; that is, how educational research should contribute to improving education and influencing policy decisions. On the other side of the debate, proponents of experimen-
for more than a century, the notion of design-based research or design experiments is relatively new, and often attributed to the works of Brown (1992) and Collins (1992). Although displaying a considerable methodological and theoretical breadth, two characteristics are shared by most design-based research projects. The first thing is that such projects attempt to provide analyses and theories that have the potential of doing “real work in practical educational contexts” (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 13), while still being able to “address the complexity that is a hallmark of educational settings” (ibid, p. 9). The second thing is that the projects include separable but interlinked phases; more specifically, they are conducted “through continuous cycles of design, enactment, analysis, and redesign” (The Design-Based Research Collective, 2003, p. 5).

The empirical studies reported on in this thesis have been conducted within a design-based research project aimed at investigating and improving educational activities in science education. In this project, teachers and researchers have jointly investigated educational activities in cycles of...
design, enactment, analysis, and redesign. By opening the black box, and addressing questions about what is going on in the activities investigated, the use of video in examining the educational activities has had a both natural and useful role in the project. Still, a critical issue has been how the descriptive and explicative rationale of ethnomethodology is to be combined with the formative and prescriptive rationale of design and improvement. As pointed out by Dourish and Button, the tradition of ethnomethodology is one of “analyzing practice, rather than ‘inventing the future’” (1998, p. 412). How, then, can ethnomethodologically informed video analysis become usable in the context of design-based research, without losing its distinguishing analytical agenda?

In a text on the implications of ethnomethodological policies for design-based educational research, Koschmann, Stahl, and Zemel argue that the issue of design and analysis should be “treated as distinct, at least logically, if not in terms of specific team member responsibilities.” (2007, p. 142) One way of keeping these issues separate—in a manner that still addresses the relevance of ethnomethodological analyses to educational design—is suggested by Heap:

To do applied ethnomethodology, we must do ethnomethodology: address our version of the social order problem. But in deciding what social orders (activity structures) to study we are led by our (acculturated) sense of what is important, educationally, to study. (1987, p. 241)

In the approach outlined by Heap, the interests and rationales of ethnomethodology and education are kept distinct by influencing different phases of the project: while educational concerns are important in deciding what to study, an ethnomethodological agenda is kept throughout the analysis. In design-based research, the tension between the rationales of description and design then re-emerges in a third phase, when results are to be used in evaluations and for improvement. Whereas the relation between ethnomethodology and design is underexplored in the field of educational research, there are fields where the connection between ethnomethodological research and design has been discussed more extensively (e.g., Button, 2000; Crabtree, 2003; Heath & Luff, 2000; Suchman, Blomberg, Orr, & Trigg). In the context of workplace studies and system design, for instance, Dourish and Button describe one common way of
working, which keeps analyses and design distinct through a division of labor between the ethnomethodologists and the designers:

Ethnomethodologists are sent into the field and return brimming with observations and an analytic frame within which to interpret them. These observations become requirements for the system design process, more or less formally. The ethnomethodologists typically also will be involved in the ongoing evaluation of design alternatives, acting as proxy for the end-users, or, perhaps more accurately, as proxy for the work setting itself. (1998, p. 408)

Despite the potential use of ethnomethodological studies in situations like this, the most important task for ethnomethodology in design projects might not only, or even primarily, be to provide input to particular projects. As noted by Heath and Luff, “in the longer term their contribution may well be more profound, providing a corpus of findings and conceptual (re)specifications” (2000, pp. 228–229). In line with this suggestion, the empirical studies in this thesis do not report on the formative observations and evaluations of the design-based research project. Instead, the studies add to a corpus of empirical findings by focusing on how teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical accomplishment of understanding in the setting. In accordance with the proposal made by Heath and Luff, the thesis also aims to “question the cogency of some of the theoretical assumptions” (ibid.) that have traditionally informed educational research—especially with regard to the relation between technology, interaction, and learning.

OVERVIEW OF THE THESIS

The thesis is divided in two parts, where the first part provides an introduction and the second part consists of four empirical studies. In the next chapter, the analytical approach of the thesis is described and discussed. The chapter begins with the proposal that there has been an interactional turn in educational research, and the first section starts out by providing an outline of this turn. In the following section, three ways of transforming video recordings into analytical accounts are presented, focusing on the aims, rationales, and type of claims made, thereby delineating the ethnomethod-
logical approach taken in the thesis in relation to other possible ways of analyzing recorded material. Chapter 3 begins with a short description of the organization of the design-based research project. This is followed by a discussion of the methods used and issues concerning the recording, analysis, and transcription of the video material. Chapter 4 consists of summaries of the four empirical studies presented in this thesis. Chapter 5 presents a short concluding discussion, focusing on issues concerning instruction, inscription and the practical achievement of understanding.
In the previous chapter, the aims and interests of the thesis were formulated, and some reasons for making detailed investigations of video-recorded lab work were provided. In this chapter, the analytical approach of the thesis is presented and delineated in relation to other potential ways of analyzing recorded interaction. A starting point for the chapter is what Erickson considers a substantial development in the field of educational research.

There is an interactional turn in educational research; a recognition that research phenomena of substantive and policy interest are interactionally constituted: for example, learning and teaching of subject matter in schools; morale of students and school staff with regard to their everyday work life in school (as alienated from their work or affiliated with it); informal relations among students—including clique formation, bullying, and interethnic relations; parent and school staff relations; and learning outside school across the life span in home, community, and work settings. All these phenomena take place in concrete occasions of social interaction as sites for educative experience. (2006, p. 177)

The turn Erickson describes can be seen as a gradual development that has been taking place since the late 1960s. Some of this research has emerged parallel with the establishment of several original traditions in social science; in particular, *ethnomethodology* (Garfinkel, 1967, 1972), *conversation analysis* (Sacks, Schegloff, & Jefferson, 1974), *interactional sociolinguistics* (Gumperz, 1964), and *the ethnography of speaking* (Hymes, 1964). At the time, the influence of these traditions was especially prominent in relation to research focusing on *educational decision-making* (e.g., Cicourel et al., 1974; Mehan,
Hetweck, & Meihls, 1986) and classroom order (e.g., Hargreaves, Hester, & Mellor, 1975; McHoul, 1978; Mehan, 1979a).¹ By making detailed studies of classroom interaction, issues of both academic and social relevance were highlighted. Studies of questions-answer sequences in schools, for instance, have demonstrated the inherent complexities in educational patterns of communication, sometimes suggesting the possibility of miscommunications and misunderstandings due to differences in cultural expectations (e.g., Erickson & Mohatt, 1982; Heath, 1982, 1983; Mehan, 1979a).²

Sociological and sociolinguistic traditions have also been influential in work that focuses on the different functions of language in classrooms (e.g., Cazden, 1986; Cazden, John, & Hymes, 1972; Mehan, 1979a). This interest is shared with studies that have their roots in educational research and efforts to improve schooling and student learning (e.g., Barnes, 1976; Barnes & Todd, 1977; Edwards & Westgate, 1986). By characterizing different communicative patterns, extensive lists of techniques used by teachers have been created. Mercer (2004, p. 145), for instance, lists three general types, each including a number of sub-categories; eliciting knowledge from learners, either directly or cued; ways of responding to what learners say, by means of confirmations, repetitions, elaborations, and reformulations; and ways of describing significant aspects of shared experiences, such as, “we” statements, literal recaps, and reconstructive recaps. Similarly, the talk among students is divided into categories such as disputational, cumulative, and exploratory talk (e.g., Fisher, 1992, 1997; Mercer, 1995, 2000). Important to this work are also so-called communicative rights and educational ground rules (Edwards

¹ Among these studies, Hugh Mehan’s Learning Lessons has been particularly influential. According to Macbeth, this book, “both marked and expressed a new promise for classroom studies, and was largely received that way as well. Much as we see in the more recent influences of activity theory and discourses on the postmodern, the programmatic initiatives of Learning Lessons were quickly recognized, taken up, and extended by a larger community. It promised, and I think faithfully so, to begin dismantling the ‘black box’ of classroom pedagogy that had been both the object and enabling premise of a prior generation of instructional research.” (2003, p. 240)

² In a retrospect remark, Goldman and Segal argue that these studies frequently aimed “to defend children, particularly minority children, against the capacities of schools to label and disable their relation to schoolwork” (2007, p. 111). The authors doubt, however, that the research ideologically, institutionally, or politically “resulted in general ways to help schoolchildren” (ibid.), even though it provided important analytical insights and started a tradition of classroom research.
referring to the implicit norms that regulate the interactions between students and teachers—which are held to generate the familiar and distinctive patterns of educational interaction. The theoretical background of these studies is often taken from multiple sources; prominent among these have been the cultural-historical psychology of Vygotsky (1978, 1986) and the functional linguistics of Halliday and colleagues (e.g., Halliday, 1975, 1993; Halliday & Hasan, 1976). Regardless of theoretical background, it is possible to see a continuum between the researchers that primarily attempt to describe and characterize communicative patterns and those that aim to find a relation between the patterns and desired outcomes such as student learning.

Much of the research referred to in the last section deals with general patterns of classroom interaction that are independent of the particular subject matter content. Since the 1990s, however, “the importance of spoken and written discourse in the learning of disciplinary knowledge is becoming increasingly recognized as a salient research focus” (Kelly, 2007, pp. 443, emphasis added). One reason for this recognition can be found in an expanded view of learning—often attributed to situativity and sociocultural approaches to learning (e.g., Brown et al., 1989b; Lave, 1991; Rogoff, 1990; Wells, 1999; Wertsch, 1991)—which has affected both the science education community and the educational research community at large. Traditionally, research on the teaching and learning of science builds on an acquisition metaphor of learning (Sfard, 1998). Learning is conceived as the acquisition and gradual refinement of conceptual knowledge that results in increasingly rich cognitive structures—which is reflected in theoretical notions such as transfer, misconceptions, and conceptual change. It is a metaphor that lends itself to the practice of classroom teaching and assessment. It

3 Greeno and Moore introduced the term situativity theory as an alternative to situated cognition, since “the phrase situated cognition often is interpreted, understandably, as meaning a kind of cognition that is different from cognition that is not situated.” (1993, p. 50)

4 These concepts have a long history and a strong connection to classical work. Lave (1988) traces the use of learning-transfer to the work Thorndike (1913) and Judd (1908), while misconceptions and conceptual change are commonly associated with Piaget’s (1973) accommodation and Kuhn’s (1962) paradigm shifts (cf. Posner & Gertzog, 1982). Thousands of studies have since then used these notions to characterize students’ learning and understanding of science.
also fits well with methods of developmental psychology and educational psychology, including *clinical interviews* and *experimental designs*.

Parallel with the mainstream research on learning and instruction, ethnographers and anthropologists have been studying learning in settings outside formal schooling, such as apprenticeships among Mexican midwives (Jordan, 1989), Liberian tailors (Lave, 1977), and non-drinking alcoholics in the United States (Cain, 1991). The impact of these studies on research on science education would probably have been marginal if they had not been used to furnish new metaphors for learning. When leaving the classrooms and research labs, traditional ways of theorizing learning—in terms of transfer and conceptual change—are not that easily applicable. Therefore, other ways of conceptualizing learning have been introduced together with metaphors such as *changed participation in communities of practice* (Lave & Wenger, 1991; Wenger, 1998) and *apprenticeship in thinking* (Rogoff, 1990). Central to these approaches is the emphasis on the situated and contextual nature of learning and cognition. It is claimed that, “there is no activity that is not situated” (Lave, 1991, p. 33), and that, “learning and acting are interestingly indistinct, learning being a continuous, life-long process resulting from acting in situations.” (Brown et al., 1989b, p. 33) As pointed out by Rogoff, the emphasis on the contextual and situated nature is intertwined with a change in research questions. In this case, from questions addressing the nature and organization of knowledge in individual students, “What is stored? Where? How? What are the effects of external influence?” (1995, p. 154), to questions concerning the social organization and characteristics of a particular situation, “What activity is this? How does it relate to others? What are people doing? With what, and how, and why?” (ibid., p. 156)

These alternative theories, metaphors, and research questions have been picked up in studies aimed at investigating the interactional constitution of teaching and learning in science education. While situativity and sociocul-

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5 This quotation is taken from a text that started an intense debate in *Educational Researcher* between proponents’ of cognitive and situativity theories of learning (e.g., Anderson, Greeno, Reder, & Simon, 2000; Anderson, Reder, & Simon, 1996a, 1996b; Brown, Collins, & Duguid, 1989a; Brown et al., 1989b; Cobb & Bowers, 1999; Greeno, 1997), which had a major impact on educational theorizing in areas such as language, mathematics, and science education.
tural approaches have been fully adopted in some studies, they have mostly been integrated with other theoretical perspectives, particularly versions of constructivism. The emphasis on the situated and contextual nature of learning has also been influential in “reconsiderations of conceptual change” (Limón & Mason, 2002), for “rethinking transfer” (Bransford & Schwartz, 1999), when “misconceptions are reconceived” (Smith et al., 1993), and in attempts to “bridge cognitive and sociocultural approaches to research on conceptual change” (Mason, 2007). In addition, and as is common in educational research, the analytical insights have been turned into instrumental and didactical projects; for instance, by trying to make the learning more authentic or by structuring the learning situations in ways that resemble apprenticeship (e.g., Brown et al., 1989b; Roth, 1995; Roth & Bowen, 1995).

Leaving particular studies and traditions, the interactional turn described by Erickson can also be seen in light of the more general social, linguistic, and interpretative turns ascribed to the field of educational research as a whole. As noted by Macbeth, “with the discovery of social phenomena by a research community whose roots are abidingly psychological, a discourse of alternatives to our prevailing conceptualizations of social science and the social world has flourished” (1998, p. 137). In the formulation of the

6 In investigations of students’ understanding of science, most research aligns with some version of constructivism. In the literature, however, there is no consensus on what actually characterizes constructivism (cf. Cobb, 1994; Driver, 1995; J. Garrison, 1997; Gil-Pérez et al., 2002; Jenkins, 2000; Niaz et al., 2003; Phillips, 1995, p. 5). Some approaches are firmly rooted in academic disciplines, such as developmental psychology (e.g., Piaget, 1973) and philosophy (e.g., von Glaserfeld, 1979), whereas others have their origin in attempts to theoretically frame empirical results of students’ understanding of science (e.g., Strike & Posner, 1985) or from efforts to progressively transform education (e.g., White & Gunstone, 1992).

7 Of these three, the linguistic turn is the most established and discussed. The notion of a linguistic turn was initially used in philosophy and is commonly linked to Ludwig Wittgenstein’s later work. In the 1960s, it gained increased recognition in the humanities and the social sciences through a diverse set of theoretical positions and interests (cf. Rorty, 1967). In educational research, the linguistic turn is commonly associated with structuralistic and post-structuralistic theories and studies that investigate talk and classroom interaction (cf. Englund, 2006; Kelly, Chen, & Crawford, 1998; Lather, 1992). When social (e.g., Lerman, 2000) and interpretative turns (e.g., Howe, 1998) are referred to, it is often to contrast some current trends and approaches with the individualistic and quantitative approaches that have long dominated educational research.
alternatives, especially in textbooks on research methodology, it is com-
mon to use oppositional pairings: between the natural and social sciences,
positivism and interpretative approaches, or quantitative and qualitative
research (cf. Denzin & Lincoln, 1994; Mertens, 1997). Although contrast-
ing oppositional traditions for expositional and rhetorical purposes might
be rewarding in some contexts, this chapter does not go into these grand
dichotomies.

Instead, the rest of the chapter stays close to the issue of how one analyzes
video recordings of activities and phenomena that “takes place in concrete
occasions of social interaction.” (Erickson, 2006, p. 177) For educational
research, this issue is more important than ever. With widespread access to
cheap, user-friendly, and mobile recording and editing technologies, it has
become relatively easy and inexpensive for a research project to record a
substantial amount of classroom interaction. Whereas technology has be-
come a central resource for doing detailed analyses of interaction in edu-
cational settings, it does not automatically transform talk and actions into
analytically revealing accounts. Compared to the recording of the material,
the work of analyzing video can be surprisingly hard. Because of the diffi-
culties inherent in analytical work, the video recordings might “encourage
mundane opinions and biases” (Goldman & McDermott, 2007, p. 121).
The problem, however, is not one of technology, but of seeing something
interesting in everyday educational activities. As Becker recollects “I have
talked to a couple of teams of research people who have sat around in
classrooms trying to observe and it is like pulling teeth to get them to see
or write anything beyond what ‘everyone’ knows.” (1971, p. 10)

In the next sections, three ways of addressing this problem—three ways
of going “beyond what everyone knows”—are presented: coding, count-
ing, and correlating; looking through and beyond the interaction; and, explicating
the seen but unnoticed details.8 All the sections focus on the aim, rationale,

8 Of course, this is just one of numerous ways of portraying the field. Erickson (2006),
for instance, makes a distinction between six sub-fields: those that mainly focus on
subject matter content; studies informed by neo-Vygotskian theory; studies that code differ-
ent functions of classroom talk; work based on the premises of ethnomet hodology and
conversation analysis; an approach influenced by the ethnography of speaking, interactional
sociolinguistics, and discourse analysis in anthropology and linguistics; and an interdisci-
plinary approach that he labels context analysis. Edwards and Mercer (1987), in contrast,
make a distinction on disciplinary grounds, dividing classroom studies into linguistic;
and type of claims made. Whereas the third section outlines the ethnomethodological approach adopted in this thesis, the first two sections are presented and discussed in order to delineate and justify the approach chosen.

**CODING, COUNTING, AND CORRELATING**

One of the most common ways to analyze interaction, including classroom talk, has been to use some kind of *pre-established coding scheme*, often involving a system of mutually *exclusive* and *exhaustive* categories, which transforms the interaction into the coded categories.\(^9\) By doing this, interactional events are made statistically analyzable and surveyable. For a researcher, this might be one of the most evident ways of going beyond what “everyone knows.” The use of coding schemes has coexisted with the very earliest attempts to investigate interaction. In the 1940s and 1950s, Robert Freed Bales—an experimental social psychologist at Harvard—investigated the interaction in small groups by tape-recording experimental settings. The recorded tapes were coded in a set of twelve categories, such as explaining, summarizing, and asking for clarification (Bales, 1950). After the tapes had been coded, they were erased and reused; thereby making the frequency distribution of the coded categories and the variables they represented the primary data, leaving the “actual, recorded conduct as a kind of scientific detritus.” (Schegloff, 1996, p. 166)

This approach of coding interaction, sometimes known as *systematic observation*, was later adapted to educational research (e.g., Bellack, Kliebard, Hyman, & Smith, 1966; Brophy & Good, 1973; Croll, 1986; Flanders, 1970). In these studies, the focus shifted from the effectiveness of group work to student achievement, attitudes, and teacher behavior. Initially, the coding was commonly done in real-time, by a researcher sitting in the classroom. In order to enhance the scientific rigor—through added preci-

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\(^9\) The focus in this section is those approaches that primarily are interested in frequency distributions and the relation between the coded categories and other “variables,” such as test-results, gender, educational background, and so on. In a broader sense, most research projects that investigate video recorded interaction involve some kind of coding, such as content logs, and all involve transformations.
sion in the coding process and inter-observer reliability—investigations of classroom interaction were increasingly conducted using video-recorded material. Now as then, the use of coding schemes is often used in so-called *process-product* studies, where the frequency distribution of the coded categories is correlated with outcome measures. In investigations focusing on students’ collaborative work in groups, for instance, a common aim is to “identify the characteristics of co-operative and collaborative working that can be used to predict performance” (Underwood & Underwood, 1999, p. 15). In such studies, a predefined coding scheme, which includes categories for different types of talk, is applied to the group work of students; then, the frequency of categories of talk in different groups is correlated with some sort of outcome measure in order to draw conclusions about the kinds of utterances that promote effective learning.

It is also common to link the performance measures and characteristics of the interaction with group composition and organization. Underwood, Underwood, and Wood (2000), for instance, use a modified version of Bales’ category system together with task performance measures to examine differences in patterns of interaction and performance between pairs of boys, pairs of girls, and mixed pairs, working with computer tasks. When the results from several studies are compared, it is not unusual to find inconsistencies between findings; while some studies indicate that pairs of girls and mixed pairs perform worse than pairs of boys, for instance, others find no significant differences in gender pairings (cf. Barbieri & Light, 1992; Howe & Tolmie, 1999; Kutnick, 1997; Underwood, McCaffrey, & Underwood, 1990). As noted by Fitzpatrick and Hardman (2000), the inconclusiveness of the results might be expected, since the investigated situations vary in several respects, including, “tasks and software, how well defined the particular problem solving exercise is, the explicitness of the task instructions to work together, how performance is measured, the appearance of the tasks, as well as the wider classroom culture and context” (p. 432).

In an early proposal, Dunkin and Biddle (1974) suggest a model consisting of four sets of variables: *presage variables*, which connect characteristics of teachers, such as social background and intelligence; *context variables*, such as student characteristics and classroom environment; *process variables*, connected to the actual teaching and learning activities; and *product variables*, measuring the outcomes of learning.
In critiques of process-product studies, the kind of complexity indicated by Fitzpatrick and Hardman is often used to argue that investigated phenomena are “characterized by more variables than anyone can manage to identify, see in relationship, or operationalise” (Peshkin, 1993, p. 27). These criticisms “routinely begin with a critical assessment of the methods and logic of natural science, and their aptness for social worlds.” (Macbeth, 1998, p. 139) Becker, for instance, refers to a conversation with Stephen Toulmin who argues that the logic behind explanation in both natural and social science rests on a peculiar case; more specifically, Newton’s explanation of planetary motion, “in which it was possible to know the few things necessary to explain, to a degree of accuracy that allowed for predictions near enough as makes no difference, the observed motions of the known planetary bodies.” (1994, p. 187) Becker continues:

> The idea that if you just know all the initial conditions of the system under investigation and the laws that govern its operation, you could predict the resulting configuration at any given moment required an amount of information, when you dealt with complicated systems, that was not, and never would be, practical to collect and collate, no matter how big or fast the computer.” (ibid.)

While the criticisms of process-product studies are usually linked to proposals for other “qualitative” methodologies, there are also researchers using coding schemes themselves who acknowledge the problems and try to overcome them. With a starting point in the recent emphasis on the social, situated, and contextual nature of learning and interaction, Kumpulainen and Mutanen state that, “explorations between interaction and learning need to concentrate on the interpretation of meanings and purposes in interaction situations.” (1999, p. 272) In order to capture “the situated dynamics of peer group interaction,” a coding scheme based on three analytic dimensions, each containing an open list of categories, is proposed: functional analysis, cognitive processing, and social processing. While the first category is made on a turn-by-turn basis, the other two are coded across turns and with the “group as a unit of analysis.” Even though the coding scheme includes two additional dimensions, the result of the coded interaction is still a frequency distribution of the coded categories. As suggested by the authors, the coded material might be put in relation to “subject knowledge, interpretations of the learning situation, motivational orientation,
age, gender, social background, learning outcomes, or of the effects of
certain pedagogical arrangements and learning tasks on students’ social
practices and learning opportunities” (p. 471). By doing this, however, the
approach taken by Kumpulainen and Mutanen becomes similar to the
process-product studies of which they are critical.11

It is important to note that the very coding of interaction entails a cer-
tain rationale since “the abstractions involved in coding practices are by
declaration bound to work in the direction of disregarding the dynamic,
multilayered nature of dialogue” (Marková & Linell, 1996, p. 361). As the
“the dynamic processes are, as it were, frozen and dissected” (Korolija, 1998,
p. 81), the coding procedures place severe restrictions on the attempts to
capture the situated dynamics of peer group interaction. Draper and An-
derson (1991, p. 99) summarize some of the problems of coding interac-
tion: the function of a particular utterance is often ambiguous when taken in
isolation; an utterance commonly serves multiple functions simultaneously;
phenomena of interest can be spread over several utterances; and meanings are
renegotiated over the course of the ongoing interaction. Even though most
researchers would agree on the propositions stated in this list, opinions
differ as to whether they make the whole project of coding inadequate, if
there is a need of new coding systems and theoretical approaches, or if the
problems are something that can be appropriately handled using current
methods and procedures. In a sense, these differences can be related to
whether one takes the list primarily as a characterization of the intrinsic
features of dialogue or as practical problems for an analyst.

For educational research, an additional and critical concern is the relation
between coded interaction and issues of learning and understanding. When
investigating students’ collaboration in science education, for instance, the

11 If, in fact, the strength of approaches that use coding schemes “lies in their capacity
to handle large corpora of data; to offer explicit criteria for comprehensively categoris-
ing the whole of a data set; to offer a basis for making systematic comparisons between
the communicative behaviour of groups of children and, similarly, to offer a basis for
relating this behaviour to measures of the outcomes of collaborative activity” (Wegerif
& Mercer, 1997, pp. 272-273), making coding schemes more complex and the studies
increasingly descriptive might undermine the value of such studies. With an increased
complexity, the time it takes to code and interpret large set of data increases. Typically,
this is addressed by handling less material, which makes it highly problematic to draw
any reliable conclusions with regard to "age, gender, social background," etc.
use of coding schemes might remove all “the semantics of the discussion so that we can no longer see what scientific theories have been developed or what critical issues have been raised.” (Stahl, 2006, p. 220) If utterances are coded with reference to their function—interrogative, informative, evaluative, and so on—a dialogue on the strengths and weaknesses of a radio show might be rendered similar to a discussion on the results of a lab experiment; solely by looking at the frequency distributions, students would seem to be involved in the same kind of activity. Even though some systems, such as the one proposed by Kumpulainen and Mutanen (1999), make distinctions between different kinds of “cognitive processing,” and thereby manage to separate the “exploratory” discussion of science from the “off-task” talk about the radio show, these systems cannot capture the ways in which lab work, Newtonian mechanics, and student understanding are interactionally constituted. There are coding schemes specifically designed for the analysis of lab work, such as the Category-Based Analysis of Videotapes (Niederer et al., 2002), which can be used to find relations between categories relating to what students are doing—such as, manipulating apparatuses or doing measurements—and categories of verbalizations of various types of knowledge, technical, mathematical, physical, etc. Although these can be used to characterize different types of lab work, and match them with different types of talk, they still gloss the local meaning and significance of these actions. By definition, coding involves a categorization and unitization of actions. When taken in their local contexts, however, actions that at first sight might look the same often differ in significant respects.

In different classrooms, schools, and communities, events that seem ostensibly the same may have distinctly different local meanings. Direct questioning of students by a teacher, for example, may be seen as rude and punitive in one setting, yet perfectly appropriate in another. (Erickson, 1986, pp. 121-122)

If meaning is locally produced, as it is suggested here, ”the world cannot be added afterwards to a model of thinking in the form of a set of contextual variables.” (Resnick, Säljö, Pontecorvo, & Burge, 1997, p. 4) According to this argument, the order of an already interpreted and meaningful world is different altogether from a world that can be decomposed into a set of variables. Macbeth (1998) makes a distinction between programs of complexity and programs of coherence. While the former understand the
difference between natural and social worlds in terms of the social worlds’ increased complexity, and thereby try to capture an ever increasing number of variables or factors, the latter understands “the fabric of the social world as an incommensurate orderliness, an abiding and systematic orderliness that is at once different in kind from the order of variance, and no less robust, durable, and methodic.” (ibid., p. 141) There are several strands of coherence programs, differentiated by the ways meaning and social order are ”made out as the play of power, value-ladenness, social location, gendered epistemologies, and/or social-psychologies.” (ibid.) Some of them are outlined below.

LOOKING THROUGH AND BEYOND THE INTERACTION

In this section, some approaches that attempt to “go beyond what everyone knows” by other means than coding schemes and correlations are presented. Although the outlined approaches are fundamentally different in many respects, a common feature is that the talk and actions of teachers and students are used as indicators of something else. By adopting certain ways of analyzing interaction, researchers aim to see through actual practices and thereby reveal something that is hidden from plain view—whether the hidden thing is structures of power, students’ understanding of mechanics, or learning as it takes place in interaction. If going beyond what everybody knows means finding something concealed, analytic instruments capable of revealing the hidden things are needed. In this way, ”the very premise of concealment delivers at once the task and authorization of formal analysis: to assemble the gaze that can reveal what the natives do not see, and its formative place in their ordinary experience.” (Macbeth, 2000, p. 249)

Nowhere is this task and authorization more pronounced than in studies that use critical theory or critical discourse analysis\(^{12}\) to uncover the play of

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\(^{12}\) Educational research conducted under the auspices of critical theory and critical discourse analysis often refers to the writings of Marx, Bourdieu, Bernstein, Habermas and Foucault. It is also commonly associated with the “new” sociology of education, neomarxian cultural studies, feminist theories, and post-structuralism. The aim of this section, however, is not to trace the history of the multitude of approaches that are categorised as critical theory or critical discourse analysis, but to discuss some common ways of “looking through” interaction in science education. For outlines of the history of critical discourse analysis, see Hammersley (1997) and Fairclough (1992); for some examples
power in educational interaction. Through a lens cast from three Marxist concepts—alienation, reification, and commodity fetish—Beach (1999) investigates lab work in a teacher education course. While observing the laboratory activities, Beach notices that the students change their results extensively during the lab in order to get the “right” answer—or, rather, to achieve what they consider to be the right answer. Consequently, what is done in the lab does not match the instructions, and what are written in the laboratory reports are not factual accounts of laboratory events or results. When asked, teachers, lab assistants, and students have no problems in relating to the observation that students commonly feel compelled to manipulate their results so that they get the “right” answers and pass the exams. Few, however, would recognize Beach’s suggestion as to what students actually are doing and the real reasons for their conduct: “whilst they often plot and contrive results, copy each others work to find what they believe is the truth, what they actually do is bow to an (economic) imperative and an ownership relation which they then deny and disguise.” (ibid., p. 164) According to Beach, students are in fact unable to realize that this is what they are doing:

Not only do students do their work in ways other than those which laboratory prescriptions and reports would have us believe and for reasons other than those which these documents indicate, but they also do their work in ways other than those they believe themselves and for reasons other than those which they are able to recognize. (ibid.)

Beach thus argues that the students might believe that they manipulate the results in order to pass the exam and get a grade, but that they are unable to recognize the real reasons for their conduct. If the teachers and students


13 Beach is not the first researcher to observe the discrepancy between instructions, lab work, and laboratory reports. In a study of the lab work of fourth graders, Amerine and Bilmes note that “the ‘experiments’ did not test the validity of a scientific principle, only the competence of the students at carrying out the instructions. The children were also provided with occasion to practice a useful social skill—accounting for discrepant outcomes within a framework of unquestioned authority.” (1988, p. 333). In contrast to the work of Beach, however, the study by Amerine and Bilmes is not formulated as a complaint but as an exploration of practical conditions when following instructions.

14 This kind of account always runs the risk of disparaging students and their un-
were to understand what is going on, Beach argues, the lab could result in an educational experience focused on the criticism of science; it would provide “reflections about how results actually were obtained on the basis of relations of domination, subordination and economic imperative and deliberation about how this might effect their status” (1999, p. 168). While the study by Beach reports on the physiology component in a biological science course, it is stated that similar analyses could have been made for labs in other areas. Given the way the analysis is performed, the theoretical concepts are applied, and the conclusions are drawn, an open question is if any lab work would not similarly show the play of formal structures and missed opportunities for reflection on domination, subordination, and economic imperative.

When adopted by researchers in science education, the critical theoretical project is commonly transformed. The issue is no longer if students should learn and do something radically different from physiology, chemistry, or mechanics—it is not that they should focus on political and historical conditions of science and science education instead—but that common ways of organizing education have negative effects on students’ learning and perception of science. Lemke (1990), for instance, observes that there are certain “myths” about school science that are commonly adopted and reproduced by teachers: that science has to be abstract and impersonal; that the voice of science should be objective, authoritative, and nonnegotiable; and that it is “special truth that only the superintelligent few can understand” (ibid., p. 149). According to Lemke, the authoritarian atmosphere found in many classrooms allows the teacher to have more control, but it also creates conflicts between teachers and students and alienates students from a true understanding of scientific concepts. 15 In common with the understanding of the situation: “What indeed natives do know of their affairs is rendered a perennial candidate for more and less explicit accounts of ‘false consciousness.’ The characterization has always, and necessarily, accompanied the critical theoretic impulse. The devalorization of not only traditionally privileged discourses, such as science, but of everyday discourses is unavoidably caught up in the stipulation of hegemonic organizations.” (Macbeth, 2000, p. 250)

15 Commonly, the organization of educational communication in sequences of teacher initiation, student response, and teacher evaluation—what is sometimes referred to as IRE sequences (Mehan, 1979b) or triadic dialogue (Lemke, 1990)—is used to exemplify this since “the teacher as an authority on the subject matter is converted into being in
analysis provided by Beach, issues of power and alienation are thus central to critical discourse studies in the field of science education. But whereas Beach relates alienation to the “classic condition of the Western lifestyle and to concern a de facto powerlessness which is determined by institutional arrangements over which individuals have very little control” (Beach, 1999, p. 157), alienation in these studies often concerns the conditions for students’ motivation to learn science.

Hanrahan (2006), for instance, argues that, “hidden facets of teacher communication are likely to be crucial in deciding whether students want to engage in learning science or not, what they learn about the nature of science, how empowered they feel in relation to it, and finally, how they are likely to identify themselves as learners of science.” (ibid., pp. 37–38) The analysis focuses on the ways two teachers introduce their classes. One of the teachers, it is claimed, adheres to stylistic norms used for “impressing a lay audience with his superior status as an apparently scientific person” (ibid., p. 24). According to Hanrahan this makes it probable that he engages just those few that already know how to talk science successfully. Much of the teacher’s conduct is described in terms of absences: including an “absence of talk that would facilitate transitions in the lesson or would help build relationships with students”; an “absence of any appreciation of narrative or dramatic intent in the homework questions”; “no checking that the students were ready to move on to the next stage of the lesson”; “no checking for understanding of concepts or of the purpose of the particular experiment”; “no sign of particular commitment to what he is saying” (ibid., pp. 20–23). Even though these observations are sensible in many ways, the observation of “absences (what we don’t do) is a delicate matter; there are too many of them.” (Macbeth, 1994, p. 324) With reference to critical discourse analysis, and with a strong professional and moral sense of what good teaching should look like, Hanrahan sees in the material that which authority not just over the conduct of the work of the classroom but over the subject matter.” (Young, 1992). While there are many researchers (Gee, 1996; Lemke, 1995) who stress the problematic nature of this way of communication, there are others (Heap, 1985; Macbeth, 2003; Newman, Griffin, & Cole, 1989) who frame it rather as an important resource for making knowledge public and learnable in schools.

16 By selecting teachers that believed that their students had a positive attitude towards science and science education, the study is contrasted with “much research in science education which simply finds fault with teacher.” (Hanrahan, 2006, p. 11) Still, it is
is missing. With a different background, or another sense of what teaching should look like, other absences would have been present; for instance, one could note the absence of talk concerning relations of domination, subordination, and economic imperative.

While Hanrahan’s analysis of the first classroom is filled with absences, the analysis of the second classroom is filled with the teacher’s good intentions. This teacher, “allowed a student to question her and took the time to give her a serious answer, and she talked in a more conversational way and used a range of intonation to make the lesson more interesting.” (Hanrahan, 2006, p. 29) She was also “making sure that all students could hear and understand the keywords.” (ibid.) Like the analysis of the first classroom, the analysis focuses almost exclusively on the talk of the teacher. It is therefore not shown how the students orient towards the lesson as interesting or how the work of ensuring that someone understands the keywords is interactively accomplished. In both these analyses, the talk and actions of the teacher are thus used as “an inherently ambiguous and incomplete stimulus that invites reaction and speculation ranging far beyond the information that is potentially available in the video clip itself.” (Erickson, 2007, p. 152) If the aim of the study were to show and discuss some aspects of teacher talk that could be seen to be aligned to good and bad teaching, this might not be a problem. When the aim is to show how issues of power, domination, and the like connect with the talk and interaction, however, it could be argued that the analysis has to stick closer to what is “demonstrably relevant for the parties.” (Schegloff, 1997, p. 183)

clear that one of the classrooms was chosen for its ability to display deficits, as it left the researcher “feeling de-energized, discouraged, and embarrassed at what seemed to me a serious lack of awareness of how to engage students in learning science,” (ibid., p. 37) and “surprised that the teacher considered the students sufficiently motivated and engaged with science to warrant his self-nomination for the project.” (ibid.)

17 These quotations are taken from a debate in Discourse and Society between Schegloff (1997, 1998, 1999a, 1999b), on the one hand, and Billig (1999a, 1999b) and Wetherell (1998), on the other. Summarizing this debate, ten Have (2005) argues that Schegloff makes an “at least” argument—claiming that one needs at least consider these terms in the light of their local organizational features—whereas Wetherell provides a “not enough” argument by claiming that conversation analysis need to include additional interpretative resources.
A similar approach—of using recorded interaction as a stimulus for theoretically and professionally grounded reaction and speculation—can be found in research that attempts to find indications of students’ learning and understanding. Whereas both Beach and Hanrahan aim to investigate “hidden” issues of power, domination, and alienation, most studies of classroom interaction in science education focus on issues related to the subject matter content. This research is far removed from the kind of critical analyses offered by Beach (1999). Despite any explicit interest in power, domination, and alienation, however, there are clear parallels between some of the studies that attempt “to find science in the dialogue” (Lemke, 1990, p. 87) and the approach adopted by Hanrahan (2006). By being grounded in a strong professional sense of what learning and understanding optimally should look like, these studies are similarly filled with observed absences, teacher intentions, and conjectures on the consequences of talk and action.

Thus, when interpretations are based on background expectancies and professional expertise, the analyses become contingent on the researcher’s particular understandings of what teaching and learning is and how it should be understood. Roschelle makes a distinction between the romantics and the skeptics in research on science education. The romantics focus on the students and tend to “get caught up in the progressive spirit of constructivist reforms and neglect to produce convincing evidence that students are becoming more scientific.” (1998, p. 1026) The skeptics, on the other hand, “lash back against constructivist reforms and insist things were better when we lectured students on the exact scientific concepts that they were to learn and then tested their retention.” (ibid.) Roschelle exemplifies the two positions by means of hypothetical responses to an episode where two students are working with a graphical simulation of the concepts of velocity and acceleration.

The Romantic leaps to a conclusion, “Sue and Tania have constructed their own understanding of velocity and acceleration. In fact, because they built the concept themselves from experience and expressed it in their own words, it will be especially meaningful and robust.” The Sceptic, on the other hand, denies the portent of this episode, “Sounds to me like they’re talking about pictures of arrows growing and pulling. How do I know that they’ve learned anything about the real world or about scientific concepts? Seems like another video game to me.” (ibid., 1029)
Although this quotation shows hypothetical reactions to a transcribed episode and not two research accounts, it highlights how the ascription of learning and understanding has an inherently and unavoidably normative aspect. As argued by Heyman, what we have access to when watching teachers and students in a classroom is instances of speaking and doing. In contrasts, the notions of teaching and learning—although useful in many cases—are labels that we ascribe to instances of speaking and doing. When using these labels it is important to recognize that the “assessment of an activity as an instance of teaching is normative, and our assessment of an activity as evidence of learning is a form of criterial relationship.” (1984, p. 17) Both the skeptic and romantic make value judgments as to the instructional value of the simulation. With regard to learning, the romantic makes the criterial relationship explicit, “because they built the concept themselves from experience and expressed it in their own words, it will be especially meaningful and robust.” (Roschelle, 1998, p. 1029) In contrast, the skeptic raises the issue of the lack of any stable criteria to use as evidence: “How do I know that they’ve learned anything about the real world or about scientific concepts?” (ibid.) Regardless of the potential value of the activity afforded by the simulation, the question posed by the skeptic is important: How is it in fact possible to know if students learn and understand scientific concepts?

Roschelle holds that a challenge for research in science education is to construct viable accounts of students’ gradually evolving knowledge that move beyond the black-and-white characterizations of the romantics and the skeptics. This is a challenge that has been taken up by an increasing number of educational researchers and has resulted in numerous inventive approaches that address the relation between interaction, learning, and understanding. In a special issue of the Journal of the Learning Sciences, for instance, several researchers, each with their own analytical approach, interest, and aim, have analyzed the same episodes taken from two mathematics classrooms (McClain, 2002). Despite many differences, all studies address the question of students learning and understanding in a way that matches Roschelle’s call for detailed analyses that go beyond black-and-white characterizations and address the gray areas. Forman and Ansell (2002) investigate how students’ use tools in the construction of argumentative positions. They furthermore claim that the investigated classroom prac-
tices resemble those found in scientific communities. Cobb examines how meaning and ways of using tools and inscriptions develop in interaction; or, using the terminology adopted in the study, how a “learning trajectory takes the form of a chain of signification that emerges as the normative ways of reasoning with tools and inscription evolve.” (2002, p. 208) Sfard addresses the ways in which the use of symbolic tools involves the gradual adjustment of former discursive habits to new contexts. This is described as the interplay of intimations and implementations, where intimations refer to more or less informed guesses about how the symbolic tools can be used and implementations refer to the “actual construction of an attended focus and its later critical evaluation.” (2002)

In commenting on the special issue, Macbeth characterize the analyses and assessments as ways “of ‘looking through’ what the students could be seen and heard to be doing, to find the evidences of design-relevant (or math-relevant) order, reasoning, and practices.” (Macbeth, 2002, p. 377) In order to get at these evidences, all the analyses make use of conceptual-analytical distinctions designed to separate the mathematical thinking from the ordinary—models for mathematical reasoning are contrasted with models of informal reasoning (Cobb, 2002, p. 208), and mathematical objects are separated from material objects (Forman & Ansell, 2002, p. 252). Since the students’ interaction does not provide clear displays of mathematical reasoning, however, the researchers have to “look through” them and make “conjectures” as to the mathematical meaning. In the words of Macbeth, this way of analyzing students’ interaction “entails an exercise of translation, or captioning, in which what they were doing is described in math-relevant terms.” (Macbeth, 2002, p. 378) For instance, in making a distinction between pronounced, attended, and intended focus, Sfard conjectures that the utterance “more consistent” has the intended focus “Consistently long-lasting battery = the set of batteries that has the larger subset of longer lasting batteries” (Sfard, 2002, p. 332). Whereas the student’s utterance taken in its local context is only vaguely and potentially mathematical, the conjectured intended focus as formulated by Sfard has acquired a patently mathematical sense. Forman and Ansell (2002) connect the utterance “more numbers” to a literal view of the representation, while “more people” is associated with a symbolic representation of the real-world situation. It is not all that clear, however, why one should be taken as literal and the other as symbolic, as
each of these utterances could also be seen as “a cogently unremarkable way of speaking in the course of their lesson” (Macbeth, 2002, p. 378). Macbeth goes on to argue:

That a math-competent reader can render what the students are saying in statistical–logical terms is not quite an answer to the question: What are they doing? It may be a far more vernacular task for them, no doubt with some math attachments. (ibid.)

As stated in the introduction, the outlined approaches presented in this section are fundamentally different in many respects. Even though the overlap between the analyses of Beach and Sfard is small, there are some resemblances: in both cases, the talk and actions of teachers and students are seen as indications of something else, and in both cases, the analytical task become one of looking through the interaction to uncover what is hidden from plain sight. Some might claim that this is a necessary aspect of qualitative research—that it is the way empirical studies manage to move “beyond what ‘everyone’ knows.” (Becker, 1971, p. 10) If one refrained from going “beneath or beyond the naively mutable evidences of the ethnographic field” (Macbeth, 1998, p. 148) how would it be possible to make an analysis showing anything that was not already known? Based on the recognition that attempts to go beneath and beyond the interaction would “ignore the complexity and texture of the surface events, and thus they would fail to explicate how an order of activities is achieved as a contingent, moment-by-moment production” (Lynch & Bogen 1996, p. 16), the next section provides a potential answer in the ethnomethodological insistence of sticking close to the surface and explicating the seen but unnoticed details of social activities and phenomena.18

18 Although the section primarily focuses on ethnomethodology and conversation analysis, a similar insistence on sticking to the surface of things can be found in studies conducted under the auspices of, for instance, sociocultural approaches (Mäkitalo, 2006), dialogism (Linell, 1998), interaction analysis (Jordan & Henderson, 1995), context analysis (Erickson & Schultz, 1997), and distributed cognition (Hutchins & Palen, 1997). Since ethnomethodology is the approach taken in this thesis, and in order to avoid repetition, the rationale of explicating the seen but unnoticed details is exemplified with some classic studies and findings of ethnomethodology and conversation analysis rather than studies in science education. The approach as applied to the domain of science education is discussed in the introductory chapter, as well as in the empirical studies.
EXPLICATING THE SEEN BUT UNNOTICED DETAILS

Ethnomethodology has been described as a “program that set out to dissolve the analytic privilege of speaking authoritatively on behalf of a world that could not know its own affairs.” (Macbeth, 2003, p. 241) The effort to dissolve the analytic privilege of scientific methods and theories is sometimes formulated programmatically, as the policy of *ethnomethodological indifference*. In short, the policy requires that the analysts abstain from the use of any “social science model, method, or scheme of rationality for observing, analyzing, and evaluating what members already can see and describe as a matter of course.” (Lynch, 1999, p. 221) When applied to the study of classroom interaction, following this policy means not using coding schemes or similar analytical apparatuses. It also implies that the ethnomethodologist refrains from using theoretical, professional, or moral preconceptions of what learning and teaching should look like as an interpretative resource in the analysis. In addition, the policy “requires an indifference to the classic distinctions between science and common sense, theory and practice, or abstract and concrete reasoning as stable bases for evaluating the field of discursive actions.” (Lynch & Macbeth, 1998, p. 271) Accordingly, distinctions such as those found in the studies by Cobb (2002) and Forman and Ansell (2002), should not be used “as normative bases for detecting and detailing the local organization of classroom lessons.” (Lynch & Macbeth, 1998, p. 271)

Even though these restrictions might seem to represent an analytical asceticism, it is important to note that the policy is not—as it is sometimes

19 In an early formulation, it states: “A leading policy is to refuse serious consideration to the prevailing proposal that efficiency, efficacy, effectiveness, intelligibility, consistency, planfulness, typicality, uniformity, reproducibility of activities—i.e., that rational properties of practical activities—be assessed, recognized, categorized, described by using a rule or a standard obtained outside actual settings within which such properties are recognized, used, produced, and talked about by settings’ members.” (Garfinkel, 1967, p. 33)

20 This does not mean that ethnomethodologists try to refrain from using any analytical concepts. As Garfinkel puts it, “There is no cure for talking jargon. You’ll cut your brains out if you stop talking jargon. But, you don’t want to trust the jargon you’re talking. Because there is still something more.” (2002, p. 177). In this context, “something more” refer to the details found in the “real worldliness” of social activities and phenomena.
claimed to be—a way of putting the researcher in a position over and above other research traditions, or providing an ethnomethodological ground zero. It should rather be seen as a reminder “that professionals (social scientists, administrative analysts, and social engineers) do not monopolize the development and use of rules, formulae, algorithms, maps, guidelines, rules of thumb, maxims, instructions, and the like.” (Lynch, 1997, p. 372)

In fact, it is an interest in the myriads of uses and developments of rules, formulae, algorithms, and so on, that provides the motive for the policy of indifference in the first place. In an oft-recounted story, Garfinkel coined the term ethnomethodology when he, together with other researchers, was to investigate the work and reasoning of juries (e.g., Garfinkel, 2002, pp. 96–97; Garfinkel et al., 1981; Heritage, 1984). To borrow a phrase from Hutchins (1995), the researchers aimed to investigate reasoning in the wild by analyzing tape recordings of jury deliberations from an actual case. As Garfinkel recalls

In 1954 Fred Strodtbeck was hired by the University of Chicago Law School to analyze tape recordings of jury deliberations obtained from a bugged jury room. Edward Shils was on the committee that hired him. When Strodtbeck proposed to a law school faculty that they administer Bales Interactional Process Analysis, Shils complained: “By using Bales Interactional Process Analysis I’m sure we’ll learn what about a jury’s deliberations makes them a small group. But we want to know what about their deliberations makes them a jury.” (Garfinkel et al., 1981, p. 133).

Garfinkel took Shil’s complaint seriously. Instead of using a coding scheme to categorize the utterances of the jury, he wanted to capture the specific and detailed ways in which the jury decided “what really happened,” what was “a matter of fact,” and what just was “an opinion.” When focusing on the ways the jury decided what might have happened, he did not compare their decision with any alternative version of what “really” happened. Neither did he compare their “vulgar” methods with what could be considered more “valid” or “scientific” ways of reasoning. For Garfinkel, the interest was not one of adequacy in relation to any criterion or standard obtained outside the actual setting. Instead, he took an interest in the ordinary, practical, but still methodical ways in which the jury came to a decision. Attention was thereby drawn to the unremarkable, “seen but unnoticed” ways through which social activities and facts are produced so as to display their
recognizable orderliness. The task for the analyst became to show “just how members concert their activities to produce and exhibit the coherence, cogency, analysis, consistency, order, meaning, reason, methods,—which are locally, reflexively accountable orderlinesses—in and as of their ordinary lives together, in detail” (Garfinkel, 1988, p. 108).

The study of the jury deliberations took place in the 1950s, and since then ethnomethodology has developed and diverged into substantially different strands of research (e.g., Maynard & Clayman, 1991; Psathas, 1995b). Of the different strands, conversation analysis (CA) has developed into a largely autonomous program of study that has accumulated a large body of research (for overviews, see Goodwin & Heritage, 1990; Hutchby & Wooffitt, 1998; Psathas, 1980; Schegloff, 2007; Silverman, 1998; ten Have, 1999). It is an approach to the study “naturally occurring talk-in-interaction,” originally developed by Harvey Sacks together with colleagues such as Gail Jefferson and Emmanuel Schegloff. In common with ethnomethodology, conversation analysis takes an interest in the ordinary, practical, and methodical foundations of social actions and activities. What distinguishes conversation analysis is the attention paid to the sequential organization of talk-in-interaction; that is, what an utterance does in relation to the preceding and what implications it has for the next. Most of the early work focused on the generic features of talk, “whether it be the home, the laboratory, the office or the street.” (Psathas, 1999, p. 141) Nowadays, much research investigates the particularities of interaction in institutional environments, sometimes using the more generic findings as a backdrop (Arminen, 2005; Drew & Heritage, 1992; Sarangi & Roberts, 2000). In line with Psathas (1995b), one can make a distinction between these studies of talk-in-interaction within

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21 In one sense, “ethnomethodological studies are necessarily diverse, since the commitment to ‘real worldliness’ of phenomena means that how studies are done and presented is (should be) shaped by the distinctive character of the phenomena under investigation.” (Hester & Francis, 2000, p. 4) Another kind of diversity can be found in historical and theoretical expositions, which “have traced the ideas, assumptions, and presuppositions in ethnomethodological writings to radical individualism, subjective irrationalism, behaviorism, operationalism, relativism, social constructivism, pragmatism, inductive realism, positivism, phenomenology, and analytic philosophy.” (Lynch, 1999, p. 213) Although this indicates some of ethnomethodology’s diversity, it does not provide any link to other theoretical programs or perspectives. For such attempts, see Heritage (1984) and Hilbert (1992).
Institutional or organizational settings and the studies of work program. Whereas the former builds on conversation analysis and aims to study talk in different institutional settings, the latter sets out to explore how work is produced, accomplished, and recognized for what it is (Garfinkel, 2002, 2007; Garfinkel et al., 1981; Livingston, 1986; Lynch, 1985).

Some of the similarities and differences between classical ethnomethodology, conversation analysis, and studies of work might be clarified with an example. The example is taken from Rommetveit, who uses it in order to outline a “social-cognitive and dialogically based approach to language and mind” (Rommetveit, 1992, p. 19). In the example, Mr. Smith, a fireman living in a suburb called Scarsdale, is mowing his lawn. For Rommetveit, what is of interest here is what Mr. Smith is seen as doing, or, rather, how people characterize Mr. Smith’s conduct when asked. Rommetveit (2003) writes:

A neighbor prying into the miserable marital relations of the Smiths may tell us that she “sees” Mr. Smith avoiding the company of his wife. And that may indeed be what Mrs. Smith feels, left alone in the kitchen with her morning coffee. But when the phone rings and her friend Betty asks, “That lazy husband of yours, is he still in bed?” Mrs. Smith answers, “No, Mr. Smith is working, he is mowing the lawn.” A short time afterward, Mrs. Smith receives another call, this time from Mr. Johnson, who, she takes for granted, is ringing up to find out whether her husband is on the job or free to go fishing with him. So, when he asks, “Is your husband working this morning?” she answers, “No, Mr. Smith is not working, he is mowing the lawn.” (p. 15)

What Rommetveit wants the reader to notice is that Mrs. Smith, in her conversation with Betty, says that her husband is working while just some moments later, in the conversation with Mr. Johnson, she claims that he is not working even though Mr. Smith—at least in some sense—has been doing the same thing all along. Rommetveit further points out that Mrs. Smith is neither lying to Betty nor to Mr. Johnson. Instead, the word “working” means different things on the two occasions since the meaning of the word is tied to different concerns: either the husband’s assumed laziness or the possibility for him to participate in a fishing trip. The story

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22 Rommetveit, in turn, borrowed the fictional character used in the example from Menzel (1978).
can be connected to three of the most well-known concepts from early ethnomethodological works: indexicality, reflexivity, and accountability. According to Garfinkel, all words and expressions are necessarily indexical. This means that they are context-bound and tied to the practical concerns of the interlocutors. Traditionally, pronouns and pronominal adverbs such as here, now and I have been considered indexical and in need of specification with respect to space, time, or person. As demonstrated by the example, however, even words like working have a contextualized sense. For the ethnomethodologist, it does not clarify anything to say that a word is indexical. The ethnomethodological notion of indexicality should rather be seen as a starting point for investigations of how people “manage to make adequate sense and adequate reference with the linguistic and other devices at hand.” (Lynch, 1993, p. 22)

This concern, of how people make adequate sense and reference, is also central to the ethnomethodological notions of accountability and reflexivity. Typically, researchers interested in accountability and accounting practices have focused on events wherein untoward or unanticipated actions are present: actions that project clarifications, explanations, excuses, apologies, and so on. In contrast to the notion of accounts, however, the notion of accountability promises something more—namely investigations of the situated, local accomplishment of producing a queue, a mathematical proof, or a question in a telephone conversation as just the social thing it accountably is. Used in this way, accountably is thus a shorthand for the formulation visible-rational-and-reportable-for-all-practical-purposes as it was presented in the first chapter, and is closely associated with the notion of reflexivity.23

The accounting practices are “reflexive” because the accounts which members provide are displayed in members’ actions. It is through their own actions that members display how they understand their own actions as well as the actions of their interactional partners. Hence, the ethnomethodological concept of “reflexivity” relates to the self-explaining, self-organizing character of members’ actions. (Czyzowski, 2003, p. 228)

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23 The term reflexivity in academic discourse often refers to professional self-reflection and textual deconstruction. How ethnomethodological constitutive reflexivity relates to these uses of the term is discussed in Lynch (2000) and Macbeth (2001).
When Mrs. Smith provides an account of what Mr. Smith is doing, this account is reflexive to the communicative project of the two interlocutors. The account of the action thereby becomes an action in itself, and as such, it does not only say something about the action reported on but also something about the understanding of the one who provides the account. Mrs. Smith’s reply, displays how she heard the utterance and thereby contributes to the continuation of the communicative project in which she is involved.

The recognition that utterances display understandings for recipients as well as analysts has been the central topic and resource for conversation analysis; the turns in a conversation “make available to the analyst a basis in the data for claiming what the co-participants’ understanding is of prior utterances, for as they display it to one another, we can see it too.” (Schegloff, 1984, p. 38) In the example by Rommetveit, Mrs. Smith shows that she understands Mr. Johnson’s prior utterance as a question by providing what is recognizable as an answer.24 In her answer, moreover, she continues after the response token “no,” thereby displaying that she understands “no” to be an insufficient answer in this context. She also shows that she understands that mowing the lawn does not count as working. If she, as the story goes, takes it for granted that Mr. Johnson wants to go fishing with her husband, she might reasonably project that he wants to talk to him and his whereabouts therefore becomes important.

One can think of a scenario where Mrs. Smith did not hear Mr. Johnson’s question as a question but as an accusation. Perhaps one made relevant by Betty’s insinuation in the previous telephone conversation. To the question “Is your husband working this morning?” she could have replied that, “My husband is not lazy.” This, in turn, might have required a repair (Schegloff, Jefferson, & Sacks, 1977) on behalf of Mr. Johnson, where he pointed out that she misunderstood him and that he was just asking to see if her husband was able to go out fishing. The fact that a turn displays an understanding of

24 In the conversation analytic literature, a question followed by an answer is often referred to as an adjacency pair (Schegloff, 1972; Schegloff & Sacks, 1973). Other types of adjacency pairs, include greeting–greeting, invitation–acceptance, and invitation–declination. This is not to say that a first part always produces the second part. However, the absences of a second part that are made conditionally relevant is commonly treated as a noticeable absence by the participants.
the previous turn or turns, thus provides the participants with a procedure for monitoring how and if mutual understanding for all practical purposes is accomplished—a so-called next-turn proof procedure (Sacks et al., 1974). For the analyst, the sequential organization of talk-in-interaction makes it possible to be guided by what is demonstrably relevant to the participants, and to parasitize the analyses that the interlocutors themselves make and display. In Schegloff’s words, “whatever seems to animate, to preoccupy, to shape the interaction for the participants in the interaction mandates how we do our work, and what work we have to do.” (2003a, p. 25)

Parallel with the development of conversation analysis, Garfinkel and some of his students and colleagues have advanced another approach that is sometimes referred to as the studies of work program, which both expresses a distinctive approach and thematic orientation. In characterizing this program, one can once more return to the example by Rommetveit and note that something is missing in the previous accounts—the actual “lawn-work” of Mr. Smith. Lynch (1993, p. 271) describes how Garfinkel and Sacks in the 1970s noted that most studies in the social sciences “miss the interactional what” of investigated practices. Studies of bureaucratic caseworkers, for instance, miss how such officials constitute the specifications of a “case,” and studies in medical sociology miss how diagnostic categories are constituted during clinical encounters. Button (2000) exemplifies the idea of a “missing interactional what” with Becker’s (1963) classic study of jazz musicians. Becker, focusing on how the musicians distance themselves from “squares,” gives detailed descriptions of their music, their clothes, their lifestyle and so on. As Button points out, however, “in all the wealth of detail there is no account of how they make music together, of the interactional and improvisational ‘work’ of playing together.” (2000, p. 327)

The study by Becker is contrasted with the work of Sudnow (1978, 2001). Like Becker, Sudnow is an experienced jazz player who conducts detailed analyses of music and musicians. In contrast to Becker, however, Sudnow investigates the embodied work of playing and learning to play improvisational jazz piano rather than addressing “jazz culture.” By doing

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25 Sometimes, this argument is also made in relation to “canonical CA,” which is said to lack “praxiological validity,” since such studies “miss the ‘interactional what’ of work and work-practice in subsuming work-practice under the ubiquitous workings of the turn-taking machine.” (Crabtree, 2000)
this, Sudnow addresses the missing "interactional what" of jazz musicians’ work. With a term taken from Garfinkel (1996, p. 13), the work of Sudnow can be characterized as a hybrid study. Whereas ethnomethodology has traditionally had a delimited sociological interest, hybrid studies have been described as a kind of “practical or applied research” (Rawls, 2002, p. 40) with the aim “that practitioners in the specialty area being studied will be as interested in the studies as professional sociologists.” (ibid.). As argued by Crabtree, the intention of the hybrid programme “is to inform the ongoing professional development of occupational practices whose workaday objects are under ‘praxiological’ study.” (2004, p. 202) In a sense then, hybrid studies of work, in their effort of informing practitioners by means of studies of the “missing interactional what,” become somewhat similar to design-based research projects that attempt to “open the black box” in order to improve educational practices.

Even though this section has indicated some differences between classical ethnomethodology, conversation analysis, and hybrid studies of work, it is important to note that they all resemble each other in their insistence on keeping the analyses close to the surface of practical activities. Instead of trying to capture and understand educative practices by applying pre-defined coding schemes, methods, and procedures, thereby transforming the interaction into manifestations of a hypothetical variable hidden “inside the mental life individuals” or “outside in the structure of society,” they treat what people are saying and doing as themselves organizing and organized phenomena. Becker’s challenge of going beyond what everyone knows is consequently met by focusing on the “seen but unnoticed details” of social activities, by investigating what students and teachers witnessably orient towards, and by uncovering the “missing interactional what.” Some practical concerns of doing such analyses are addressed in the next chapter.
This thesis builds on video-recordings of lab courses in which students, of different ages and backgrounds, are using probeware and other educational technology. Adopting a design-based research approach, a group consisting of both instructors and researchers has collaboratively documented and analyzed the workings of educational practices with the dual aim of improving the design and enactment of these practices and contributing to the educational research literature. In total, approximately two hundred hours of video have been recorded during several years of empirical investigations. Most of the recordings are of lab activities afforded by probeware, but also traditional labs, lectures, and so called interactive lecture demonstrations (cf. Bernhard, Lindwall, Engkvist, Zhu, & Stadig Degerman, 2007; Sokoloff & Thornton, 1997) have been documented. In addition to the video recordings, interviews with selected students have been conducted and standardized tests—such as the Force Concept Inventory (Hestenes et al., 1992) and the Force and Motion Concept Evaluation (Thornton & Sokoloff, 1998)—have been used prior to and after the courses. Since the empirical studies presented are based on the video recordings together with collected graphs and work sheets, the interviews and the test results are not discussed.

1 In a course for engineering students, for instance, all students participated in the same lectures (20 h), and problem-solving sessions (12 h), but 25 students of 125 participated in labs afforded by probeware instead of labs with traditional equipment (16 h). Whereas the students that used probeware achieved a 48% normalized gain on standardized tests, the students who took part in more traditional labs attained an 18% normalized gain.
In the design-based research project, the video recordings have made it possible to examine—collaboratively and in detail—how previous design decisions have affected the ways students work with technologies and tasks. Such observations and ongoing evaluations have been consequential for the ways lab work has been reorganized, instructions have been reformulated, and technology has been used (cf. Bernhard, Lindwall, Engkvist, Stadig Degerman, & Zhu, 2007). While most of these observations have only been used to improve design, some of them have been disseminated at conferences and workshops (e.g., Bernhard & Lindwall, 2003; Lindwall, Lymer, Degerman, Lindström, & Bernhard, 2005; Lindwall, Lymer, Lindström, & Bernhard, 2005). As stated in the introduction, however, the empirical studies in this thesis do not report on the formative and prescriptive parts of the design-based research project. Adopting an ethnomethodological approach, the studies rather aim to provide analytical findings and conceptual respecifications.

Akin to the design-based research project, the analytical work with the studies has been conducted in iterative and ongoing cycles: transcriptions have been written and re-written, tapes have been watched and re-watched, and tentative findings have been presented and reformulated. Given the non-linear nature of the analytical work, the headings of the following sections—recording video, analyzing video, and transcription and translations—should be seen as divisions made for expositional purposes rather than representing different phases of the research.

RECORING VIDEO

If video recordings easily “encourage mundane opinions and biases” (Goldman & McDermott, 2007, p. 121), as it is argued in the last chapter, why should video be used in the first place? One argument repeatedly found in the methodological research literature is that video and audio recordings reduce the risk that analytical considerations “arise as artifacts of intuitive idiosyncrasy, selective attention or recollection, or experimental design.” (Heritage & Atkinson, 1984, p. 4) Even though Goldman and McDermott are right in their observation that analyses of video in educational research have a tendency to reflect mundane opinions and biases, the medium also has certain affordances that can be used to counter these tendencies. The
permanency of the recordings might reduce the tendency to reify preconceived notions about the material since “questions of what is actually on the tape versus what observers think they saw can be resolved by recourse to the tape as the final authority.” (Jordan & Henderson, 1995, p. 45) It is also commonly held that collaborative and interdisciplinary group work—made possible by joint watching of video recordings—can be an effective antidote to “idiosyncratic biases on the part of individual analysts.” (ibid., 43)

While these opinions and observations point to the merits of using video in the research process, they might also be read as suggesting that the same kind of analysis could have been performed without video, just not that reliably. Considering the amount of detail presented in analyses, and the iterative, non-linear, and continuous nature of the analytical work, this suggestion is highly improbable for any of the studies presented in this thesis. In one of the analyses, for instance, attention was drawn to the methods a teacher used when trying to make some students see a linear relationship in a graph. In order to see how he synchronized verbal utterances and gestures, and how he used the students’ minimal responses in his instructive work, the sequence was replayed repeatedly, sometimes in slow motion. Throughout the project, the repeated viewings of video recordings have in this way been necessary for coming to grips with the seen but unnoticed details of the practices investigated. The possibility of playing and replaying the interaction has also been important for the continuous development of analytical foci and interests. Late in the project, attention was drawn to instances were teachers and students explicitly refer to “understanding.” By having permanent records of the interaction, it was possible to go back and systematically examine the episodes in which this was done. The possibilities of investigating details of interaction and gradually finding things in the lab work worth analytical consideration have thus been enabling conditions for the analyses, rather than something that increases the trustworthiness of them.

Despite these merits, it is important to note that video does not present a transparent window to what actually happened; recordings always present the situation from a certain perspective, which usually reflects a particular research interest or a presupposition of what is important and what is not. In a school science laboratory, as well as in the classroom, it is impossible to
capture everything that is going on—there is always a risk that significant aspects of the activity happen outside the frame of the recordings. In the lab course investigated, one camera was assigned to each group. Consequently, not all potentially relevant aspects of the activity were captured. By reviewing the tapes from the early recordings, it was found that certain ways of placing the camera made it possible to capture the computer screen, some of the students' notes, and most of their interaction in a fairly adequate way. The cameras were all placed on tripods and connected to separate microphones placed in close proximity to the students in order to enhance the quality of the sound. During the video recording there was little movement of the camera and no zooming in or out. Since the students handed in the graphs they had produced, and by knowing what tasks they were working with, it was usually possible to overcome the limitation of not seeing exactly what happened on the computer screen or what the students wrote in their notebooks. The video-recordings together with the printed graphs and work sheets made it possible to reconstruct what the students were referring to and what the graphs looked like.

When recording, attempts were made to minimize the intrusiveness of both researcher and cameras. The influence of the camcorder could be seen a special case of what is sometimes called the observer's paradox (Labov, 1972)—to be able to observe people, researchers have to be in the scene, which, in turn, may affect what people are doing. As many researchers have pointed out (e.g., Duranti, 1997; Jordan & Henderson, 1995; Speer & Hutchby, 2003), there is no general solution to the paradox other than to stop doing this kind of research or observing in secrecy. As these alternatives are not realistic options, what one can note is that “the camera adds another eye, a potentially very public one, to the scene and therefore its presence, like any other participants' presence, must be negotiated.” (Duranti, 1997, p. 346) One way to negotiate this presence is to clearly state what the additional eyes are looking for. At the beginning of every investigated course, it was emphasized that the research interest did not concern the performance of individual students, but rather the learning environment as a whole. The students were also informed that all participation was voluntary and that the tapes would be used for research or educational purposes only. None of the students objected to being filmed and most did not seem to be bothered by the camera. At times, the students oriented
themselves towards the cameras by, for instance, joking about being movie stars or by expressing embarrassment when realizing that a personal story was being taped. Such apparently “off-task” talk, it should be noted, was excluded from transcription and analysis. Most of the time, the students did not take any notice of the cameras in any manifest way. Since they were doing a physics lab, a lot of equipment surrounded them and the camera seemed to blend into the background. Also notable is that there are several instances in the recorded material were the students show that they are “cheating,” continually checking if the instructor was nearby, but without taking any notice of their acknowledged cheating being recorded.

**ANALYZING VIDEO**

The policy of ethnomethodological indifference has been important to the analysis, which has implied an effort to abstain from the use of any “social science model, method, or scheme of rationality for observing, analyzing, and evaluating what members already can see and describe as a matter of course.” (Lynch, 1999, p. 221) The studies have also been guided by Schegloff’s exhortation that “whatever seems to animate, to preoccupy, to shape the interaction for the participants in the interaction mandates how we do our work, and what work we have to do.” (2003, p. 25) What, then, do these policies or requests entail as regards actual analytical work? Sacks, arguing for what he calls an “unmotivated looking,” provides one suggestion:

> It is not that I attack any piece of data I happen to have according to some problems I bring to it. When we start out with a piece of data, the question of what we are going to end up with, what kind of findings it will give, should not be a consideration. We sit down with a piece of data, make a bunch of observations and see where they will go (1984, p. 27)

The practice described by Sacks might easily be seen as representing some sort kind of naïve inductivism—it is as if the researcher has to bracket all preconceptions and interests. When conducting practical analytical work, however, it is hard to imagine what such a situation would look like. Macbeth, although being in general agreement with the “caution to resist the importation of frames, commitments, or constructs that work to fill the lives and projects of the field with our own” (1990, p. 193), nonetheless
claims that “the issue and caution could not be to resist bringing interests to the field, if only because that would pose an impossible instruction.” (ibid.) In relation to the sociological interests of Sacks, moreover, the interests of educational research are somewhat different. In the introductory chapter, applied ethnomethodology was described as an approach where an acculturated sense of educational importance guides the selection of episodes to analyze (cf. Heap, 1987, p. 241). Without such an acculturated sense or interest, one might risk conducting what Erickson describes as analyses “of great elegance that have very little to do with the concerns of educational practice, especially as that practice involves subject matter teaching and learning.” (Erickson, 2006, p. 187) Describing “seen but unnoticed” details of classroom interaction, then, is no guarantee of educationally relevant analyses.

From the outset of the project, the studies have aimed to open the black box provided by previous experimental studies by examining what is going on in activities in which students use the probeware technology; more specifically, the project has focused on the ways teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical accomplishment of understanding in the setting. Even though these interests have provided the analyses with a direction, the policy of ethnomethodological indifference and Schegloff’s exhortation have still been important in order to keep an open mind as to where analytically revealing episodes might be found. As pointed out by Brown (1992), there is a tendency in educational research to select those “golden moments” where everything seems to go well. She further argues that this kind of research commonly bases “claims of success on a few engaging anecdotes or particularly exciting transcripts.” (p. 173) Although a selection based on normative ideas about what good teaching and learning looks like is typical for educational research, there is a risk of “anecdotalism” (Silverman, 1993) in all research that makes detailed analyses of a few video recorded examples. In view of this, the studies in the thesis have primarily focused on the routine and mundane activities that are at the core of education. As noted by Payne and Cuff:

The fact of the matter is that whatever else may happen in schools, whatever far-reaching or revolutionary educational issues may be
exhibited or addressed there, the routine, mundane practical activities are fundamental. For teachers and pupils in schools the mundane is inescapable; whatever else may be going on, whatever else may be consequential for wider educational matters, the mundane makes up most of what goes on day by day. (1982, p. 3)

Whereas all the studies in the thesis take the routine and mundane aspects of lab work as a point of departure, there are different grounds for selecting episodes for further analysis. In the first study, a short episode is chosen for its ability to demonstrate how the probeware technology and task structure shape the students’ interpretation of a graph in kinematics. The second study contrasts an episode where students use probeware with an episode in which they use a simulation. In both these studies, the selection is made on grounds of typicality and for the episodes’ abilities to display the topics discussed. A problem with such a selection is that the typicality cannot easily be shown. The claim that most of the students solve the assignment in similar ways leaves unspecified what “most” and “similar ways” means. Even though the issue of typicality is interesting and important, it does not have a general solution; it has to be decided in relation to the particular issues brought up in the analysis and the claims made. It is always possible to question the rationale for the selection of episodes, but given the nature of the project—to open the black box in search of how students and teachers witnessably orient towards the practical accomplishment of understanding—there are no alternatives to the arduous analytic work of repeatedly watching the material in search of significant episodes to select for further analysis.

In the third study, the selection of episodes is turned into a focal topic. It is argued that an exclusive focus on either “misconceptions” or “clear cut instances of learning” would miss most of the students’ problems and the lion’s share of the work done in the lab. The study then sets out to analyze some episodes chosen for their ability to display the cognitive and practical competencies involved in producing, recognizing, and understanding graphs in mechanics, and the interactive work by which these competencies are made into objects of learning and instruction. The fourth study takes another route to the selection of episodes by “building a collection” (cf. Hutchby & Wooffitt, 1998) of instances where teachers and students are explicitly referring to “understanding” or “getting it.” These instances
are then categorized into four different themes with three or four instances representing each theme.

According to some critical reviewers, ethnomethodological indifference not only provides the researcher “with little or no framework for selection” (Atkinson, 1988, p. 446), but also produces analysis that “is reminiscent of the French *nouveau roman* of authors such as Alain Robbe-Grillet: minute descriptive detail is assembled in a hyper realist profusion, until the reader loses any sense of meaning.” (ibid.) Whereas it is true that the indifference does not provide a framework for selection—even though there are rationales for the selections made—one could question the claim that ethnomethodological studies only provide descriptions. Button, for instance, makes a distinction between scenic and analytic fieldwork, where the first is comprised of “*scenic depictions of settings and doings*” (2000, p. 328) and the second consists of “*analytic explications of how activities are done and ordered.*” (ibid.) In Button’s account, it is the latter approach that is associated with ethnomethodology, and he argues that “fieldwork that merely describes what relevant persons do may well be missing out on the constitutive practices of how they do what they do, the ‘interactional what’ of their complexes of action.” (ibid. 329) Although a sharp distinction is hard to make, scenic fieldwork alone is not sufficient to explicate how teachers, task formulations, and technology make mechanics visible and learnable, or how students and teachers witnessably orient towards the practical achievement of understanding in the setting. In the process of analysis, scenic descriptions have thus been analytically and iteratively worked through with the aim to “uncover, describe, and analyze the ways in which social order is ongoingly produced, achieved, and made recognizable in and through the practical actions of members.” (Psathas, 1995a, p. 66) As pointed out in the previous chapters, a central resource for making the analytical explications is the way the students and teachers sequentially orient towards each other’s utterances and actions, making it possible to “inspect subsequent actions in order to determine how the participants themselves are responding to, and displaying their understanding of each other’s conduct.” (Heath, 1997, p. 187) In the inspection of subsequent actions, as well as in the presentation of the sequential order of actions and utterances, transcription plays an important role.
TRANSCRIPTION AND TRANSLATION

As stated earlier, approximately two hundred hours of video recordings have been collected in the research project. When watching the tapes the first time, content logs (cf. Jordan & Henderson, 1995; Suchman & Trigg, 1991) were made to provide an overview of what was happening, which assignments the students were working with, and if something particularly interesting occurred. Whereas the initial logs were important at the beginning of the project, they gradually lost their significance as research questions and interests developed. Instead, the use of transcription became increasingly important, both for getting an overview of the material and for getting at the details of the activities. In total, approximately fifty hours have been transcribed. The transcriptions have been made on different levels of granularity and have been based on different analytical considerations. As noted by Jefferson:

I take it that when we talk about transcription we are talking about one way to pay attention to recordings of actually occurring events. While those of us who spend a lot of time making transcripts may be doing our best to get it right, what that might mean is utterly obscure and unstable. It depends a great deal on what we are paying attention to. It seems to me, then, that the issue is not transcription per se, but what it is we might want to transcribe, that is, attend to. (1985, p. 25)

Whereas the transcripts make it possible to attend to certain things, they do this by simplifying, idealizing, and transforming the activities investigated. In texts about transcription, it is therefore repeatedly pointed out that no transcription is ever “complete” and that, “all attention to particulars on a videotape involves processes of sampling that are always influenced by theory, whether explicitly or implicitly.” (Erickson, 2006, p. 178) In the project, the process of selecting features to include in the initial transcripts was not only guided by certain interests or “theories,” but also practical concerns. Most of the transcriptions have been made verbatim, omitting prosodic and para-linguistic features, such as intonation, voice quality, and rhythm. Although a central interest in the project concerns the use of technology and the interpretations of graphs, these aspects of the interaction were not included in the first transcripts. It would have required too much time and effort.

The initial transcriptions have been used to find specific instances in the material and for obtaining a quick overview. The transcription could
therefore be seen as an indexical surface pointing back to the video. Some of these episodes have then been transcribed in further detail as part of the developing analysis; commonly by using conventions adopted from conversation analysis, with added pictures and descriptions displaying gestures and orientations towards the material and graphic environment. A small portion of the transcriptions has been used in articles and research papers. These have been adapted to the specific analytical concerns of the studies and have often included pictures of different sorts. In publications, a “transcript can be an unhappy object, forever tempting the reader to skip ahead to more ‘tidy’ fields.” (Macbeth, 1994, p. 314) This is especially true when the transcripts are filled with descriptive details about graphs, gestures, orientations, and other embodied conduct. In order to address this issue, in ways that retain the identifying details of the activities analyzed, some conventions from comics have been used in two of the studies. Sometimes, comics are referred to as sequential art (Eisner, 1985), and it is this sequentiality, together with the possibility of visually presenting what the students do and say, that makes this mode of representation suitable for the activities investigated. Like transcripts, the comics are analytic renderings filled with decisions on what is important. The use of comics also necessitates additional considerations with regard to the organization of time and space: What should be put in a panel? How do the actions fit on a page? How is time represented by means of space? What must be stated explicitly in textual comments and what can be shown with pictures?

Since the majority of the material is in Swedish and not English, it has been necessary to translate the interaction. As noted by Linell and Persson Thunqvist, “translation of naturally occurring talk-in-interaction is a difficult task, and it is impossible to make the transcriptions match the originals at all points.” (2003, p. 415) In doing the translations, the focus has been on what the students do by talking, gesturing, and acting, and how others respond to these doings, rather than the words and sentences at their face value. Since the analyses do not focus on syntactic features, and in order to provide transcripts that are easy to follow, the translated transcripts have not been complemented with a line in the original language (cf. Bilmes, 1996; ten Have, 1999). The actual analyses have been performed on the video recorded material together with Swedish transcripts, and the translated transcript, like the comics, can therefore be seen as an end product of the analytic process.
CHAPTER 4

SUMMARY OF STUDIES

ORGANIZING TIME AND SPACE

This study provides a detailed analysis of a pair of students’ work with an assignment in which they are requested to replicate a velocity vs. time by using the probeware technology. First, the students interpreted the graph presented on the computer screen in terms of how they were going to move in front of the detector in order to replicate it. After having made an initial interpretation, the students turned the measurement on and walked towards and away from the motion sensor while trying to match the predefined graph. In their attempts to replicate the graph, the students received direct feedback from the screen in the form of a new graph corresponding to the students’ movements plotted on top of the existing graph. Once the students had constructed a graph, they discussed similarities and dissimilarities between the two graphs and made a new attempt. The analysis highlights the ways the students produce increasingly precise interpretations, how they fluently switch between different modes of meaning, how the interpretations are both prospectively and retrospectively oriented, and how visual properties of the graph are merged with movements in the room. In addition to the verbal contributions, particular attention is drawn to the students’ spatial orientation, gaze, gestures, and movements.

In the students’ interpretation, the spatial organization of the graph is turned into a temporal sequence of discrete segments, such as “zero,” “the speed increases,” and “stop.” On the one hand, this makes the students’ analyses similar to the reading of a text. On the other hand, there are critical differences between the act of reading and the interpretative work of
the students. One of these differences concerns the “loose fit” between the graph and the formulation of the graph. A particular point in the graph can alternately be referred to as “zero,” “stop,” or reasonably be excluded from verbal interpretation altogether; what constitutes a “part” of the graph, moreover, is something that has to be decided by the students. Another difference is the way their analyses are grounded in previous difficulties and designed for their later attempts to replicate the graph by moving back and forth in front of the motion detector. When a student says, “there you can’t stop,” simultaneously pointing at a place in the graph representing constant velocity, he is not talking about the represented velocity in general. In most contexts, this would in fact be a strange way of talking about graphs. Here, however, this remark serves an important role in highlighting a feature of the graph that they had previously had problems with—the inadequate interpretation of a constant velocity as a constant position—and thereby it prepares for the later replication of the graph. In instances like this, the student thus intertwines past experiences, the present interpretation, and the future movement in one discursive event. One can also note that the utterance merges visual properties of the graph with movements, or in this case the absence of movements, in the room—the word “there” simultaneously indexes a particular part of the graph and works as a prospective indexical for the future movement.

Some researchers have suggested that the interactivity provided by probeware makes it amenable to thinking about the computer in terms of “a member in the group and conversation” (Kelly & Crawford, 1996, p. 706). There is always a danger in making too much of analogues like this in analytic work. As argued by Schegloff, saying that something is “‘like an X’ is to concede that it is not an X—else one would have said, ‘this is an X.” And it is to give up the search for what it is, and settle for what it is like.” (2003, p. 175) Although the computer can respond to the students’ actions by plotting a representation of their movements on top of the pre-defined graph, and thereby display problematic interpretations in the form of discrepancies, this responsiveness is of a different order than that of the students. Throughout the episode, the students constantly monitor each other’s actions in order to find possible implications and potential problems. When a student is saying something and simultaneously points towards the graph, the other student does not only have to hear the words that are being
said, but also actively locate what was being referred to in the graph. Even though it is possible to describe the graphs in many ways, this does not mean that every interpretation is treated equally: the students comment on each other when they “miss” a part or when the interpretation is in some sense wrong.

It is often held that traditional lab work results in “a reasonably successful student who can produce a graph but can’t say what it means.” (Redish, 1994, p. 796) Like the investigated activities, traditional labs in kinematics are commonly divided in different phases. Without the probeware technology, however, these phases differ significantly from those found in the investigated activity: the first part of a traditional lab is often used to set up the equipment, the second to collect data, and the third to plot a graph and calculate results. In this way, the observation of a movement and the plotting of the graph become separated in time. As is noted by Redish, it is thus possible to produce a graph without being able to say what it means in terms of movements. In contrast, it would be hard for the students in the investigated activity to match the velocity vs. time graph without knowing how the different parts correspond to movements. As part of the matching assignment, they had to separate velocity-time from position-time graphs, make distinctions between constant and accelerating velocity, and between positive and negative velocity. A failure to make these distinctions would inevitably result in a visible discrepancy.

DIFFERENCES THAT MAKE A DIFFERENCE

In research on science education, it is frequently shown that participation in activities afforded by probeware results in better gains on post-tests than participation in other activities, including traditional labs, lessons, and simulations. As a result of positive learning outcomes, there have been several attempts to find the “mechanisms governing the success” (Linn, Layman, & Nachamias, 1987, p. 252). Common suggestions include the use of multiple representations, real-time graphing, active student engagement, and support for collaboration. In this study, the use of probeware is contrasted with the use of simulation software called Graphs & Tracks. In the assignment based on probeware, the students were requested to replicate a velocity-time graph by moving back and forth in front of a motion detector.
simulation, the general task was to arrange a symbolized track and a set of initial conditions in a way that made the motion of a simulated ball correspond to a predefined graph. Although the simulation is different from probeware in several respects, it can be described with reference to the same “mechanisms governing success”: it makes use of multiple modalities, real-time graphing, and supports collaboration and active student engagement. This study investigates what these general characteristics mean when applied to actual educational contexts. The aim of the study is to show that some important differences between the local enactments of the two technologies are to be found in the practical work of the students; more specifically, in the ways that students orient to the subject matter content.

The use of probeware is illustrated with a short sequence where a pair of students tries to interpret and replicate a velocity vs. time graph, by walking back and forth in front of a motion detector. In their attempts to replicate the graph, the students received direct feedback from the screen in the form of a new graph corresponding to the students’ movements plotted on top of the existing graph. In previous assignments, the students had only produced and interpreted position vs. time graphs. With this limited experience, one of the students tries to match a part of the graph representing constant velocity by standing still, as if it represented constant position, which creates an observable discrepancy between the pre-defined graph and the produced graph. In the episode, this discrepancy is not only visually represented on the computer screen but also responded to by the students. While the initial reaction of the students is one of surprise and frustration, a subsequent utterance relates the graph to the previous actions, “it is ‘cause you stand still here.” In this way, the student identifies the problem and implicitly resolves it; by referring to the movements and to how these movements result in certain visual properties of the graph, the two students establish a distinction between position vs. time and velocity vs. time graphs. To sum up, the short sequence illustrates some characteristics of students’ use of probeware: they talk about the graph in terms of movements; they try to figure out what the probe measures; they highlight certain problems and single out aspects that are difficult; relevant concepts are introduced; and, the descriptions are constantly refined.

When using Graphs & Tracks, the computer presents a position versus time graph, a diagram of a ball on a set of tracks and a number of initial
conditions. In the simulation, six symbolized posts support a track and the
students are able to alter the height of these posts. The general task is to
arrange the track and the initial conditions in a way that makes the motion
of the simulated ball rolling along the track correspond to the predefined
graph. Prior to the episode that illustrates the use of Graphs & Tracks, two
students had made several adjustments to the track. In the episode analyzed,
the two students return to an earlier configuration without remembering
whether it was similar to an earlier trial. They confer with each other about
how to proceed with the assignment and reason about various outcomes;
referring to the height of one the posts, one student says, “think it should
down a little bit,” then she decreases the height and asks, “what happens if
it is like this.” In this episode, the rationale for making adjustments, as ex-
pressed in and through the students’ actions, is considerably different from
that exhibited in the students’ work with probeware. Instead of introduc-
ing conceptual distinctions or discussing the relation between graphs and
motions, the students make small adjustments based on how much the two
graphs visually resemble each other. As the students work on the assignments,
they repeatedly forget what setups they had already tried out, and their
verbal communication is directed at specific details rather than the overall
color of the represented motion. In short, the approach taken by the
students can be described in terms of trial and error.

The analysis of the video-recorded lab work, which is illustrated by the
two episodes, highlighted several critical differences between the use of
probeware and Graphs & Tracks. These differences are found in the ways
graphical representations and references to concrete movements are made, the
use of conceptual distinctions, and the incremental progression of the students’
interpretations of the graphs. Rather than referring to general aspects of the
technology or activity, these differences point to the specific ways in which
the students orient towards the subject matter content. It is not that students
orient towards graphical representations and references to concrete move-
ments that make the use of probeware different from many other activities,
but how this is done in concrete detail. In order to be appropriately under-
stood, the characteristics should therefore be understood in relation to the
students’ actions and orientations as illustrated in the analysis and not as
conceptual abstractions.
THE DARK MATTER OF LAB WORK

In the project reported in this thesis, approximately two hundred hours of video from students’ lab work have been recorded. With the aim of making detailed analyses of what students do in the lab, a key issue is what instances to analyze and present. In research on science education, two kinds of episodes are often selected for further analysis: episodes where students display some sort of misconception and episodes that clearly show learning taking place. Although such sequences might be highly informative, they constitute a very small portion of the two hundred hours. Consequently, an exclusive focus on these episodes would miss most of the students’ problems and the lion’s share of the work done in the lab. With this as a starting point, the aim of the study is to describe and discuss the dark matter of lab work; that is, the ordinary backdrop to the extraordinary sequences that are easily recognizable as clear-cut instances of learning.

The notion of dark matter is illustrated with an assignment where the students are asked to construct three graphs showing the interdependencies between Force, on the one hand, and Acceleration, Velocity and Position on the other. The assignment was designed to provide the students with an illustration of Newton’s second law, Force equals Mass times Acceleration. Instead of just providing an illustration and confirmation of the laws of mechanics, however, the assignment turns out to be highly problematic for some students. The study focuses on a sequence of ten minutes, where a pair of students asks a teacher for help. At the beginning of the episode investigated, the students doubt the status of the graphs as showing anything: they do not understand their significance, do not see what there is to be seen, and do not know how to continue. As a response to the students’ problems, the teacher engages in focused instruction as to the proper way of seeing these graphs. Among other things, he contrasts the acceleration vs. time graph with the other two and he points out that the students “should in principle be able to draw a straight line there,” thereby disregarding noise when making out shapes in the graphs.

Put simply, the episode analyzed shows an instructor telling two students how they should see a line in a graph and that this line is called a linear relationship. Despite this minimal formulation of a seemingly trivial activity, the episode demonstrates a rather complex problem, central to the students’
understanding of Newtonian physics. In order to see the relationship, several jobs are being done simultaneously: the graph is to be seen as a straight line; a straight line is to be seen as a relationship; and a relationship should be construed as the relation between force and acceleration as expressed in Newton’s second law. Thus, the apparent triviality of the activity could be questioned.

The episode also yields insights concerning the inherently interactive work that takes place between instructor and students. The students act on the visible shapes in the graphs in their attempts at addressing the lab assignment’s questions, and use the instructor’s actions to gain access to relevant subject matter knowledge. The instructor, on the other hand, formulates this knowledge as responses to the students’ actions; more specifically, as responses to the competencies or lack of competencies visible in the students’ actions in relation to the graph. Consequently, the subject matter knowledge, as made instructively available, is inherently co-constituted in interaction between instructor, students, and concrete materials.

Investigating dark matter episodes is a way of acknowledging that educational practices such as lab work are not designed to display the learning that is taking place. If anything, they are designed to result in learning, which then might be assessed and displayed by other means, such as quantitative tests or enhanced performance in later lab-work. One aim of the study is to show that an interest in sequences that look confused and open-ended, that lack happy endings in terms of insights or clearly visible conceptual changes, might be analytically revealing. It is further argued that an understanding of such episodes is crucial for our understanding of lab work and the practical and interactional circumstances in which learning is necessarily situated.

TOPICALIZATIONS OF UNDERSTANDING

There is an immense body of educational research where theoretically developed and motivated formulations of understanding are used as rationales for the choice of certain educational activities rather than others, as rhetorical means for advocating such activities, in assessments, and in empirical research. The formulations in the literature, however, although being formulations of and for science education, are not formulations in the practice of science education. There, students and teachers address understanding
for different practical purposes and in so doing, make specific interactional moves. For this study, thirty hours of video-recorded and transcribed interaction taken from a lab course in a teacher education program have been investigated. In this material, explicit references to students’ understanding, through formulations like “I don’t understand” or “do you get it,” are strikingly frequent. This has motivated the analysis of the use, reference, interactional significance, and positioning of these formulations. In the study, the material analyzed is presented and organized into four themes, with three to four episodes representing each theme.

First, some episodes where students state that they “don’t understand” to a fellow student or an instructor who supposedly does understand are examined. Expressed in this way, “I don’t understand” is commonly taken as a request for help. Sometimes, the utterance together with its sequential and material context is enough to generate the guidance asked for. At other times, the students’ problems have to be further articulated and discerned, for instance by contrasting what the students do not get with what they actually do get. Second, episodes where students ask other students if they understand are presented. When posed to another lab group, the question is often taken as a request for help, either resulting in attempts to provide the guidance needed, or—if the recipient group answers in the negative—as an opportunity to dwell on the problems with the assignments. In contrast, when posed to a student in the same lab group, the question is commonly used to check that the other student “follows,” thereby ensuring a joint understanding of the task. Third, some sequences are presented, in which claims of understanding or lack of understanding are used in conjunction with the decision to move on with a new assignment. In these cases, the practice of formulating understanding is often put squarely within the context of pragmatic considerations of how much time is left, of wanting to go home some time today, and so on. Fourth, some sequences where the instructors explicitly address the students’ understanding are presented. In these sequences, understanding is regularly oriented to something other than the ability to complete the lab assignments: the students are asked, for instance, to “try to understand as well,” even after finishing assignments. These episodes also show some problems involved in asking students about their understanding: when the instructors’ question “do you understand” receives a positive answer, the answer is a claim and not a display of the
sought-after understanding. An alternative line of action is to engage in lengthy “Socratic” dialogues, eliciting other types of responses than a yes or a no, allowing the instructors to exercise their skills, responsibilities, and rights to judge whether the students have “really understood.”

With a starting point in the episodes analyzed, the discussion begins with the distinction between claims and displays of understanding (Sacks, 1992, p. 252). In ordinary interaction, it is often enough, for all practical purposes, to provide a minimal response, such as an “uhm” or a “yeah,” to signal that one has understood what another person has said. As shown in the material, however, agreeing on the interpretation of a graph by saying “right,” is treated as a less certain display of understanding compared to participating more actively in the interpretative work. Similarly, claims of understanding such as a positive answer to the instructors’ question, “do you get it?” is commonly oriented to as problematic, requiring supplementary displays of understanding in order to be accepted.

Another relevant distinction is between understanding as being able to go on and understanding as seeing the point. In an oft-cited passage, Wittgenstein writes, “Try not to think of understanding as a ‘mental process’ at all. – For that is the expression which confuses you. But ask yourself: in what sort of case, in what kind of circumstances, do we say, ‘Now I know how to go on’” (Wittgenstein, 1953, no. 154) When Wittgenstein writes about understanding in this context, he primarily uses the example of being able to continue with a number series. The practical circumstances of knowing how to go on with such a task are relatively clear and specified, and what counts as understanding is therefore fairly straightforward. Although some instances of knowing how to go on in the lab are similar to the continuation of a number series, what is to be understood is usually not that clear, and what counts as understanding, or being able to go on, is not exhaustively specifiable. Both instructors and students visibly orient to the possibility of going on without having understood; in the words of a student, “I don’t understand how are you supposed to be able to write a lab report, we did that and that, and that and it’s like pointless.” Even though the students understand the particular task in terms of being able to go on with the assignment, their understanding, as the accomplished sense, meaning, and relevance of the activity, is called into question in and through that formulation of pointlessness.
Looming over the lab work are the assignments’ correct answers and the professional and disciplinary concerns tied to these. Despite the ongoing interactional establishment of understanding sufficient for all practical purposes, and despite well-motivated decisions that understanding has now been reached, there is always the risk that students’ understanding turn out to be inadequate. The *for-all-practical-purposes* part of the preceding sentence might be key, since what is a practical purpose could change from one moment to the next; through, for instance, a teacher’s intervention, making the practical purpose now the answering of a sequence of probing questions designed to elicit some grounds for making normative assessments as to whether students really understood.
Sometimes, lab work in science education is divided into two opposite types. On the one hand, there are traditional lab activities where students’ actions are specified in a step-by-step manner and where a typical goal is to show the correctness of a certain textbook equation. Some authors and educators therefore use the name *cookbook labs* to characterize them (e.g., Domin, 1999; Leornad, 1991; Lochhead & Collura, 1981; Roth, 1994; Trumper, 2003). On the other hand, there are labs whose design is informed by the progressive and student-centered ideology that has dominated education in many countries in recent decades. These labs, which are sometimes described as *discovery labs* or *open inquiry*, are characterized by reference to the students’ active engagement and exploratory investigations (Domin, 1999; Leornad, 1991).

Cookbook labs are often criticized, as it is argued that, “when students are regimented by lab manuals that dictate *what to think, how to think*, and *when to think*, lab activities essentially lose impact for learning.” (Pushkin, 1997, p. 240) Roth (1999), building on several years of classroom observation, provides a list of what he considers to be problematic issues with traditional labs: the students do not have a clear sense of the purpose of the labs since they just follow recipes; there are seldom demands on reflective action; the students spend much time on off-task activities, which force the teacher to increase the pace in regular classroom periods; and the theory-laden nature of observations is not accounted for. From an instructional perspective, not only cookbook labs but also unstructured discovery labs—in which students are supposed to “work out things for themselves”
(Edwards & Mercer, 1987, p. 33)—are often conceived of as problematic. Bergqvist and Säljö (1994) present an investigation of a secondary school science lab. The goal of the lab work, from the teacher’s point of view, was to let the students investigate and discover scientific properties of light, such as “light travels in a straight line,” and that, “light does not go through solid objects.” Although the purpose of the lab was clear to the teacher, the students had problems seeing the relevance of the lab. According to some students “nothing happened” and when interviewed afterwards some students conceptualized the intended goal as learning “how to fasten lamps and things on the bench.” Bergqvist and Säljö argue that the discrepancy between the viewpoint of the students and that of the teacher primarily arose because the students lacked interpretative resources needed for seeing contextually significant aspects of the event. This is often pointed to as a general problem with student centered and inductive approaches, and it is argued that the appealing pedagogical ideas of making students active learners and young scientists seem to be difficult to achieve in practice (cf. Edwards & Mercer, 1987; Hodson, 1990; Lilja & Lindström, 2002).

The kind of lab work that has been investigated in this thesis is often put forward as the superior alternative to cookbook labs and unstructured discovery labs. The characteristics of the alternative, and what makes it different from other activities, are suggested in names such as interactive-engagement (Hake, 1998; Royuk, 2002), guided discovery (Ausubel, 1968; Novak, 1979), and computer supported inquiry learning (van Joolingen, de Jong, & Dimitrakopoilou, 2007). Even though these names and the associated theoretical characterizations fit the investigated activities, they also leave out much of the practical and mundane work that goes on in the lab. Returning to a formulation by Garfinkel: “There is no cure for talking jargon. You’ll cut your brains out if you stop talking jargon. But, you don’t want to trust the jargon you’re talking. Because there is still something more.” (2002, p. 177) In the studies presented in this thesis, this “something more” has been addressed by means of detailed explications of the interpretative work performed by students and teachers as they struggle with the practical contingencies presented by the tasks, the technology, and the subject matter content as made visible through the material arrangements of the lab.

At first glance, the lab work investigated comes across as less exciting than formulations such as interactive engagement or guided discovery.
might suggest. Many of the characteristics attributed to cookbook labs and unstructured discovery labs can also be ascribed to the activities investigated: there are several instances where students have problems in seeing the purpose of the lab; the students lack a lot of those interpretative resources that are needed for seeing contextually significant aspects of the events; and in many instances not much reflective action can be seen. Recognizing that most of their interaction could be seen as equally messy and incomplete, it is argued that the episodes selected, despite their ordinariness, have a fundamental role to play in this type of lab work. Thus, instead of exclusively looking for episodes that clearly display “conceptual changes,” detailed studies of the slow progress in the interpretation of a velocity vs. time graph, the non-closure of seeing a linear relationship, and the many vague formulations of understanding that are made in lab work might be equally, if not in some respects more, revealing as to the conditions under which the learning of science is irremediably situated.

INSTRUCTION, INSCRIPTION, AND INTERPRETATION

Instructions and the following of instructions are at the heart of lab work. This holds equally true for interactive-engagement activities, discovery labs, as it does for cookbook labs. In all these activities, instructions guide both actions and perception; they specify how one should proceed, what to focus on, what is relevant, and what is not (cf. Amerine & Bilmes, 1988). No matter how carefully formulated, however, “a great deal more is necessarily done than can be comprised in the instructions.” (ibid, p. 325) There are always some singularities of the situations that have to be accounted for. Lynch and Jordan note that the local effectiveness of instructions are tied to the production and coordination of action, and they hold that:

Formal instructions become adequate only when the practitioners who use them rely upon a locally organized ‘sense’ of what the instructions are saying. This “sense” is found, recognized, and displayed in the very looks of the things at hand, and in the historicity and conditional relevancy of successive moments of action. (1995, p. 228)

Some of the studies have set out to explore how localized sense is found, recognized, and shown in relation to graph interpretation. In the matching tasks investigated—where the students were to replicate a velocity vs. time
graph by moving back and forth in front of a motion sensor—different kinds of instructions can be found. First of all, there was the written instruction saying what the students should do: that they first should discuss the represented movement, then turn the sensor on and try to replicate the graph, and finally discuss the discrepancies between the graph produced and that which they were supposed to match. The students spent little time with this instruction; they read it, started the task, and never returned to it. Another kind of instruction, which acquired more interpretational effort, was to be found in the graph they were to produce. By itself, a graph does not provide an instruction. In the context of the matching tasks, however, the students had to find an instruction in the graph. In order to match the graph, the students had to move in certain ways, and these ways was specified by the graph.

In the students’ verbal interpretations, the graphs were carved up into discrete sections, where each section represented a qualitative change in the way that the students had to move. These interpretations were formulated as instructions, and could therefore be seen as constituting a third type, closely interconnected with the other two. The instructions formulated by the students gradually developed over time and became more specific, detailed, and adequate for the purposes at hand. Returning to a formulation repeatedly used in the introduction, it was through these instructive interpretations the graph and the movement became “visibly-rational-and-reportable-for-all-practical-purposes” (Garfinkel, 1967, p. vii).

In the case of the matching tasks, the students seldom needed any help. Through the joint efforts of the group, and by repeatedly trying out new ways of moving in front of the motion sensor, they eventually arrived at a solution they were satisfied with. Whereas the matching tasks provided the students with a clear picture of what the end result should look like, most lab assignments were not structured like this. Commonly, the students did not know the end results of their experiments, which made it hard for them to detect errors in their own performance. In one of the episodes investigated, for instance, the students were asked if they could find a linear dependency in any of three graphs they had produced. Since the students did not know what a linear dependency in a graph would look like, they were unable to know if they had managed to follow the instruction or not; they did not know if there in fact were anything there to be seen. Having
the relevant competencies, the teacher could directly see that there was no visible relationship in the graph, and that the students therefore must have done something wrong. After having helped the students in the production of an adequate set of graphs, the teacher attempted to show the students how a linear relationship could be seen in the graph. In his attempts to make the relationship visible to the students, the teacher used an array of visual, interactional, and embodied methods. These methods were all made relevant by the students’ displayed problems and understandings. Given that this instructive work was inherently interactive and responsive to the way the students present their difficulties, it would consequently be hard to instantiate in text-based media, such as textbooks or laboratory instructions.

THE PRACTICAL ACHIEVEMENT OF UNDERSTANDING

One reason for focusing on activities afforded by probeware rather than other educational technologies has been the stably positive results of quantitative measures (e.g., Bernhard, 2003; Thornton, 1997). In relation to the clear-cut test results, however, there is little clear-cut evidence of learning to be found in the actual lab work. This is not particularly strange. Most learning environments, including the one investigated here, are not designed to show learning as it takes place, but to result in learning. However, if one looks close enough, accepting that there are few clear-cut instances of learning, and leaving the issue of whether students really have understood to the members of the setting, there is still much to find out and say about the conditions for learning in the situations investigated.

None of the studies set out to explore if the students actually learned the subject matter content. To investigate that, a clinical interview or a standardized test might do a better job. Instead, the studies have opened the black box provided by general characterizations, such as interactive engagement and real-time graphing, by focusing on the ways teachers, task formulations, and technology make mechanics visible and learnable, and how students and teachers witnessably orient towards the practical achievement of understanding in the setting—achievements that despite being of a conceptual and theoretical nature nevertheless are “practical, temporal, contingent, and thereby open to failure, and thereby again, equipped with resources
for their repair that are no less actionable” (Macbeth, 2007, p. 2) Focusing on the practical achievement of understanding, rather than learning, has been a way to stay close to what is “demonstrably relevant for the parties” (Schegloff, 1997, p. 183).

When the students attempted to match a graph in the kinematics labs, the issue of the practical achievement of understanding was relatively clear to them; they needed to understand the graph in terms of movements to be able to accurately reproduce it. Although the students often negotiated the correctness of the interpretations and the graphs produced, the materiality of the graphs and movements provided ample grounds for their assessments. They could see and point to what they considered to be mistakes and misunderstandings. The way that the produced graphs showed an understanding of the interpreted graph, also made it is possible for a teacher to move around in the room in search of publicly displayed misunderstandings. In the case where a teacher tried to make the students see a linear relationship in the graph, however, there were no clear grounds in the situation for deciding whether the students actually had achieved an adequate perception of the graph. Even though the teacher, through his instructive work, made many cognitive and practical competencies involved in producing, recognizing, and understanding the graph materially manifest, the students’ understanding remained elusive; their perception was not straightforwardly assessable, and thus open to negotiation.

When taken together, the studies display a tension inherent in all lab work. On the one hand, they show how technology, task structure, and teacher interventions worked to make both mechanics and student understanding visible, accessible, and manifest. On the other hand, they highlight the inherent openness as to the criteria for assessing whether understanding has actually been achieved.
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