Uniformity in physics courses and student diversity

A study of learning to participate in physics

Anders Johansson

UPPSALA
UNIVERSITET

Abstract
Johansson A. 2015. Uniformity in physics courses and student diversity. A study of learning to participate in physics. 59 pp. Uppsala.

This licentiate thesis describes an investigation of participation and achievement in undergraduate physics courses with a discourse analytical lens. Issues of unequal participation have been a growing concern for the physics education research community. At the same time, these issues have not been explored to any large extent using already developed theoretical tools from fields of social science and humanities. This thesis builds on earlier studies in physics education research but crosses disciplinary boundaries to bring in perspectives from gender studies. The two papers use a discourse theoretical framework to explore what it might mean to participate in physics, whether that is one's primary subject or not, in courses in electromagnetism and quantum physics. A general conclusion that can be drawn from these empirical studies is that physics courses may often be taught from a narrow physics perspective, and that this may limit the possibilities for identification for many students. For instance, engineering students whose main area was not physics failed to see much significance in studying electromagnetism and then just "studied to pass". Additionally, students on physics programmes may find that the limited positions in quantum physics which can be characterized as mainly focused on "calculating", are hard to reconcile with their interest in physics. Using a discourse perspective, I broaden this critique to a discussion of the culture of physics: What does it mean to become a physicist and what physics culture follows from different "productions" of physicists? These results inform continued research in physics education by raising issues of identity and providing critical frameworks for exploring them. They also point to the importance of including broad views of physics in courses. Critically examining participation in physics, this thesis aims at widening the discussion and provide new ways to talk about these issues in physics education research.

Keywords: undergraduate physics education, science participation, discourse, identity, subject position, quantum physics, electromagnetism

Anders Johansson, Institutionen för fysik och astronomi, Ångströmlaboratoriet, Lägerhyddsvägen 1, 751 20 UPPSALA

urn:nbn:se:uu:diva-267308 (http://urn.kb.se/resolve? urn:nbn:se:uu:diva-267308)

List of papers

This thesis is based on the following papers, which are referred to in the text by their roman numerals.

I Andersson, S., Johansson, A. (2015, under review) Gender gap or program gap? Students' negotiations of study practice in a course in electromagnetism, *Physics Review Special Topics – Physics Education Research*

II Johansson, A., Andersson S., Salminen-Karlsson, M., Elmgren, M. (2015, submitted) "Shut up and calculate": the available discursive positions in quantum physics courses, *Cultural Studies of Science Education*

Contents

Preface

When I started studying physics, about 30 people started on the programme with me. Now, almost ten years later, 14 of these people have a degree in physics. That is a pretty good result. However, the story does not end there, and neither do my research questions. The question of becoming a physicist is not only a question of getting a degree, it is also a question of *becoming someone*, and what strikes me as particularly intriguing about my experiences is that, even though they may have a degree in physics, my former classmates may not necessarily see themselves as physicists, and certainly not as the kind of physicist they imagined themselves becoming when they started at the university. Surprisingly, several of the people who initially aimed for a research career in physics and were successful in their studies have changed directions and are now working in other areas. What does it *mean* to become a physicist, and how does this affect *who* can become a physicist?

Asking these kinds of questions means asking questions about identity and culture in physics education. If we, in a sociocultural tradition, view learning as not only an acquisition of content knowledge, but also as becoming part of a community and forming an identity, we can begin to find some answers. In particular, we can begin to ask the uncomfortable but necessary questions of who is welcome into the culture and community of physics, and who is not, and whether these inclusions and exclusions are as neutral and meritocratic as is often wished for. Employing a discursive view of identity and culture, I aim to ask these kinds of questions in order to provide a valuable and critical picture of physics education as a social practice, how it may be reproducing certain physics cultures and how it can work as an arena for negotiations of identity. Doing this will hopefully enable us to better see the problems and virtues of physics education and the people in it, beyond a mere counting of possibly laureled heads.

1. Introduction

1.1 Participation in science

Taking a starting point in my own experiences of physics education, I want to explore what it means to become a physicist and who can participate in physics. However, the discussion about participation in science has been taking place for a long time. The discussions about science participation can often be characterized as a discussion of a "lack", conceptualized in what has been called a "deficit framework" (Zeidler, 2014). This can be stated as "Europe needs more scientists" (European Commission, 2004), or in asking the question "why so few" women study science and engineering (Hill, Corbett, & St. Rose, 2010). The issue in this view seems to be how to get more (of certain kinds of) people into science. More or less working under these premises, scientific studies of recruitment and retention of university students however give many different answers to how this can be approached. Students' interest in science has been shown to be declining in western countries and large assessments like PISA show that girls are generally less inclined towards a science career than boys (Sikora & Pokropek, 2012), i.e. girls "lack" science interest. Thus much effort has been put into increasing school students', and particularly girls' interest in science, with mixed results.

Studies in recent years have employed perspectives from social theory, regarding identity negotiations of young people in late-modern societies to explore the processes behind their study choice (Holmegaard, Ulriksen, & Madsen, 2014; Department of Education and Professional Studies, 2013; Archer et al., 2012; Schreiner, 2006). Similarly, studies of students' negotiations about leaving or staying at their university education have shown that the reasons are multiple (Seymour & Hewitt, 1997), but that students may often attribute all reasons for "failure" to themselves (Johannsen, Rump, & Linder, 2013). Studying student retention with the novel statistical approach of network analysis, the influence of different parts of the system on students' choices can be mapped in greater detail, and results from such studies have indicated that relationships between teachers and students play a large role (Forsman, Mann, Linder, & van den Bogaard, 2014; Forsman, Linder, Moll, Fraser, & Andersson, 2014).

Thus, research has taken the question of "lack", from lacks in women's (and minorities') ability or interests, to addressing problems in institutions or attitudes in society as a whole. These structural factors can be seen as "excluding" or "repressing" certain students, making science still "lack" these people.

But, drawing from Foucault's notion of power as not simply repressing, but rather producing (Foucault, 1975/1995, p. 194), I want to pose the questions in a different way and ask what culture and identities are (re-)produced in physics education. This shifts the focus from the lack of certain people or certain people as lacking ability or interests to scientific culture itself. Feminist science studies have long argued that the culture of science holds many problems, for instance in its androcentrism (Merchant, 1980/1989; Harding, 1986; Keller, 1985/1995), but I want to investigate the role of the culture of science in the specific context of undergraduate physics education, my disciplinary home.

1.2 Physics education research

Research on physics education at the university level (PER) has been a distinct research field for almost 30 years. Situated at physics departments, with an in-depth knowledge of physics but drawing on other education research, PER-researchers have been successful in detailing students' learning of physics and effecting change of teaching practices at many institutions. PER is a multidisciplinary field, drawing on physics, education and at times psychology, and some claim that this multidisciplinarity must be taken seriously and should not, for example, be "based on a smattering of physics and education knowledge, but on a solid foundation in both disciplines" (van Aalst, 2000, p. 67). My project aims at taking this multidisciplinarity seriously and widening it by bringing a perspective from gender studies into physics education research.

1.3 What gender studies brings to PER

My research, as PER in itself, is interdisciplinary in its nature, aiming to inform PER with theoretical frameworks from gender studies and similar fields. This interdisciplinarity is reflected in my background, in physics and gender studies, in the composition of the group of supervisors and in the genres of academic writing employed.

The goal of the project is to provide valuable insights into questions of identity and other social aspects of physics education, questions that have to a large part been absent from PER. Particularly, my aim is to provide theoretical frameworks that could be useful for approaching these issues in physics education. PER has often been discussed as lacking theoretical frameworks (Redish, 2014), and in approaching new ground by studying social issues, there is certainly a need for informing this research with theories already developed to deal with these issues in the social sciences and humanities.

However, my aim is not only to provide PER researchers and physics educators with more tools to understand how to attract students to physics and get them to learn it. A part of my project also aims at discussing the role of the culture of physics in physics education and in society. Thus, while PER, as a kind of Disciplinary Based Education Research (DBER), can be characterized as investigating "learning and teaching in a discipline using a range of methods with deep grounding in the discipline's priorities, worldview, knowledge, and practices" (National Research Council, 2012, p. 9), my aim is to not be too deeply indebted to the "priorities" and "worldview" of physics, instead opening up for questioning the discipline of physics in itself. In simple words, taking the critical research standpoint used in most gender research and using it in physics.

1.4 Overview of the papers and coming chapters

This text provides a framework to discuss and situate the included papers, but before doing this and discussing the papers more in detail a short overview of the papers is needed.

Paper I is a study of what at first look seems to be a "gender gap" in students' achievements on a course in electromagnetism. Using a discourse theoretical framework, Staffan Andersson and I show how students negotiate their practice in the course in relation to discursive identities which are perhaps not primarily related to gender, but rather to study programme. The overall gender distribution of the physics and engineering programmes included in the study however give an overall statistical gender difference. In the paper we discuss how this could be conceived in terms of manifestations of gender on different levels of society, and how a qualitative, discursive approach helps us approach these problems better.

Paper II, my main project, is a study of the discourse of quantum physics courses. Based on my observations of classes and interviews with students, I, along with my co-authors, have analysed the discourse in three quantum physics courses and found that there seems to be limited approaches to "doing" quantum physics. We argue that these limits, characterized by the "calculating quantum physics" practice, makes certain positions as a quantum physics student "unintelligible", thus perhaps in the long run also reproducing a physics culture premiering a "shut-up-and-calculate" attitude.

Both these studies apply a discursive view of identities in physics education, and the rest of this text will situate this research in relation to other studies in PER and science education, describe the theoretical background of the frameworks used and go into some detail in how discourse analysis can be carried out.

2. Situating my research

This project is situated in a PER context, but also draws on recent developments in the wider area of science education and theories and methodologies from social science, particularly gender studies, to elaborate on issues of identity and culture. This chapter provides an overview of how my project relates to the traditions and research paradigms in these fields. I will start by describing the background of research in science and physics education, continue with outlining contemporary research in the field of PER and discuss what research paradigms are dominant in PER and science education in general. Then comes discussions of the concept *identity*, how it has been used in PER and science education in general and how identity studies could be informed by theories from gender studies. My critical re-formulation of the questions of participation in science concludes the chapter.

2.1 The background and development of research in science education

Research in physics education, and in science education in general, started to expand in the decades after World War II. In an American context, this is connected to the educational reforms initiated in the US after the successful launch of Sputnik, when scientists were urged to contribute to a renewed science education that would make Americans more prepared to compete with the Soviet Union in the "science race" (National Research Council, 2012, p. 20). After this, science education research has gone through several waves of resurging interest. According to De Jong (2007), these waves can be characterized by the different theoretical frameworks emerging at the time. The first, post-Sputnik, wave, was influenced by "descriptive behaviourism" and "cognitive development" theories; the second, after the disappointments of the first wave and the 1983 publication of the American report "A Nation At Risk", was influenced by "cognitive psychology" and "information-processing", and brought active learning into the scene; the third, and still ongoing wave, (2000s) is then influenced by "social constructivist" and "sociocultural" perspectives (De Jong, 2007, pp. 16–17). Despite these developments, much research in science education and physics education has been inspired by a scientific (or scientistic) world view, meaning that the means of improving education are seen as doing experiments or other kinds of empirical studies to

determine what measures that best seem to increase students' learning. This is most obvious in the policy documents urging for better STEM (Science, Technology, Engineering and Mathematics) and research aligned with these (see Zeidler, 2014; Treagust, Won, & Duit, 2014). What students should learn is often taken for granted in this context. Though this may be challenged by for example social constructivist perspectives, a large part of science education can still be viewed as working in a "post-positivist" paradigm (Treagust et al., 2014). Some critics even pose mainstream research as well as research influenced by other paradigms as largely influenced by "scientism" and "crypto-positivism" (Kincheloe & Tobin, 2009). I will discuss the different research paradigms in science education and physics education further below, but I will start by characterizing the research traditions in PER.

2.2 An overview of physics education research

The post-Sputnik curriculum developments also concerned the recruitment and education of science professionals at universities, but it was not until the late 1970s that in-depth explorations of student learning of university physics took its start, as researchers at the University of Washington started investigating students' understandings of kinematics (Trowbridge & McDermott, 1980, 1981; McDermott, 2001). Since then, PER has grown into a wide and independent field, mostly focusing on education at undergraduate level and with most research still done in the US where up to 100 different groups, both situated in and outside physics departments, are conducting research in physics education. In the rest of the world, 15 more groups are registered on the *PER Central* web page, administered by the American Association of Physics Teachers, (AAPT, 2015), but several more exist, although they do not necessarily communicate widely with the international (English-speaking and US-centered) PER community. For example, several groups in Germany do PER (Physikdidaktik) but publish almost exclusively in German.

Physics Education Research is an example of what is usually called Discipline-Based Education Research (DBER), that is, research of teaching and learning in a specific discipline (of science and engineering), where the researchers combine an extensive knowledge of their discipline with methods and theories from, among other fields, psychology, educational theory, and anthropology (National Research Council, 2012, p. 10). As is common for DBER, PER groups are often situated at the departments of their discipline, although different arrangements and collaborations exist (National Research Council, 2012, p. 21). Being situated at physics departments have been argued as necessary for the success of PER, mainly because: "education research conducted by physicists in physics departments is more credible, more accessible, and, in general, more relevant to physics faculty than that conducted in col-

leges of education or departments of psychology (although the conclusions are typically consistent)" (Heron & Meltzer, 2005, p. 391). However, being situated in a physics department is not always easy for researchers doing interdisciplinary work, and one of the obstacles discussed by PER researchers is the struggle to be accepted, both as physicists (Barthelemy, Henderson, & Grunert, 2013, p. 10), and as legitimate researchers at all, as teaching and learning has often been viewed by conservative physicists as more of an art than a science (Cummings, 2011, p. 7; McDermott, 2001; Beichner, 2009). Another problem can be that PER researchers often are not taken as serious researchers, but instead viewed as "resource people whose major responsibility is to provide local support for instruction rather than to conduct scholarly research" (Heron & Meltzer, 2005, p. 392).

A characteristic of PER that may both be an asset and a hindrance is the tendency to approach problems of teaching and learning that are in some ways inherently psychological and social with methods inherited from physics and natural sciences (Heron & Meltzer, 2005), for example manifested in a preference for "papers in which the approach and the rules of evidence are close to those traditional in the physics community" (McDermott & Redish, 1999, p. 757) when overviews of PER are put together. This focus on measurement, experiment and statistical validity has made PER more acceptable to physicists, but perhaps more ignorant of perspectives and methods from the social side of educational research, the side of PER that should not be forgotten (van Aalst, 2000). One indication of this (scientistic) tendency is that PER has borrowed methods and results from cognitive psychology and neuroscience more often than from other fields (McDermott & Redish, 1999, p. 765).

2.3 Major areas of contemporary research in PER

As PER has grown, several different aspects of physics teaching and learning have been explored. This section will shortly describe some of these fields.

2.3.1 Conceptual understanding

PER began, as have been described above, with investigations of how students come to understand kinematics. Since then, a large part of the research in physics education has been concerned with how students learn (or do not learn) certain physics concepts. These kinds of studies were initially largely based around identifying students' "misconceptions" about physical concepts and resulted in extensive "catalogs" of possible misconceptions (Docktor & Mestre, 2014, p. 2). The term "misconceptions" has been debated and "modified to 'student difficulties,' 'naïve conceptions,' or 'intuitive understanding' in an attempt (which was not entirely successful) to minimize the negative

connotations of the original name" (Beichner, 2009, p. 13). Even though using "misconception" might be considered too "degrading" to students' everyday thinking, it is still used today (see e.g. Temiz & Yavuz, 2014).

The dominant methods for probing students' conceptual understanding has been individual "demonstration interviews", developed by the University of Washington PER-group and modeled after Piaget's clinical interviews, and "concept inventories", large-scale questionnaires distributed to assess the conceptual understanding of large groups of students (McDermott, 2001, p. 1128; Cummings, 2011, p. 12). Studies of students' conceptual understanding started out as empirical investigations not employing extensive theoretical frameworks (McDermott & Redish, 1999, p. 765), but over time a few different frameworks for describing how students come to understand or not understand science concepts have been proposed and used (Docktor & Mestre, 2014, p. 3). Some of the main theories are the "conceptual change"-theory first put forward by Posner, Strike, Hewson, and Gertzog (1982); different "knowledge in pieces"-views like the resources view of Hammer and others (Hammer, Elby, Scherr, & Redish, 2005); the "facets"-view of Minstrell (1992); and the "ontological categories"-view of Chi and others (Chi & Slotta, 1993). Whereas the earlier theories described students' conceptions in relatively stable terms, as naïve theories or alternative frameworks, this was criticized for instance as not taking context into account (Linder, 1993a), and much recent research has focused on "microprocesses of change", in line with the resources framework, and e.g. viewed students' understandings as reflecting "multiple local coherences" (Frank & Scherr, 2012, p. 1).

The research on conceptual understanding started with concepts in the introductory courses of college physics, for instance kinematics and dynamics (Trowbridge & McDermott, 1980, 1981; Viennot, 1979). Interpretations of graphs was also an early area of interest (McDermott, Rosenquist, & van Zee, 1987), along with electricity and magnetism (Fredette & Lochhead, 1980; Fredette & Clement, 1981; Cohen, Eylon, & Ganiel, 1983) and sound (Linder & Erickson, 1989; Linder, 1993b). Studies exploring understanding of more advanced physics topics have been undertaken more widely in recent years, though some early examples exist. Examples of topics are special relativity (Hewson, 1982; Scherr, Shaffer, & Vokos, 2001; Scherr, 2007) and quantum mechanics (Fischler & Lichtfeldt, 1992; Johnston, Crawford, & Fletcher, 1998; Wittmann, Steinberg, & Redish, 2002; see Falk, 2007, for an in-depth review). A comprehensive list of what had been done up to 1999 is also available in the resource letter by McDermott and Redish (1999).

2.3.2 Problem solving and representations

Another large area of PER is research on problem solving. It is an area initially centered in practice: physics and physics education involve a lot of prob-

lem solving, and this often causes problems for students. The first studies in this area examined how students solved or categorized problems compared to experts (Larkin, McDermott, Simon, & Simon, 1980; Chi, Feltovich, & Glaser, 1981; See Docktor & Mestre, 2014, for a longer discussion). These comparisons grew into discussions of how successful scientists think (Van Heuvelen, 1991) and into promoting the learning of what is sometimes called "expert-like thinking" (Adams & Wieman, 2011).

Some of the research on problem solving has developed into investigations of how representations of physical concepts are used in physics and physics education. These studies, more common in the last decade, have studied what representations are used in problem-solving, how students translate between different representations (often in contrast to experts), and also what using specific representations entails (Docktor & Mestre, 2014, p. 7; Ibrahim & Rebello, 2012; Kohl & Finkelstein, 2008; Meltzer, 2005). Newer developments in this area have brought in results from linguistics and social semiotics to explore the utilization of "semiotic resources" in physics learning, arguing that different resources afford different understandings of physics concepts (Fredlund, Airey, & Linder, 2012).

2.3.3 Students' attitudes and beliefs

PER researchers have, like other science education researchers, been interested in studying students' and teachers' attitudes and beliefs. This research aims at understanding e.g. how students and teachers view physics learning, general attitudes towards science, and what epistemologies students use to make sense of physics; all these questions evaluated in the light of what may lead to the best learning of physics (Docktor & Mestre, 2014, p. 35). Both qualitative and quantitative methods have been used to explore these issues, with several large surveys developed to assess student populations (see below), but also interview studies with students (Hammer, 1994) and teachers (Henderson & Dancy, 2007). These studies have shown that there are often problems for students learning physics, related to what learning approaches and epistemological views they hold (Elby, 2001, 2010). One example of this is that "students perceive 'trying to understand physics well' to be a significantly different activity from 'trying to do well in the course'" (Elby, 1999, p. 52). The problems have also in this case been formulated as a transition from journeyman to expert "epistemological skills" (Bing & Redish, 2012).

2.3.4 Development of teaching and curricula

Along with investigating physics education, PER naturally aims at improving physics education. Several teaching methods, teaching materials, and curricula have been developed and tested by PER researchers and people inspired by

PER, and the methods have been more or less closely related to PER research. One of the more influential methods is *Peer Instruction*, popularized as a way of reforming lectures by Eric Mazur and others (Mazur, 1997; Crouch & Mazur, 2001; Crouch, Watkins, Fagen, & Mazur, 2007). This method is informed by PER in using the central fact that *interactive engagement* generally leads to better conceptual understanding for students (as has been shown in several large surveys, cf. Hake, 1998; Freeman et al., 2014) and in using knowledge about common "alternative conceptions" in creating questions. The PER group at the University of Washington have, closely based on their research on students' conceptual understanding, developed two influential curricula, the lab-based *Physics by Inquiry* and the model for reformed tutorials *Tutorials in Physics* (McDermott, Shaffer, & Rosenquist, 1996; McDermott & Shaffer, 2002; McDermott, 2001).

Other curricula and methods developed by PER researchers include the almost completely lab-based *Investigative Science Learning Environment* (Van Heuvelen & Etkina, 2005; Etkina & Van Heuvelen, 2007; Etkina et al., 2010) and other methods reforming the whole classroom like *Studio Physics* (Wilson, 1994; Cummings, Marx, Thornton, & Kuhl, 1999) and more recently SCALE-UP (Beichner et al., 2007). A few general physics textbooks have also been based on research in PER, e.g. *Understanding Physics* (Cummings, Laws, Redish, & Cooney, 2004) and *Matter and Interactions* (Chabay & Sherwood, 2010, 2007).

2.3.5 Tools for assessing student understanding, attitudes, and epistemology

PER researchers have developed several tools for assessing students to be able to compare and determine the efficiency of different educational strategies. These tools mainly consist in questionnaires distributed before and after teaching specific subjects. The surveys for assessing students' understanding of different physics concepts are generally referred to as "concept inventories". A few of the more widely used (along with a few newer ones) are:

- Mechanics: The *Force Concept Inventory* (FCI, Hestenes, Wells, & Swackhamer, 1992), the *Force and Motion Conceptual Evaluation* (FMCE, Thornton & Sokoloff, 1998), and the *Test of Understanding Graphs in Kinematics* (TUG-K, Beichner, 1994).
- Electricity and magnetism: *Conceptual Survey in Electricity and magnetism* (CSEM, Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), *Brief Electricity and Magnetism Assessment* (BEMA, Ding, Chabay, Sherwood, & Beichner, 2006), and *Colorado Upper-Division Electrostatics diagnostic* (CUE, Chasteen, Pepper, Caballero, Pollock, & Perkins, 2012)
- Quantum mechanics: *Quantum Mechanics Conceptual Survey* (QMCS, McKagan, Perkins, & Wieman, 2010)

Several surveys have also been designed for assessing students attitudes towards science, approaches to learning physics and epistemological beliefs. These include:

- The *Maryland Physics Expectations survey* (MPEX, Redish, Saul, & Steinberg, 1998), which probes for general beliefs about physics and learning physics.
- The *Views About Sciences Survey* (VASS, Halloun, 1997).
- The *Epistemological Beliefs Assessment for Physical Science* (EBAPS, Elby, 2001), designed for high school physics.
- The *Colorado Learning Attitudes about Science Survey* (CLASS, Adams et al., 2006), which builds on the others and tries to include a broader scope of issues.

2.4 Contemporary PER: Mainstream, periphery and paradigm

As described in previous sections, physics education research is a mature field that has been able to contribute greatly to the understanding of physics learning and the improvement of physics teaching. It has done this through a tight involvement with physics and physics teaching, and this has enabled studies that use a deep understanding of physics together with a thorough experience of physics education to provide deeper insights in what matters for the learning of physics. However, although PER has widened to include a lot of different areas and research methods, the main part of the research still being done today can be classified as "exploring students' understanding of physics concepts". A limited survey of articles published in *American Journal of Physics*, *European Journal of Physics*, and *Physical Review Special Topics – Physics Education Research* between 2011 and 2013, conducted along with fellow Ph.D. students at the PER group at Uppsala University, revealed that about half of the published studies could be categorized as "conceptual understanding" or (simple) "teaching improvements". It needs to be mentioned though, that there is a difference between journals where PRST-PER in general seems to include more broad topics and demand a wider contextualization than the other journals.

In this section I will describe some of the current debates in PER and point to what may be topics outside the mainstream of PER.

2.4.1 Use of theory

Most early studies in PER were empirical and exploratory and did not employ any coherent theoretical framework. McDermott and Redish (1999, p. 765) argue that this is perfectly acceptable for a new research field but that

a theoretical framework nevertheless can be useful. Several theoretical frameworks have since been utilized in PER. Karen Cummings, in a report describing the development of PER, argues that early PER research was "born of a Piagetian framework both in regard to ideas of concept formation and use of clinical interviews to determine them" (Cummings, 2011, p. 9) and lists several other frameworks that have also been used: Vygotskian social constructivism (Smith, diSessa, & Roschelle, 1994), a theory of "cognitive apprenticeship" in expert-novice transition discussions, and different versions of a "knowledge-in-pieces" frameworks, from diSessa's p-prims (1993) to the resources framework elaborated by Hammer, Elby, Redish and others (Hammer & Elby, 2003; Redish, 2003; Hammer et al., 2005).

Several authors state that the theoretical frameworks developed in PER do not come close to being as well-developed and having the same predictive power as physical theories, and warn that this may never be the case, even though they do not exclude that possibility (McDermott & Redish, 1999, p. 765; Heron & Meltzer, 2005, p. 391). This is rather surprising, given the social nature of education research. Perhaps the claim by Heron and Meltzer that some PER researchers aim at "elucidating a few fundamental principles from which broad explanatory if not predictive power can be derived" (2005, p. 391) can be taken as evidence of the "scientistic" tendency of some of PER mentioned earlier, where the dream of a unification of science still thrives.

In the debate over theory, some researchers argue more strongly for the necessity of using a theoretical framework. Edward Redish is one of the most influential proponents of this view, and his advocacy of the resources framework took its real start in the beginning of the 2000s when he delivered the paper "A theoretical framework for physics education research" and has continued ever since (Redish, 2003, 2014). Similarly, Cedric Linder has been an equally strong proponent for theory and this has influenced the theoretical focus of the PER group in Uppsala. Yet, other PER researchers maintain the view that "empirical studies that are not necessarily closely identified with a specific theoretical framework will continue to lead to significant advances in instruction" (Heron & Meltzer, 2005, p. 391). This is also the view of Lillian McDermott according to Cummings (2011, p. 9).

2.4.2 Research paradigms in PER

PER inherits some of its methodological views from physics, but has from the beginning used many qualitative methods, including interviews and classroom observations. Still, comprehensive and statistically significant evidence gathered through large surveys is often seen as the most legitimate source for claims about physics learning. Robertson, Scherr, and McKagan (2015), in an unpublished pre-print, argue that there are two broad paradigms in PER, which do not necessarily have a one-to-one correspondence with spe-

cific (quantitative or qualitative) methods, but rather is defined by their ontological and epistemological premises. The paradigms they outline are: recurrence-oriented and case-oriented research (which may however be mixed), and they argue that to understand each other, researchers from the different paradigms may need "translation" (Robertson, Scherr, & McKagan, 2015, p. 20). In a companion paper, Robertson, McKagan, and Scherr (2015), try to provide parts of this translation as an explanation of the basis for and practices of case-oriented (mostly qualitative) PER, for "researchers who primarily identify with the recurrence-oriented PER paradigm" (Robertson, McKagan, & Scherr, 2015, p. 1)

As a researcher using qualitative methods, I am interested in how and why other researchers in PER advocate qualitative research. In the few texts I have found discussing qualitative research in PER, I find that "qualitative" in PER entails a rather specific view of the social world, one that in the terminology of Guba and Lincoln (1994) mostly seems to match a post-positivist paradigm of qualitative research. In the discussion of Guba and Lincoln (1994; elaborated in: Lincoln, Lynham, & Guba, 2011) qualitative research can be interpreted in line with four (later five) paradigms: positivist, post-positivist, critical theory and constructivism (and participatory research). They describe how a great deal of critique of the realist views of traditional positivist and post-positivist paradigms have led to the more elaborate views of social reality defended in critical theory and constructivism (Guba & Lincoln, 1994, pp. 106–107).

Reading what PER researchers write about qualitative methods, I find little awareness of the discussions of e.g. the "crisis of representation" that have led researchers in other fields of social science to question the realist assumptions of traditional views. Instead, PER researchers seem to be arguing for using qualitative methods to come closer to the "real" meanings of what happens in social interactions. In a report from a seminar at the PER conference in 2002, Sandifer and Johnsson discuss problems with the validity of qualitative research as possible "inaccurate perceptions" of the student or researcher (Sandifer & Johnsson, 2002). They also describe "influencing the subject" as a significant risk of interviews. This understanding of qualitative research seem to adhere clearly to a post-positivist view, where we can approach knowing the real processes of social interaction (but not prove that we know them) if we are sufficiently careful. In a similar vein, Otero and Harlow (2009), in a "manual" for doing qualitative PER research, discuss the validity and reliability of qualitative research as requiring "triangulation" and "thick description" to get an "accurate view of the participants' reality" (2009, pp. 59–60). Robertson, Scherr, and McKagan describe social reality as complex and multi-layered, but still argue for getting to these meanings as "participants' *real* experience of the context" (Robertson, Scherr, & McKagan, 2015, p. 13). They also describe the goal of qualitative PER as finding cases

to illustrate or expand theory in order to arrive at more or less "universal" theories (Robertson, Scherr, & McKagan, 2015, p. 13).

In most of these accounts, I fail to find the critical discussion of meaning making, power, and knowledge that have taken place in educational research and other social science relating to the crises in "representation" and "authority" (Lincoln et al., 2011, p. 124). Taylor (2014), in outlining the paradigms of qualitative research in science education, argue that these kinds of views, where qualitative research is seen as easily reconciled with quantitative research, "tends to result in research designs governed by the epistemology of the post-positivist paradigm" (Taylor, 2014, pp. 40–41). For instance, he claims that "triangulation is an automatic 'weapon of choice' to optimize the validity and reliability of many contemporary mixed-methods research designs, situating them clearly in the post-positivist paradigm" (Taylor, 2014, p. 45). Contrary to this, the epistemological starting-points of contemporary qualitative researchers working in the paradigms which Taylor (2014) lists as interpretive, critical, and postmodern, rather serves to take into full consideration the epistemological crises of representation and authority, and develop research according to this.

I believe that PER would benefit from taking part in the theoretical and methodological developments that have come with interpretive, critical and postmodern paradigms, similarly to what many researchers in the latest wave of science education have done. This is also something my project aims at doing. Maybe PER should take heed of the claim of Robertson, Scherr, and McKagan that "PER is a case of a social science" and that "our understanding of PER as a discipline can be informed by our understanding of research in the social sciences" (Robertson, Scherr, & McKagan, 2015, p. 21; cf. the claims of van Aalst, 2000). In doing so, a wider discussion of what epistemology and methodology, be it quantitative or qualitative, is most applicable when studying physics education might take place.

2.5 On the periphery of PER and science education: Studying gender and identity

As I argued above, the mainstream of PER still mostly revolves around conceptual understanding, and, up until recently, mostly around concepts in introductory university physics. However, a growing focus on upper-division courses has developed over the last ten years, and a recent "Focused Collection" in PRST-PER gathers recent work in this area (Loverude & Ambrose, 2015).

Taking a look at science education in general, we can note that similarly to PER, the dominant topics concerns scientific concepts and conceptual change (Chang, Chang, & Tseng, 2010). In science education, with its focus on pre-university education, several other fields of inquiry apart from what is done

in PER exist as well. Chang et al. (2010), in a content analysis of 1400 science education articles between 1900 and 2007, list 9 major categories: Scientific concept, instructional practice, conceptual change & concept mapping, professional development, conceptual change & analogy, nature of science & socio-scientific issues, reasoning skill & problem solving, design based & urban education, and attitude & gender.

However, in both PER and science education, issues of a more social nature, i.e. equity, gender, etc., seem to be peripheral. As my research can be characterized as concerning these issues, the coming sections will discuss the research that has been done in PER and science education regarding gender and equity, with a specific focus on the use of the identity construct. To characterize this research in PER, I have done a literature search and evaluated the relevant articles. The overview of science education is based more on the critique of others, but also contains a discussion of directions and examples of studies I find promising.

2.5.1 A review of current PER literature concerning gender, identity, and equity

Physics education research has up until recently focused very little on issues of gender and equity. Heron and Meltzer, in their characterization of PER, exclusively "highlight those directions that address intellectual issues that are specific, but not necessarily unique, to the subject matter and reasoning patterns of physics" and therefore "omit important work on investigating gender-equity issues, for example" (Heron & Meltzer, 2005, p. 390). When these issues are attended to, it generally seems to be in a limited way. Docktor and Mestre, in their commissioned paper to the National Research Council (which was later published as Docktor & Mestre, 2014), argue for the importance of social issues in a way that is quite symptomatic:

> Another general area that needs attention is the disaggregation of data in terms of underrepresented minorities or academic majors. Most research studies do not consider multiple, diverse student populations in their design or in reporting results.
>
> The small fraction of women and minorities participating in physics is cause for additional attention to the issues facing these groups, including additional research to explain observed performance differences on concept inventories. (Docktor & Mestre, 2011, pp. 144–145)

To characterize the PER research made in these topics, I have made a literature search that can be seen as an update of the one presented in Anna Danielsson's thesis (2009, p. 24).

Danielsson made a literature search in the main Physics Education journals as well as some Science Education journals for search terms such as "gender,

girl, woman" and "gender AND physics" (depending on journal) and found a few ways in which gender issues were discussed in PER, based on the 57 articles from the search that were deemed relevant. She listed these ways as: "Comparison of man and woman students", "Classroom practices" (comparing men and women or aimed at increasing participation), "Textbooks and tests" (implications of changed wordings, etc.), and "Teacher's attitudes and knowledge" (about gender stereotypes, etc.). In particular, she found that most of these studies were lacking the critical perspective on gender and science which can be found in e.g. some anthropological studies of physics education (Nespor, 1994; Hasse, 2002).

I have made a similar search, examining three of the top PER journals: *American Journal of Physics*, *European Journal of Physics*, and *Physical Review Special Topics Physics Education Research*. This will certainly miss some relevant articles which could be classified as PER published in other channels, but should nevertheless give a fairly accurate view of how these issues are discussed in the mainstream of PER. I also widen the scope by using somewhat different search terms. I searched for the terms "gender", "equity", and "identity" in such an inclusive way as possible (for all dates until August 2014, and in titles, abstracts and full text) in the three journals. "Identity" was chosen as a relevant term since theories about (social) identity is a common way to frame these questions in education research in general (Brickhouse, Lowery, & Schultz, 2000; Tonso, 2006; Carlone & Johnson, 2007; Holmegaard et al., 2014), and it would be illuminating to see if and how this was done in PER. This search yielded hundreds of results (mostly because "identity" is a word used in many contexts), but a screening of titles and abstracts reduced these to in total 45 articles judged relevant, i.e. discussing issues of gender, equity or social identity to some extent apart from just e.g. reporting statistical differences. This limited material largely fits into Danielsson's categories.

The largest field is still the reporting of "gender differences" in concept inventories, grades or other measures. Several studies specifically discuss the "gender gap" in performance on concept inventories, what factors seem to influence them and how they could be overcome (Lorenzo, Crouch, & Mazur, 2006; Pollock, Finkelstein, & Kost, 2007; Kost, Pollock, & Finkelstein, 2009a; Kost-Smith, Pollock, & Finkelstein, 2010; Kreutzer & Boudreaux, 2012; Bates et al., 2013; Madsen, McKagan, & Sayre, 2013). This is in general done through quantitative methods, and recent years have seen explorations of more factors that might influence the gap. A paper by Madsen et al. (2013) analyses 26 articles about gender gaps on mechanics concept inventories and the possible factors put forward as involved in these articles. They conclude that no single factor can account for the total gap which is "most likely due to the combination of many small factors" (Madsen et al., 2013, p. 1), something which in another article has been referred to as a "smog of bias" (Kost-Smith et al., 2010, p. 15).

Some of the newer "factors" that have been brought into the discussion of "gender gaps" are "identities" and "stereotype threat". Identity when used as theoretical concept in PER seem mostly borrowed from a social-psychological perspective where qualitative studies aim to explore how people identify themselves in certain situations (Barthelemy et al., 2013; Dabney & Tai, 2013; Kelly, 2013; Irving & Sayre, 2014). However, "physics identity" can also be something that is (easily) measured by a survey and included as a factor possibly contributing to a gender gap (Kost, Pollock, & Finkelstein, 2009b). The psychological mechanism of stereotype threat, where a person subjected to a negative stereotype about the abilities of a group they belong to perform worse, has also recently been suggested as an important, though of course not complete, explanation for gender gaps (Kost et al., 2009a; Willoughby & Metz, 2009; Kost-Smith et al., 2010; Kreutzer & Boudreaux, 2012).

A category of studies that largely corresponds to what Danielsson calls "Classroom practices" and "Textbooks and tests" are the studies which to some extent try to answer the question of how to attract "minorities" (including women) to physics, and retain and help them when there. Some of the recent studies in this field explore how modern teaching methods possibly are more inclusive than traditional teaching (Brewe et al., 2010; Gunter, Spiczak, & Madsen, 2010; Chasteen, Pollock, Pepper, & Perkins, 2012; Van Ness & Widenhorn, 2012).

A few studies discuss inclusion and participation in terms which seem to have emerged quite recently in PER. These are "norms", in the classroom and in interactions between students (Gunter et al., 2010; Turpen & Finkelstein, 2010; Irving & Sayre, 2014), and "interaction networks" (Brewe, Kramer, & Sawtelle, 2012; Bruun & Brewe, 2013).

Danielsson criticizes the lack of critical perspectives on gender and science in PER, claiming that most of the studies she reviews "do not critically examine the meanings of science, but rather see physics as something relatively fixed", and that "[c]ritical perspectives on gender and the learning of physics are rare" (2009, p. 30). This holds true also for the articles I have evaluated.

Gender is almost exclusively seen as a static category that divides people into two groups which can be compared. This is of course in some way needed to argue for gender inequity, but also risks reifying gender too much, making it the new "politically correct" name for "sex", or whatever it is that is recorded in e.g. university databases (for a discussion of the "rise of gender and decline of sex" in academic usage, see Haig, 2004). This is apparent in uses of gender like: "The two genders make different use of being allowed multiple tries to solve online homework problems: male students frequently attempt to immediately solve the problem, while female students are more likely to first interact with peers and teaching assistants before entering answers." (Kortemeyer, 2009, p. 1) But treating gender as static also runs the risk of seeing it as "the" culprit of gender gaps. In statistical language, gender becomes a "factor" that possibly influences students' results. We have: "Gen-

der as a factor of science achievement" (Cataloglu, 2007, p. 770). All this is in contrast to how gender is conceptualized in for example gender studies, but also more critical examinations of gender and education like those published in journals like *Gender and Education* or *Cultural Studies of Science Education*. Here gender is most often viewed as dynamic, a part of an ever-changing social identity, and something that is "done" or "performatively constituted" rather than something one has (West & Zimmerman, 1987; Butler, 1990/1999, see also the theory section below).

These shortcomings in the view on gender also imply a limited view of social structures and social change. One of the common explanations considered for gender differences in PER is "stereotype threat", which is a well developed field of inquiry (see for instance Steele, 2011), which nevertheless discusses the problem as an individual psychological phenomenon. A problem with this view may be that inequity is reduced to "stereotypes", and no account is paid to for instance sociological theories about inequity and social relations. Perhaps, that "stereotype threat" seems to be a preferred explanation in PER, can be explained by the preference for psychology over other fields of inspiration for PER. Another aspect of this limited view of social structures and social change perhaps comes from the most often atheoretical approach of PER. Theory concerning inequity, from a starting point inside the quantitative paradigm in PER, perhaps only gets as far as claiming inequity as a result of a "smog of bias" (Kost-Smith et al., 2010). In other fields, processes of inequity, enactment of norms, gender production, etc., is often studied with explorative qualitative approaches.

The discussion of social issues in the field of PER may however be widening. More and more researchers seem to be studying the social aspects of education and a 2014 call for papers for a Focused Collection on gender in PRST-PER states both the more traditional comparisons of "men to women in physics", and the newer "[s]tudies of gender identity in physics" in the list of relevant topics (Henderson, 2014). Paper I in this thesis was submitted to this Focused Collection.

2.5.2 Science education, gender and identity

Hussénius, Andersson, Gullberg, and Scantlebury (2013), in a critical examination of the attention paid to gender in science education, outline three different approaches of research with a gender perspective: Research addressing gender, gender research, and feminist research. Whereas "Research addressing gender" is characterized as any research using "sex or gender as analytical categories", the two later categories of research are using "gender theoretical frameworks" and/or "gender perspectives to analyse power" (2013, p. 302). Additionally, "Feminist research" has the stated aim of changing power imbalances, i.e. subscribing to a critical research paradigm (Taylor, 2014; Treagust

et al., 2014; Guba & Lincoln, 1994). Doing literature searches, the authors point out that very few studies in science education consider gender, and that those doing so are almost exclusively of the "addressing gender" kind. This also holds true for all the PER studies discussed above.

The lack of critical perspectives, in PER and science education, can perhaps be related to the still dominating post-positivist paradigm in both fields. Sandra Harding, in discussing science and gender 30 years ago, claimed that:

> [R]esearch programs where remnants of empiricist, positivist philosophies of social science hold sway have been systematically inhospitable to gender as a theoretical category. At best they have been willing to add gender as a variable to be analyzed in their subject matter—as a property of individuals and their behaviors rather than also of social structures and conceptual systems. (Harding, 1986, pp. 33–34)

Taking issue with the contemporary feminist discussions of science, Harding describes five more or less radical research programmes, from "equity studies", which ask why there are so few women in science, to elaborations of feminist epistemologies, which take the critique to the very root of knowledge production (Harding, 1986, pp. 21–24). Using the discussions of Harding and Hussénius et al., which argue for the necessity of a critical perspective on gender and identity that does not take "science" for granted I will discuss how a few different science education articles use gender and identity.

In recent years, many researchers in science education have started employing an identity perspective. Especially studies of attitudes have moved from earlier psychological notions of students "holding" attitudes, to attitudes negotiated in relation to social identities (Tytler, 2014). However, identity can be used in many ways in educational research, and even though it might be regarded as "'the missing link' in the researchers' story of the complex dialectic between learning and its sociocultural context" (Sfard & Prusak, 2005, p. 15), it needs to be used in a thoughtful manner (Sfard & Prusak, 2005). A common way of using the identity concept, perhaps related to a mostly interpretivist paradigm (Guba & Lincoln, 1994), is that learning means acquiring an identity. Here the task of educational reformers and researchers is to help students gain a suitable identity. This is the perspective of for instance Allie et al. (2009), who "views learning in engineering as a process of coming to participate in the discourse of the engineering community and taking on the identity of being a member of this community" (Allie et al., 2009, p. 360). A similar framework is used by Irving and Sayre (2015a, 2015b) who discuss "becoming a physicist" as acquiring a physics identity and being recognized by the physicist community. I believe that this view is especially valuable when asking questions about student retention and attrition, but there is a risk that the research aligns itself with an instrumental (from the point of institutions) view of students if this is not combined with a critical perspective

of science. If *becoming a part of some scientific community* is taken for granted as an evident goal, we miss the perspectives of the students who actually resist a "physics identity" and do not want to be part of the physics community, and we fail to critique the possibly undemocratic tendencies of that community. The "acquiring a science identity"-perspective is thus not critical enough in the frameworks of Harding and Hussénius et al. Some studies, while using "science identity" as a construct, nevertheless puts the meaning of it under critical scrutiny. I will discuss a few such studies here.

Carlone and Johnson (2007), in a more explicitly feminist oriented and widely cited study, explore the possibilities of achieving a viable science identity for women of colour. In this paper, a "science identity"-model is defined as a tool for examining these women's pathways, even though this might have problems that the authors themselves acknowledge:

> We understand the limitations of using an a priori definition and prototype of a person who has a "science identity." There are many ways of being a "science person" and defining one prototype may reproduce status quo and overly narrow conceptions of what counts as a science person. However, because our study examines women who were largely pursuing science degrees and science-related careers, we argue that they had to confront, in some way, the historically enduring "science identity" prototype. Thus, we argue that it is appropriate to clearly define this prototype to make sense of the ways the women accepted, rejected, and/or transformed it. (Carlone & Johnson, 2007, p. 1212)

In this way, Carlone and Johnson aim at taking a critical stance towards the normative view of science. However, it is interesting to note how these authors describe that the women holding "Altruistic science identities" "redefined what they meant by science" (Carlone & Johnson, 2007, p. 1199), without explanation. This seems to imply that these women necessarily carried a mainstream view of science from the start, something that is of course probable, but should not perhaps be taken for granted. This shows the difficulty of upholding a critical view throughout.

Part of the ASPIRES project (Department of Education and Professional Studies, 2013), another feminist science education study by Louise Archer and co-authors examines what science identities are available for girls of different class and ethnicity in British schools (Archer et al., 2012). This study comes with very essential and critical recommendations as to what could be done in schools, and do this in opposition to the standard views of the "lack of women" or "women as lacking" in science:

> We advocate providing students and teachers with the tools to question taken-for-granted assumptions around "who does science" and to understand how and why various areas of life (e.g., particular subjects and careers) have become gendered in particular ways. […] We suggest that this would appear to be a

> more fruitful approach than merely providing young people with "fun" experiences of science or by presenting "positive images" of scientists as a means for encouraging more girls and women into science careers. (Archer et al., 2012, pp. 983–984)

In a study of the education of physics Ph.D. students, Allison Gonsalves (2012) builds on the model of Carlone and Johnson to examine what forms of being a physicist are "recognizable" for Ph.D. students. Using a social constructionist, poststructuralist view of gender and identity, she specifically asks what "subject positions" are available to female doctoral students in physics. Gonsalves finds that the available positions seem limited; in particular, she argues that as competence in experimental physics seems to bear strong masculine connotations, the female physicists always seem to stand out as "other". At the same time, stereotypical femininity is constructed in opposition to the purported "neutrality" of physics, and this means that performing a recognizable woman physicist position relies on difference both from "other women" and "ordinary physicists". The theoretical perspective employed in this study lies close to my own and I particularly find the notion of "positions as a physicist" in discourse useful.

These are some of the few studies in science education that explicitly take a feminist and critical view towards science. Although many of the studies mentioned here focus on women in science and physics, I want to stress that the theories around identity used are not specific to "women" or "gender", but can be used in conceptualizing identities across multiple differences. This is what is often done in contemporary gender studies, which is for instance captured in the popular notion "intersectionality", an attempt to focus on the "intersections" between different axes of difference and power. Hence, speaking about "science identities" could imply inclusions and exclusions along many social dimensions, although gender has been studied and discussed more than others.

Studies of "gender" in science education are not the only ones taking a critical standpoint towards science either. A critical perspective is common in some other research areas as well, especially studies labelled as "urban", "indigenous", or with "cultural views" of science education, along with parts of the Nature of Science (NOS) field (see overviews of Calabrese Barton, Tan, & O'Neill, 2014; Carlone, Johnson, & Eisenhart, 2014; Lederman & Lederman, 2014; work by e.g. Aikenhead, 2006, or much of the research published in *Cultural Studies of Science Education*). In summary, many researchers in science education have brought identity, feminist and critical perspectives into their work. Still, the attitude towards science in these studies can vary, as well as the sophistication of the theoretical tools used. My aim is to build upon the work of others and combine this with a solid theoretical framework around discourse and identity, to enrich the discussion and perspectives on social issues in PER. In developing this framework, I have been inspired by

the social constructionist, poststructuralist discursive theories often used in gender studies, and in the next section, I will go deeper in describing these theories, with a specific focus on how to conceptualize identities.

2.6 Perspectives on gender and identity: A discursive view

As described above, the concept "identity" has been used more and more in science education, to conceptualise learning and the complex interactions between students and educational environments. However, studying identity in education can be a difficult endeavour. First, it often requires qualitative methods where getting good empirical data and being able to interpret it in a good way can require years of training. Second, there is no consensus as to what "identity" should mean, or if it even is the right concept to use. Traditional views of the human subject have been questioned by poststructuralist theorizing and this challenges some of the common usages of concepts like identity. Taking my departure from gender studies where many of these ideas have been taken into account and developed, I ask what a more critical, poststructuralist view of identity would mean for research in PER and science education.

This section will start with a discussion of the concept "identity" as being attached to human "subjects" and the shortcomings of that view, then continue with a description of how social constructionist and poststructuralist theorizing have reimagined these concepts. A discussion of what these views entail for studying identity in education concludes the section.

2.6.1 The concept "identity"

Questions about identity have troubled philosophers and social scientists for a long time. Identity has many meanings, stemming from the literal meaning of "sameness". In philosophy, questions of *personal* identity have been discussed for centuries. These questions regard what it means to be a person, how a person can persist through time, etc. (Olson, 2010). In psychology and social science, questions of identity have been asked more along the lines of what makes a person specific. Here identity is more related to the concept of *personality*, what makes you *a certain kind* of person. The personality concept has been criticized as having too essentialist connotations (Burr, 2003, p. 106), but these connotations also lie at the root of the concept identity which initially "emphasised innate differences between people, especially in terms of race, class and sex" (Holmes, 2011, p. 187).

In social science, identity is often discussed in collective terms. We have e.g. *group* identity and *national* identity. The construct *social* identity captures the idea that identity is something that is defined in relation to other

people, in social interaction, and one's personal identity is often understood as connected to larger collective identities. Examples of theorizing identity in this way include *symbolic interactionism*, where identities are understood as a "social location" and "the name we call ourselves" (Charon, 2010, pp. 84,85); Lave and Wenger's *situated learning*, where learning is reconceptualized as, among other things, a "construction of identities" (Lave & Wenger, 1991, p. 53); or different forms of *social constructionism*, where identities are viewed as constructed through discourse (Burr, 2003, p. 105). At times a more temporary, or "socially situated" identity may be viewed as separate from a more stable "core identity" (Gee, 2011, p. 41), but some social constructionists would deny the existence of any such *not* socially constructed identity (Burr, 2003, p. 105).

Several issues regarding the nature of identities arise in these discussions. First, there is the question of the stability of identity: Can people be said to have a "core identity", which is more or less persistent and perhaps modified over time, or should identity be seen as a temporary construction, always in the process of being constructed and reconstructed? Second, and related, is the question whether identity is something someone has a possibility to choose or whether it's something that is imposed from the "outside". A part of these questions are what will be explored in the rest of this section by turning to poststructuralist conceptualisations of human subjects in terms of *subjectification*.

Another question that arises in relation to identity is what identity is a property *of*. If identity is a property of a person, what is a person? In philosophy the question of personhood has been discussed with the concept *subject*, which can be defined as a thinking being, the thinking "I" in Descartes' famous phrase "I think, therefore I am". This equation of a human person with a thinking (mostly rational) and independent subject who possibly bears identities has functioned as the ground for much of western metaphysics and political thinking ever since Descartes, but also been the subject of much critique (Hall, 1996, p. 1). For example, the discussion of how the subject, far from being fundamentally independent, always forms in relation to others starts with Hegel and Nietzsche and continues to this day (Butler, 1997, p. 3). Judith Butler, following Nietzsche and Michel Haar puts forth the idea that the humanist view of the subject is informed by a "metaphysics of substance" which assumes that "the grammatical formulation of subject and predicate reflects the prior ontological reality of substance and attribute" (Butler, 1990/1999, p. 27). This critique questions "the very notion of the psychological person as a substantive thing" (Butler, 1990/1999, p. 28) treating it as a confusion of grammar with reality, starting already with "Descartes' certainty that 'I' is the subject of 'think'" (Haar, 1977; quoted in Butler, 1990/1999, p. 28).

2.6.2 Who needs identity?

As the classical ideas of subject and identity seem to indicate too stable and "essentialist" views of the person, or of cultural groups (Hall, 1996, pp. 3–4) one is led to ask, as Stuart Hall does in his essay on the question, "Who needs 'identity'?" (1996). Hall argues that perhaps one should rather pose the question as a "question of *identification*" (Hall, 1996, p. 2), but quickly notes that this concept of course does not solve all problems, even though it points more to processes than static entities. Hall nevertheless goes on to argue for using "identity" in a new way, "not an essentialist, but a strategic and positional one [...], directly contrary to what appears to be its settled semantic career" (Hall, 1996, p. 3). This view "accepts that identities are never unified and, in late modern times, increasingly fragmented and fractured; never singular but multiply constructed across different, often intersecting and antagonistic, discourses, practices and positions" (Hall, 1996, p. 4). Thus identity could be used in line with social constructionist theories. Vivien Burr, in her text on social constructionism argues for the worth of identity as an "implicitly social" concept which "avoids the essentialist connotations of personality" (2003, p. 106), seeing no big problems with the identity concept in itself.

A careful use of the "identity" concept thus seems compatible with social constructionist or poststructuralist theorizing. Nevertheless, "identity" in common speech usually implies a too "psychological" view of the person, and it might be worthwhile to employ other concepts at times. The next section will introduce some poststructuralist understandings of subject formation and the possibly fruitful concepts these yield.

2.6.3 Discursive subject positions: Social constructionist and poststructuralist views

Instead of taking human subjects as stable and whole, social constructionism "replaces the self-contained, pre-social and unitary individual with a fragmented and changing, socially produced phenomenon who comes into existence and is maintained not inside the skull but in social life" (Burr, 2003, p. 104). This has sometimes been called "the death of the subject", expecially regarding the more extreme positions which forecloses "any notion of human agency" (Burr, 2003, p. 121). But perhaps proclaiming the death of the subject is an all to hasty conclusion, and what really has to be done, as Hall, in line with Michel Foucault, urges us to do is to reconceptualize the subject and "[think] it in its new, displaced or decentred position within the paradigm" (Hall, 1996, p. 2). This means "rearticulat[ing] the relationship between subjects and discursive practices" (Hall, 1996, p. 2), i.e. asking questions like: Is the subject the origin of social practices or is it constituted by them?

Theorists of the "discursive turn", inspired by Foucault, consider all human interactions as dependent on contingent "systems of representation", or

"discourses". Thus there can be no "objective", social relations, or "essential" human properties. I turn to Hall for a kind of definition of this approach:

> Discourses are ways of referring to or constructing knowledge about a particular topic of practice: a cluster (or *formation*) of ideas, images and practices, which provide ways of talking about, forms of knowledge and conduct associated with, a particular topic, social activity or institutional site in society. These *discursive formations*, as they are known, define what is and is not appropriate in our formulation of, and our practices in relation to, a particular subject or site of social activity; what knowledge is considered useful, relevant and "true" in that context; and what sorts of persons or "subjects" embody its characteristics. "Discursive" has become the general term used to refer to any approach in which meaning, representation and culture are considered to be constitutive. (Hall, 1997, p. 6)

Many writers have taken the view of subjects as constituted in discourse seriously. For instance Ernesto Laclau and Chantal Mouffe, in their mediation between poststructuralist and Marxist theory state:

> Whenever we use the category of "subject" in this text, we will do so in the sense of "subject positions" within a discursive structure. Subjects cannot, therefore, be the origin of social relations – not even in the limited sense of being endowed with powers that render an experience possible – as all "experience" depends on precise discursive conditions of possibility. (Laclau & Mouffe, 1985/2001, p. 115)

While their account is rather abstract and macro-sociological, the concept "subject positions" has also been used "in a way that acknowledges the active mode in which persons endeavour to locate themselves within particular discourses during social interaction" (Burr, 2003, p. 113) in the context of the "positioning theory", developed by Davies et al. (1990). Here, the concrete interaction between people and discourse is considered.

Judith Butler, elaborating the Foucauldian view and bringing a psychoanalytic notion of identification into the mix, has been one of the most influential scholars in the establishment of a discursive understanding of identities, particularly gendered and sexual identities (Hall, 1996, p. 14; Holmes, 2011, p. 188). In her much-cited *Gender Trouble* (1990/1999; and in *Bodies That Matter* 1993/2011), Butler puts forth a *performative* account of how gender and sexuality is established and sustained. In line with the critique of the "metaphysics of substance", Butler radically argues that: "There is no gender identity behind the expressions of gender; that identity is performatively constituted by the very 'expressions' that are said to be its results." (1990/1999, p. 33) This is coupled with a questioning of the very distinction between sex and gender:

> Are the ostensibly natural facts of sex discursively produced by various scientific discourses in the service of other political and social interests? If the immutable

> character of sex is contested, perhaps this construct called "sex" is as culturally constructed as gender; indeed, perhaps it was always already gender, with the consequence that the distinction between sex and gender turns out to be no distinction at all. (Butler, 1990/1999, p. 10)

Taken together, this means that identity on all levels (even the purportedly neutral biological parts) are discursive and stabilized by the power of discourse, but at the same time subject to change through continuous small acts of subversive performativity, i.e. "failed", "wrong", or "parodic" repetitions of expected gender (etc.) behaviour.

Another important aspect of Butler's account builds on the recognition that subjectivity always depends upon a disassociation between the self and the "Other". Parts of this disassociation takes place on the level of discourse and for Butler this means that, as Hall puts it, "all identities operate through exclusion, through the discursive construction of a constitutive outside and the production of abjected and marginalized subjects, apparently outside the field of the symbolic, the representable" (Hall, 1996, p. 15). In Butlers account, what are viewed as "intelligible" subjects and identities "inside" discourse are structured by normative power relationships and she poses that for instance "'[i]ntelligible' genders are those which in some sense institute and maintain relations of coherence and continuity among sex, gender, sexual practice, and desire." (Butler, 1990/1999, p. 23) This assumed coherence that constructs some identities (e.g. gay and trans*) as more or less "unintelligible" is usually referred to as "the heterosexual matrix" (Butler, 1990/1999, Note 6 to chapter 1, p. 194). The notion of intelligibility is not only useful in discussing gender and sexuality, but can be usefully brought into discussions of what it means to perform an "intelligible" physicist subject position (see e.g. Gonsalves, 2012).

In a later work, *The psychic life of power* (1997), Butler engages further with the question of *subjection* (or *subjectification*), i.e., the process whereby subjects are produced. She paints a picture where achieving subjecthood implies a process of mastery, "indistinguishable from submission" to social regulatory power, and where "desir[ing] the conditions of one's own subordination is thus required to persist as oneself" (Butler, 1997, pp. 30,9). One of the important points of this treatment is that a, or "The", subject should never be used as a synonym to "person" or "individual", but rather "ought to be designated as a linguistic category, a place-holder, […] the linguistic occasion for the individual to achieve and reproduce intelligibility, the linguistic condition of its existence and agency" (Butler, 1997, p. 10). This means, in line with the critique of the "metaphysics of substance", that a person is not something that necessarily exists prior to its representation in language, at least not as an intelligible concept.

Butlers developments leave us with a picture in which persons are subjected into discursive subject positions and in that way become intelligible

subjects in discourse. I mean that this process can be viewed on different levels: A more fundamental level of becoming an intelligible person with expected gendered, sexual (etc.) identities, and a more contextual of achieving intelligibility in certain contexts, e.g. becoming "a 'good student,' a 'good cook,' a 'gang member,' a 'competent lawyer,' a 'real basketball fan,' or a 'real Catholic'" (Gee, 2011, p. 34). I believe that this contextual view of intelligible subject positions are especially valuable for education research. It emphasizes the power-permeated discursive construction of educational subjectivities but can avoid going into the more "fundamental" questions of what it means to be a person.

2.6.4 Doing education research inspired by poststructuralist theories

As stated before, identity seems an important concept (or a "missing link") for research in education. However, studies of identity in education may often implicitly assume a coherent subject taking on different identities, making discursive identities something that can be chosen at will by a free agent. Using the poststructuralist accounts of subjectification outlined above might be a way of getting a more nuanced and critical picture.

With a poststructural view of identities, two slightly different approaches can be taken towards identity studies. First, one could emphasize agency and discuss how people actively position themselves in discourse. Second, one could ask more structural questions and try to map out prevailing discourses and how people are subjected into them. Examples of the first are using for instance the positioning theory of Davies and Harré (1990) or perspectives from discursive psychology (see Jorgensen & Phillips, 2002) to study what subject positions people take in different contexts,

Doing the second could involve discussing the construction of "educational subjectivities" in more general or structural terms. Bronwyn Davies, in a paper describing the merits of the concept of subjectification for studies of identity in education, argues that subjectification viewed in terms of mastery/submission is a useful model in school contexts. Thus, to "master" something in school, means to submit to the discourses of this topic and what a "good" student of it should be; to be recognized as a legitimate "school subject" means submission (Davies, 2006). Another question with a structural emphasis is asking what subject positions are constructed as intelligible in certain contexts/discourses. One example of what this can entail is a recent study by Solli, Bach, and Åkerman (2014). In this study, it is shown that through the discourse in the undergraduate education of biotechnologists certain dispositions/thoughts/ways of being are excluded from an identity as a biotechnologist. Specifically, political-economical rationales for opposing GMO are excluded from the discourse, presenting GMO opposition as

mostly irrational and unavailable to students (supposedly) striving to be scientific, rational and objective biotechnologists (Solli et al., 2014). Here we see how the construction of intelligible identities requires a boundary making, the construction of a constitutive outside.

Doing educational research of identities within a poststructuralist framework bids us to question many taken-for-granted humanist ideas about the subject and instead reimagining it in terms of discursive subject positions achieved through a complex process of mastery/submission called subjectification. This also questions the usefulness of the concept identity. Using these theories, we might be more helped by talking about intelligible subject positions in discourse, even though this makes our vocabulary seem more impenetrable than when using established concepts like identity.

2.7 Re-framing the questions

Taking all the considerations in this chapter into account, the questions of participation in science in general and physics in particular can be re-framed in two ways. First, instead of asking "who", comes to and stays in physics, I want to ask "what" discursive subject positions or (fragmented) identities are made intelligible in the discourse of physics. This avoids an essentialist view of human subjectivity, where people are supposed to "have" certain interests and dispositions, and instead allows me to talk about the discursive construction of certain "physics identities" and cultures. Second, and related, talking about the discursive construction of identities in physics means I have to focus on the discourses, and the culture of which they are part. In this way, I can ask the criticalist question of what kind of physics culture is reproduced in the discourse of physics education.

In the next chapter, I will describe how these questions can be approached through using the poststructuralist and gender theoretical concepts described above and a methodology of discourse analysis.

3. Methodology: Discourse and identity

This chapter will detail how a discursive view of identities has informed my research, and how my research has been conducted using such a perspective.

3.1 Studying discourse and identity

With a poststructuralist, discursive view of the social world and identities (or subject positions), we need tools to study *discourse* in one way or another, to be able to say something about the context in which the positions/identities we want to study are enacted. Several different approaches to discourse analysis exist, with different theoretical commitments. Jorgensen and Phillips (2002), in their instructive book on approaches to discourse analysis, separate three directions, "Laclau and Mouffe's discourse theory", "Critical discourse analysis", and "Discursive psychology". They describe the varying focus of these approaches, from macroscopic political discourses (Laclau and Mouffe) to interpersonal interactions (Discursive psychology), and the varying scope of "discourse" used, from a completely social constructionist standpoint where the material world can not be conceptualized outside discourse (Laclau and Mouffe) to discourse as just one social practice among others (Critical discourse analysis as put forward by Norman Fairclough). Although discourse analysis is not just a method, but rather "theory and method" or "a complete package" as Jorgensen and Phillips (2002, p. 3) claim, it is possible to blend different perspectives and create "one's own package" (2002, p. 4) as long as the theoretical commitments match the methods used. My work does this blending in a sense. Specifically, I use some of the tools of discourse analysis described by Gee (2011), in analysing the discourses of physics education. Gee, while inspired by critical discourse analysis, is especially pragmatic in his approach to discourse analysis, and blends several perspectives. Mainly analysing "language in use", Gee nevertheless acknowledges discourse to contain much communication other than written or spoken language and denotes this: "Discourse" with a big "D" (Gee, 2011, p. 34). While Gee uses language is in narrow sense, it could also be used to mean all kinds of "communication" or "signifying systems" (see e.g. Hall, 1997), perhaps corresponding to Gee's notion of "Discourse".

Some of the tools which Gee outlines are the "building tasks" of language. He writes:

> We make or build things in the world through language. [...] For example, I can make (or break) a relationship with other people through language. If I talk to you in an informal, bonding sort of way, I am "bidding" to have you accept me as a friend, someone with whom you are comfortable. If you talk that way back to me, that sort of relationship becomes "real" (at least for that time and place) and has consequences in the world (e.g., it is now harder for you to turn down my invitation for you to come to my house for dinner).
>
> Whenever we speak or write, we always (often simultaneously) construct or build seven things or seven areas of "reality." Let's call these seven things the "seven building tasks" of language. In turn, since we use language to build these seven things, a discourse analyst can ask seven different questions about any piece of language-in-use. (Gee, 2011, p. 17)

Gee lists the building tasks as: "significance", "practices", "identities", "relationships", "politics", "connections", and "sign systems and knowledge" (2011, pp. 17-20), and puts forward several questions to ask of "language-in-use" to find out what it is building. In the papers, we have used Gee's questions for "practices", "significance", and "identities" and the connections between these building tasks to analyse what identities (or discursive positions, see below) the discourses in our material seem to communicate. Particularly, we have found the notion that a practice always implies an identity, a "who-doing-what" (Gee, 2011, p. 30), to be illuminating.

One thing that has to be sorted out in my approach to a discourse analytical view of social identity is the terms used. In Paper I, we use "identity", pretty much in line with Gee's usage of the term. Inherently socially constructed and produced in the interaction of the interviews, we still take the identities that seem to be enacted by the students as part of larger groupings or "cultures", which the students themselves refer to. When a student says "I am not like those who ... like ... love Maxwell's equations just because they are there", she constructs an identity for herself and "dis-identifies" with others, while at the same time referring to somewhat concrete groups of people, belonging to certain "student cultures", whom this identity is seen to pertain to. Nevertheless, these identities are discursive in nature, and this is in a way demonstrated by some of the students themselves, in their rejection of gender essentialism.

In Paper II, we chose not to use "identity", but rather talk about "discursive positions". This is due to several reasons. As described above, if not used carefully, "identity" may have too essentialist connotations. However, the main rationale for using "discursive positions" is that the positions described are inferred in the general discourse of the courses (strongly related to "practices"). They are not necessarily "lived" identities that any student take on for a longer or shorter time. Neither do we want to describe them as "subject positions", to avoid claiming that they structure subjectivities in quan-

tum physics education so strongly. We don't have enough results to claim that. Nevertheless, we claim, these positions limits the discursive space in quantum physics, and makes it difficult for students to imagine themselves in other positions relating to quantum physics.

Another concept that is used to some extent in both papers is "culture". Culture is of course a term that has many definitions, and even though some of the earlier work that I relate to use it in a mostly anthropological sense (see e.g. Hasse, 2002; Traweek, 1988), I borrow my usage from cultural studies:

> To put it simply, culture is about "shared meanings". Now, language is the privileged medium in which we "make sense" of things, in which meaning is produced and exchanged. Meanings can only be shared through our common access to language. So language is central to meaning and culture and has always been regarded as the key repository of cultural values and meanings. (Hall, 1997, p. 5)

In my interpretation, language in Hall's terms can be directly replaced by (a broad notion of) discourse, or "signifying systems", and hence culture is what discourse ultimately constructs. To quote Hall again on the connection between identities and culture: "Without these 'signifying' systems, we could not take on such identities (or indeed reject them) and consequently could not build up or sustain that common 'life-world' which we call a culture." (Hall, 1997, p. 5)

One might ask whether discourse, in the broadest sense, is not the same thing as culture, but I would like to maintain a distinction between these two terms. I find it especially fruitful to be able to separate different discourses existing in parallel in the same culture, but perhaps struggling for hegemony, in the terms of Laclau and Mouffe (1985/2001). Jorgensen and Phillips, borrowing from critical discourse analysis, call this macro-level of discourses "orders of discourse", and insist on the importance of studying the interactions between discourses in an "order of discourse" (2002, p. 141). As an example, the culture of physics (at a certain place) can certainly be imagined to accommodate several discourses (or even orders of discourse) that defines physics and physicists in different ways, which however are intelligible across any single order of discourse.

3.2 Knowing discourse

Doing discourse analysis is doing a kind of qualitative research, in an interpretive, hermeneutic tradition. This means that results are neither absolute truths, as if any scientific results were, nor totally subjective opinions. The questions one should ask of interpretive qualitative research are not questions of validity and reliability, but of trustworthiness (Taylor, 2014, p. 44): Are

these interpretations reasonable given the "data"? Is the researcher honest in accounting for the production of the results? Additionally, in studying discourses, with a more or less radical social constructionist perspective, researchers can never properly be "outside", the discourses they study, and observe them in some kind of "objective way". Jorgensen and Phillips (2002) describe the role of the discourse analyst as methodically "distancing" oneself from the material and trying to reflexively analyze "taken-for-granted" meanings (2002, p. 21).

This closeness to the research context is of course particularly important for me, as I have gone through the very same education I am researching. As is common, however, the theoretical perspectives I carry with me does mean that a certain distancing and reflexivity, the requisites of qualitative research, are possible. Nevertheless, I as a researcher can not avoid being a part of constructing the meaning-making I study. This is where reflexivity and an awareness of the situatedness of knowledge is of help. The social epistemologies put forth by feminist philosophers have in particular been highlighting the role of the social (and power-) relations between researcher and researched for the results of research. Particularly, many feminists discussing epistemology, one of the more influential being Donna Haraway, have argued for the understanding of all knowledge as "situated". Haraway claims, that claiming knowledge from a "disembodied", "objective" position is a power move, a "god trick", which hides the conditions and power plays underlying knowledge production (Haraway, 1988). What we should aim for instead is recognizing our situatedness and its role in producing knowledge. As Haraway puts it: "The moral is simple: only partial perspective promises objective vision." (Haraway, 1988, p. 583) This means, for me to practice "objective" (or good, qualitative) research, is to be reflexive, and take my position in regard to research subjects and others into account.

A final point that needs to be made regarding the production of knowledge of discourses is the question of what a discourse "is". Jorgensen and Phillips argues for treating discourses and the delimitations between them as more of "analytical concepts" than entities existing "out there" (2002, p. 143). This avoids some tricky ontological questions, but I nevertheless want to maintain that the discursive "patterns" that we outline in the papers are "there". However, the delimitation of these patterns into different discourses, or discursive practices, positions, and identities are of course mainly analytical choices.

3.3 Studying enacted discourse

The discursive approaches taken in the two papers aim at exploring the discursive identities present in the discourse in (or about) physics courses. To be able to analyse these discourses, some representative discursive material has to be collected, and the two methods for doing this that we have used are par-

ticipant observation of classes and single and group interviews with students. The field notes, recordings and transcripts from these activities were then the main material used for discourse analyses. This section will expand on each method, and its merits as a means of studying discourse.

3.3.1 Participant observation

Participant observation as a method has been used for a long time by anthropologists doing "ethnography", and has since been adopted in many fields. Traditional ethnography, as it is understood in anthropology and some of sociology, has long intended to give an understanding of how a studied culture "works": "that is, to grasp what the world looks like to the people who live in the fishing village, boarding school or mining community" (Delamont, 2012, p. 343). Traditionally, it has been informed by a naturalist epistemology, where the researcher should study the social world in a "natural state" to be able to give as true an account as possible of the social workings of the specific studied context (Hammersley & Atkinson, 2010, p. 7). This implies a social realist view of the social world, as something lying out there being "discoverable" for a researcher (Hammersley & Atkinson, 2010, p. 13). However, my aim has not been to write "an ethnography" of undergraduate physics education, and get a broad understanding of how this social context "works" (this has in part been done by others, see e.g. Hasse, 2000), but rather to examine the discursive productions in a few physics courses in the same subject. I would also like to avoid the classical naturalist epistemology of ethnographic research. In educational research, ethnographic studies are usually not as extensive as in anthropology and sociology, and certainly not as immersed as the round-the-clock-living-at-the-field-site, anthropological variant of ethnography (Delamont, 2012, p. 343). I have followed this tradition and mainly borrowed parts of the methods of ethnography in a "light-weight" participant observation.

My familiarity with the setting has allowed me to focus on the specific discourses at play in the classroom rather than fighting to understand an unfamiliar context. Of course, there are also possible problems with knowing and assuming too much about the situation. Sara Delamont, in discussing ethnography in education, describes the most common problems of observation in educational settings as "over-familiarity and boredom" (Delamont, 2012, p. 345). This was also my impression after doing the first few observations, but after a while, I realized that focusing on the discourse in the many quotes in my field notes with some tools of discourse analysis allowed me to distance myself from the context and discover patterns that were not obvious at the onset.

3.3.2 Interviews

To get a view of students' negotiations of identities, me and my co-author Staffan Andersson have conducted interviews and group interviews for the two papers. From a social constructionist perspective, when doing interviews, the performative co-construction of identities between researcher and interviewee has to be taken into account. This has been realized, for instance in ideas such as "postmodern interviewing" or "InterViews" (Taylor, 2014, p. 48; Gubrium & Holstein, 2003; Kvale & Brinkmann, 2008). When doing a group interview, in contrast to a single interview, the interaction can perhaps be conceptualized a little differently depending on the less (or occasionally more) "constructed" setting of the group interview. For example: How is the interview influenced if the interviewees are peers who would perhaps normally discuss the things brought up in the interview? What consequences does the researcher's construction of the interview situation and questions bring to the interaction?

The interaction of interview participants can be analysed using several tools. If an insight into the concrete positionings during the interview is sought after, perhaps discourse psychology or positioning theory are especially suitable (Halkier, 2010). In our analyses, we have occasionally focused on the positionings during the interviews, but also considered the students' utterances as referring to wider discourses about who they are and what groups they belong to, using Gee's notion of building tasks to discuss how certain things are "built" in the discourse of the interviews.

3.3.3 Analysing discourse

To analyse the discourse in the material from observations and interviews, I have used several methods. In a sense, an interpretative analysis starts already when starting to do the research, even before research questions are formulated, and continues through the collection of research material to the writing and publishing itself. In between, though, there is the process of sorting through the material and trying to find discursive patterns.

The selection of concepts used to analyse and describe the discourse in Paper I was done in collaboration with Staffan Andersson, who did the interviews and initial analyses. As the initial focus of that study was on understanding how students related to the Electromagnetism course, the analysis of interview recordings and transcripts focused on their descriptions of their *practice* in relation to the course. In many statements this could be connected to the *significance* the students attributed to the course in relation to *who* they were or wanted to be, and in such a way a coherent picture, similar across the interviews, of the discursive identities the students related to could be drawn. This led us for instance to the conclusions about *programme identity* versus *gender identity*, described in the paper.

For the analysis in Paper II, I started by collecting the notes I scribbled during observations into formatted field notes, while at the same time annotating the text with "open" codes or index phrases.[1] After discussing the field notes and interview transcripts with my co-authors, we realized that using Gee's building tasks as a focus would be a way forward for this analysis as well. I continued the analysis with extracting and sorting through the parts that I had coded as in any way concerning a "practice" and in that way could collect patterns in the material that pointed at the few discursive practices that are outlined in the paper. However, the analysis is not only based on the written material, but my experience of the concrete quantum physics classrooms goes into the description of the dominant "discursive practices" (including some non-linguistic aspects) in the courses as well.

3.4 Using mixed methods

Paper I, apart from discourse analysis of interview material, uses statistical analyses of student grades as a starting point and a confirmation of the notions expressed by the students, and is as such a case of "mixed methods" research. Mixed methods is sometimes viewed as a way of going beyond dichotomizing distinctions between qualitative and quantitative research that are "not only unproductive but fallacious" (Treagust et al., 2014, p. 13; see also the discussion on question-oriented PER, by Robertson, Scherr, & McKagan, 2015). Mixing various types of data is claimed to result in more precise results through the notion of "triangulation" (Treagust et al., 2014, p. 13). However, triangulation "does not necessarily serve the epistemological interests of interpretive researchers" (Taylor, 2014, p. 44). Instead, it may serve to place qualitative results as starting points or extra confirmations of quantitative research, aiming at "optimiz[ing] the validity and reliability of many contemporary mixed-methods research designs, situating them clearly in the post-positivist paradigm" (Taylor, 2014, p. 45).

In Paper I, the qualitative results are primary. It is an attempt at answering the question "why do women have lower grades in the Electromagnetism course", but even though a quantitative answer can be given in the form "it is a programme gap rather than a gender gap", that is not the end of explanations. As we show, in understanding students' negotiations of course practice, attention must be paid to negotiations between identities and cultures, both at the local, institutional level and on a society-wide level. This has to be approached in an interpretative way.

[1] This was done using the text-editor Emacs, with org-mode and a custom library to extract, list and export coded sections. This library is available at http://github.com/andersjohansson/orgqda.

3.5 Conducting ethical research

Research does not only have to be well-designed and answer significant questions, it has to be carried out in an ethical way as well. Research ethics does not only concern not harming participants, but also providing benefit, and it is not something that is done once, perhaps reviewed by an ethics committee, and then completed. Doing critical or postmodern research, ethics concerns the aims and results of research as well as the methods (Taylor, 2014). The aim of this project is clearly emancipatory in the long run, it is motivated by problems of unequal participation in science, but this does not mean that it is necessarily beneficial or risk-free for participants. I have followed customary guidelines, and conducted this research with informed consent from teachers and students, and all personal information has been kept confidential. Additionally, in the text of Paper II, special care has been taken to avoid singling out and making identifiable any of the teachers. These are just a few of the ethical considerations taken. The good of the project itself can perhaps not be judged before it is published and reused and maybe makes a difference somewhere.

4. About the papers

4.1 Paper I

The study reported in the first paper, "Gender Gap or Program Gap? Students' Negotiations of Study Practice in a Course in Electromagnetism", began as an investigation initiated by teachers, who were concerned that women taking the course in electromagnetism in general seemed to get lower grades than men. Electromagnetism in Uppsala is taken by a large group of students, students on physics-oriented programmes, but also students from many different engineering programmes. My co-author, Staffan Andersson, who was director of studies at the time, started researching the apparent gender gap in a manner influenced by Scholarship of Teaching and Learning, where development of education goes hand in hand with research of education. Staffan interviewed representative samples of students who had taken the course about how they related to it. A first round of analysis showed that students needed more things to relate to in the course, especially the students on programmes that were further away from physics. This was reported back to the teachers, who started to implement changes, such as more examples and guest lecturers from different areas, to respond to these ideas.

We realised later that the material could be interpreted with the discursive view of identity that I have been using in my Ph.D. project, and this is the analysis presented in the paper. We show how students' negotiations of their *practice* in the course is coupled to the perceived *significance* of the course, which in turn is related to discursive *identities*. Particularly, these identifications seemed to take place along axes of different directions of study. A follow-up statistical analysis revealed that the apparent "gender gap" could rather be conceptualized as a "programme gap", as there were few statistically significant differences in achievement between women and men in the same programmes. We discuss the clash between students' programme identities and the course as a kind of cultural mismatch, as the course could be seen to be constructed from a narrow "physicist" perspective, while the students identified with many other positions of engineering interest. In our discussion of these results, we highlight the importance of doing qualitative studies with a discursive view of gender and identity. In particular, we use Hardings (1986) notion of "levels of gender" to discuss the uneven distribution of women and men across engineering programmes with different directions in terms of society-wide gendered discourses. We conclude by giving a few recommendations for making more students feel at home in electromagnetism courses.

4.2 Paper II

The study reported in Paper II, "'Shut Up and Calculate': The Available Discursive Positions in Quantum Physics Courses", has been the primary work of my Ph.D. project until now. Here, using the discourse theoretical framework outlined above, along with participant observations and interviews with students, I have aimed at characterizing the discourse in three quantum physics courses and what discursive positions seem available to students. Quantum physics was chosen as it is both a vital step for students becoming "physicists", and a symbol for modern, "fun", and complicated physics.

The analysis in the paper, done in collaboration with my co-authors, outlines three *practices* as being made intelligible in the context of the classrooms: "calculating quantum physics", "exploring quantum physics" and "applying quantum physics". We argue that the dominating focus on "calculating" both in the language and the practical arrangements of the courses, may limit the positions students can take towards the course. Although students have high expectations and view the course as exciting, in the end the overall course practice seems to come down to one of "shutting up and calculating", and we argue that this may reproduce an instrumental culture of physics, where for instance philosophical questions have no place. Additionally, we argue, this culture may be "elitist" in the sense that only a few students will be able to "transcend" the dominating focus on calculating and take a position as a "smart" and "open-minded" physicist. Concluding the paper are a few recommendations for what could be done for a perhaps more inclusive quantum physics education.

4.3 Discussion: Uniformity in physics courses and student diversity

Both of the papers presented in this thesis discuss the theme of identity in physics education. How do the discursive identities constructed among students relate to the discourse of physics courses? Are some possibilities excluded and others produced? What approaches fit in?

In both cases, me and my co-authors have shown that students taking physics courses in general are diverse, and may describe "who they are" in relation to physics in many different ways. However, the studied physics courses mostly seem to be given in a specific cultural framework, and have a certain kind of discourse, a physics culture with a "physics for physics sake"-discourse. These narrow discourses of the courses do seem to provide limited possibilities of identification for students taking them, and can be excluding, not only for students whose main area is not physics, but also for students on the physics programmes. In highlighting these issues, we can point to some

measures that could be taken to accommodate more students, and make them feel more at home in physics or more comfortable using physics. However, these measures are not only about adding some extra bits and pieces to courses and "being nice to students". In the long run, a critical view towards the culture of physics itself, and what an identity as a physicist means, is needed.

Exploring participation in physics, these studies have aimed at bringing theories from gender studies and related fields into PER, thus widening its multidisciplinary scope. As a multidisciplinary PER-project, the publication of these results have also been aimed at different audiences, with one paper submitted to the major PER journal, and the other to a science education journal with a wider cultural scope. In the view of van Aalst (2000), this is perfectly reasonable: "Someone who does PER would publish both in journals that are likely to be read by physicists [...] and in journals intended for education researchers" (van Aalst, 2000, p. 68).

Using discourse theoretical frameworks allows us to look at identities and gender in a critical and non-essentialist way, and gives us tools to analyse the multiplicity of students' relations to physics education. What we have shown in these two papers is that importing tools and theories generally used in gender studies and related fields, we can explore not how physics courses includes or excludes pre-defined categories of people (like women), but how they rather produce certain approaches and "physics identities" as intelligible and valid. This may in turn relate to gender and other social categories, but it is not primarily an issue of gender, but of physics. In this context, a discourse analytical framework is a valuable tool for discussing and critiquing dominant discourses in the culture of physics. In the end, the hope is to make physics a more open and diverse place, something that would benefit both the people there, physics in itself, and perhaps the wider role of physics in society.

5. Future directions

As the research reported here is just the first part of my Ph.D. project, it is suitable to discuss some of the future directions which I, or other researchers, could take, building on these results.

Taking a starting point in the quantum physics project, a concrete continuation would be to focus more on students' individual negotiations of positions in third level physics courses. The research done so far and reported in Paper II, focuses on what discursive positions are made intelligible in the courses, mainly by teachers and the practical arrangements of the courses, but an increased attention to how students respond to these signals would certainly strengthen the project and provide many new insights about students' interactions with physics education. Some methods for doing this could involve for instance participant observations with students outside class or different kinds of interviews with students, perhaps using some elicitation techniques or combined with student "journals" reflecting on their experience of studying physics.

Another way of extending the project could be to broaden the view by collecting similar material from quantum physics courses in other national contexts. Doing this would allow me to ask comparative questions about how cross-national physics teaching cultures seem to be, and whether the patterns seen in the different Swedish courses can be seen at other places. A widening to other "advanced" physics subjects would also provide interesting comparative material. Do "quantum physics course discourse" differ from other physics discourses?

The empirical questions that I have found especially worth continuing work on concern the discursive positions in physics education in general. Perhaps these questions can continue to be posed in terms of what a position as a "competent" (Gonsalves, 2012; Due, 2012) or "good" (Paper II) physics student entails in different contexts. What is included? What is excluded? What physics positions are made unintelligible in the dominant discourses of physics education? A continued use of poststructuralist discourse theory will be one way of discussing these themes, and make a critique of the values of physics education possible, to further the goal of a diverse physics education, and discipline of physics, which allows more people to participate in physics and allows for a broader conception of physics. Perhaps, using these perspectives we may gain some answers about what it *means* to become a physicist. In that way, we may paint the complex picture of what happens to people like my first year classmates in more vivid colours.

Acknowledgements

Producing this work has of course not been an individual effort and could never have been done in isolation. A thanks could go on for much more than the pages already written, with tracing all the personal, intellectual, and material relations that have gone into the production of this single work. However, a short thanks, mainly to the people involved, will have to do.

First: supervisors, co-authors, and critical readers, thanks to Staffan Andersson, Maja Elmgren and Minna Salminen-Karlsson for being there for me so much and for keeping up your faith in my work. Specifically: Staffan, for good co-authorship even though time has often been short and for the joy you have shown in working with me; Maja, for helping me with goals and structure in hard times; Minna, for always trying to wring clarity out of my confused ramblings. A collective thanks to all colleagues at the Division for Physics Education Research, for engaging discussions across a great breadth of topics in education, as well as everything else, during our lunch and fika breaks. A particular thanks to our professor, Cedric Linder, for keeping the only PER group in Sweden together and always working hard for improving the opportunities of the group's Ph.D. students. A collective thanks to everyone at the Centre for Gender research: Co-teachers, fellow Ph.D. students, critical minds in discussion, friends.

A few of my Ph.D. student colleagues deserve special thanks: Johanna Larsson, friend, room mate, always on my side and ready to engage in all kinds of discussions. My work would not have been what it is without you. Klara Goedecke, friend, room mate, co-teacher and the first stop for all questions of gender theory. My work would not contain as much laughter without you.

Not to be forgotten, a thanks to all the students and teachers participating in my research for letting me get into and critically examine your world. Also thanks to all colleagues I have met at conferences and courses, or whose work I have only read. You have all collectively contributed some part to this work.

Everything is not work though, and I would not have been where I am today if it were not for Stina. Thanks for bearing with me, my sometimes too hearty cooking and for giving me occasional opportunities of doing the "fun" parts of "hard" science. A similar, albeit collective, thanks has to be given to all the rest of family and friends: you made me. Particularly, Ingrid and Eje, you gave me my moral compass and critical thinking. And all the children of siblings and friends. You have made the last years a much pleasanter time. Special thanks to Ture for lightening up the very last weeks of writing.

Last, I cannot fail to acknowledge the great debt that I am in to all the social and material conditions that have made this work possible. Social welfare, schools, public libraries, the medical industry, colonialism, cheap oil, composting, … The list goes on and perhaps means not only thanking, but also asking forgiveness.

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