Becoming a physics teacher

Disciplinary discourses and the development of professional identity

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Abstract
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In this Licentiate thesis I examine the system of physics teacher education. Physics teacher education is important because it is one of the main ways to influence how physics is taught in schools. By extension, physics teacher education has the potential to affect both *who* chooses to pursue physics as a career and *how* physics is perceived by Swedish society as a whole. In order to approach this problem, I chose to investigate the professional discourses of Swedish physics teacher educators. I focus on how these discourses potentially afford and constrain trainees' possibilities of performing a professional physics teacher identity. While the topic of teacher identity has been extensively explored in the literature, the influence of the educational environment on what it means to become a physics teacher has remained very sparsely researched. Theoretically, I view identity as socially constructed in discourse. I connect identity to trainee learning by arguing that *what* trainees learn will be dependent on *their possibilities to perform* professional physics teacher identities in their educational programme. Using discourse analysis of interviews with physics teacher educators, I identify four discourse models. These four models paint a picture of the educational program as fragmented with no coherent way of viewing the educational program as a whole. I further suggest that the culture of physics departments plays a pivotal role in the success or otherwise of creating good quality physics teacher education. I demonstrate how an implicit assumption, that the purpose of teaching physics is to create physics experts, appears to unintentionally undermine and devalue physics teacher education within physics departments. The findings presented in this thesis have the potential to inspire teacher educators and physics faculty to examine their own assumptions about what the goal of physics teaching is, and to facilitate the negotiations needed to create a common understanding of the goals of the physics teacher education.

Keywords: physics teacher education, discourse analysis, professional identity.

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Till Ture och Tekla

List of Publications

This thesis is based on the following publications, which are referred to in the text by Roman numerals. My contributions are outlined below each publication.

I Airey, J., Larsson, J. (2018) Developing Students' Disciplinary Literacy? The Case of University Physics. *In Global Developments in Literacy Research for Science Education*, (pp. 357-376) Springer, Cham.

I developed the theoretical ideas together with the first author. I did preliminary analysis for the third part of the chapter. The first author wrote the first draft.

II Larsson, J., Airey, J., Danielsson, A. T., & Lundqvist, E. (2018). A Fragmented Training Environment: Discourse Models in the Talk of Physics Teacher Educators. *Research in Science Education*. https://doi.org/10.1007/s11165-018-9793-9

I proposed the idea, collected the data, did the analysis and wrote the first draft. Each stage was discussed with my co-authors.

III Larsson, J., Airey, J. Lundqvist, E., (2019, in review) Swimming against the tide: Four myths about teacher education sustained by the culture of physics. *Physical Review Physics Education Research*

I proposed the idea and did the analysis. I wrote the first draft together with the third author.

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Supporting work

Airey, J., & Larsson, J. (2014, November). *What Knowledge Do Trainee Physics Teachers Need to Learn? : Differences in the Views of Training Staff.* Presented at the International Science Education Conference ISEC, November 2014, National Institute of Education, Singapore.

Airey, J., Larsson, J., & Linder, A. (2017). *Investigating Undergraduate Physics Lecturers' Disciplinary Literacy Goals For Their Students*. Presented at the 12th Conference of the European Science Education Research Association (ESERA 2017) 21-25 Aug. 2017. DCU Dublin

Larsson, J., & Airey, J. (2013a). *Exploring the interplay between disciplinary and professional discourses and the developing professional identity of trainee physics teachers*. Presented at the Nordic Physics Days, Lund University, June 12-14, 2013. Lund, Sweden

Larsson, J., & Airey, J. (2013b). *Hur samspelar disciplinära och professionella diskurser i utvecklingen av fysiklärarstudenters professionella identitet?* Presented at the Teknisk-naturvetenskapliga fakultetens Universitetspedagogiska Konferens 2013, Uppsala universitet; Uppsala, Sweden.

Larsson, J., & Airey, J. (2014a). *Searching for stories: The training environment as a constituting factor in the professional identity work of future physics teachers*. Presented at the BERA 2014, British Educational Research Association Annual Conference, 23-25 September 2014, London

Larsson, J., & Airey, J. (2014b). *The competing discourse models future physics teachers' meet during teacher training*. Presented at the International Science Education Conference ISEC 2014, National Institute of Education, 25-27 November 2014, Singapore

Larsson, J., & Airey, J. (2015a). *Discourse Models in Swedish Physics Teacher Training: Potential Effects on Professional Identity*. Presented at the 16th Biennial EARLI Conference for research on learning and instruction, Limassol

Larsson, J., & Airey, J. (2015b). *The "physics expert" discourse model – counterproductive for trainee physics teachers' professional identity building?* Presented at the Conference of the European Science Education Research Association (ESERA) 2015, Helsinki, Finland

Larsson, J., & Airey, J. (2017). *Four discourse models of physics teacher education*. Presented at 6th New Zealand Discourse Conference, 6-9 December 2017, New Zealand

Larsson, J., Airey, J., & Lundqvist, E. (2017). *How does the culture of physics affect physics teacher education?* Presented at the ESERA 2017 Conference Dublin City University, Dublin, Ireland 21st - 25th August 2017.

Adams, J. et al. (2018). The Role of Science Education in a Changing World. Retrieved from NIAS Press website: http://www.lorentzcenter.nl/lc/web/2018/960/extra.pdf

Contents

1 Introduction

> In the beginning I made one of the other teachers angry with me when I said that I was the only physicist in the school, the others were physics teachers. Because it's not until you've been the leader of a research group that you can really call yourself a physicist.

This quote is from one of the first interviews I did for this thesis, spoken by an experienced upper secondary school physics teacher who mentors future physics teachers through their first experiences of teaching at school. It contains the interesting sentiment that the label of "physicist" is a special privilege only awarded to the leaders of research groups. This is a surprising opinion to encounter, especially since many people call themselves physicists even though they have never been involved in a research group. Perhaps even more interesting is *why* this physics teacher was so eager to distinguish himself as a physicist rather than a teacher. He was prepared to be the source of ill will among the teachers at his school in exchange for the privilege to call himself the only "real" physicist at the school. But what about the privilege to call yourself a physics teacher?

The above quote typifies a narrative about teaching, from the first study of this thesis, that is called "the fallen angel". This is a narrative of someone who used to be successful in physics but who has "fallen from grace" and is now teaching. The "fallen angel" is a former successful physicist who just happens to be teaching and, in order to "pull off" this narrative, it is important to draw a hard distinction between physicists and physics teachers, as in this quote. This narrative could perhaps be restated as "I chose to become a physics teacher because I wasn't a good enough physicist" and is common in society at large, cemented in the phrase "Those who can do, those who can't teach". Failing to "do", however, is of course very far from the only thing that leads people into teaching physics. Furthermore, this saying, and the implied failure of the fallen angel, is silent on what learning to teach involves. Surely being unable to "do" does not automatically mean that you have the ability to teach.

The way becoming a teacher is framed will naturally affect the teachers that are attracted to the profession. If a narrative of failure defines how teachers are thought about in general and if this narrative is allowed to define how physics teachers think of themselves, then this will affect the physics teaching going on in schools. It will also influence *who* chooses to become a physics teacher. The fallen angel is a weak subordinate position in relation to the physics discipline. This is clearly not an optimal position when we want to encourage more students to become physics teachers and when we are trying to increase the status of the teaching profession in general.

Large problems with underrepresentation of women and minorities in higher education physics (OECD Publishing, 2017) further point towards the importance of how physics is presented in school. The culture of physics, as portrayed in school, affects who can see themselves as a future physicist, and consequently reproduces patterns of unequal participation in physics (Archer, 2019; Francis et al., 2016). Images of physics as connected to smartness, nerdiness and for elites (Johansson, 2018a) and notions such as the effortlessly "clever physicist" (Archer, 2019) can discourage in particular female students from continuing with physics. Physics teachers have a real possibility to affect these messages, and this means that their understanding of the nature and purpose of physics is crucial.

In general, the discourse around the teaching profession in Sweden is predominantly negative. Becoming a teacher is not seen as an attractive choice, and voices have been raised that it is too easy to become a teacher in Sweden, with the entry requirements for teacher training being too low. See for example the newspaper articles "Eleverna ska inte kunna mer än sina lärare," (Dagens Nyheter, 2019), "Jag förstår varför ingen vill bli lärare," (Aftonbladet, 2011), "Undermålig utbildning löser inte lärarkrisen," (Dagens Samhälle, 2019). In the light of this discourse, the "fallen angel" narrative is perhaps not so surprising. Who would choose to become a teacher with all the negatives associated with that role? Even framing oneself as a "failed" physicist must surely be better than that? This is borne out in the current situation, where very few students attend physics teacher education in Sweden despite a documented need for new physics teachers and a close-to-guaranteed job at the end (Swedish national audit office, 2014). Ultimately, there are people who *do* choose to become physics teachers and who follow a programme of physics teacher education. This thesis is concerned with the educational program these people meet.

While the topic of becoming a teacher has been extensively explored in the literature, a focus on the inherent messages signalled in physics teacher education about what it means to become a physics teacher has remained very sparsely researched. For many people in the discipline of physics and the wider society, the problem of the status of the physics teacher is simply an unavoidable fact one needs to work around. I suggest that this is not good enough, especially when we need more, more diverse, and perhaps "better" physics teachers.

To address this topic, I attempt to understand the range of experiences made available to future physics teachers by their education. In particular, what possibilities for framing oneself as a successful professional physics teacher are made available by teacher educators? The aim of the research presented in this thesis is thus to investigate the differing ways to be recognized as a professional physics teacher, as made available in teacher education programmes. I chose to examine how meanings around learning to become a physics teacher are constructed in the discourse of the physics lecturers, education lecturers and school mentors that trainees meet during their education. I take the perspective that learning to become a physics teacher is a process of becoming fluent in a new discourse, that is a socially agreed system of talking and acting. To be recognized as a professional physics teacher means to "pull off" a physics teacher identity within this discourse (Gee, 2005). I see professional teacher identities as recognisable identity performances within a professional context (Archer et al., 2017; Butler, 1990; Davies, 2006). The overarching aim for this Licentiate thesis is thus to investigate the differing ways to perform a professional physics teacher identity, that are made available in the discourses of educators in physics teacher education.

In Publication I, I take a theoretical approach to the problem of becoming a physics teacher within the context of physics teacher education. Here, my co-author and I explore physics lecturers' disciplinary learning goals (Airey, 2011b) for their students and discuss the contexts of physics teacher education from a Bernsteinian disciplinary knowledge structure perspective (Bernstein, 1999, 2000). The research question for this publication is:

1. Can Bernstein's constructs of hierarchical and horizontal knowledge structures be used in a fruitful way to understand the specific difficulties of combining physics and educational science in a physics teacher education programme?

Publication II explores the possible ways of being recognized as a physics teacher that are made available in the discourses of teacher educators. The research questions for this paper are:

1. What discourse models (here ways of making sense of the education of physics teachers) can be identified in the talk of the teacher educators that trainee physics teachers meet during teacher training?
2. What physics teacher identity performances might we expect to be recognised and valued within these discourse models?

Publication III uses one part of the results of Publication II, the idea that everyone should desire to become a physics expert, and explores this more deeply as a facet of physics culture as it pertains to teacher education. The research questions for this publication are:

1. What properties of physics culture with respect to physics teacher education can be identified in the talk of physicists?

2. What effects might these aspects of physics culture have on physics teacher education?

Throughout this Licentiate Thesis, I use the pronoun “I” when discussing, for example, the choices that I made in its formulation and writing. However, all the supporting work was collaborative and cannot be attributed to me alone.

The Licentiate is written in such a way that it can be read from start to finish and make sense without needing to also read the three publications that are included at the end. Because of this, some sections are of necessity almost identical to sections in the publications. In many cases, descriptions have been expanded and enhanced for better clarity in this new context where I get to tell the fuller story of my research.

1.1 Contributions

The findings presented in this Licentiate thesis are based on discourse analysis of 17 interviews with teacher educators who in different functions meet trainee physics teachers during their education. In the thesis I make the following contributions to Physics Education Research:

- I present a theoretical description of how the Bernsteinian constructs of disciplinary knowledge structures combined with the concept of disciplinary literacy can give insights to the potential problems for trainee physics teachers as they move between the different environments of the educational programme.

- Building on the analytical tools described by Gee, I introduce an approach to discourse analysis in educational environments. The talk of informants is used to create a number of discourse models. Together these discourse models describe what is tacitly valued in a particular educational environment. What is new here is that each discourse model has a single overarching goal.
    - Having identified these tacit goals, they help us interpret the actions of people in the environment – put simply, they offer a possible explanation of why things are as they are.

- I use the developed approach as a way to operationalise how the discourses of the teacher education programme potentially enable the performance of different physics teacher identities.

- I identify four discourse models. These are: *The practically well-equipped teacher* model, *The critically reflective teacher* model, *The curriculum implementer* model and *The physics expert* model. These models enable

and limit the kinds of identity performances trainee physics teachers can enact. I suggest that knowledge of these four discourse models of physics teacher education can be used in two ways.
  - They can facilitate physics teacher educators to make conscious, informed decisions about their own teaching practice.
  - They can empower trainee physics teachers to make informed choices about their own particular approach to becoming a professional physics teacher.

- I make theoretical contributions to a strand of Physics Education Research that take a social rather than psychological approach to physics teacher professional identity. Here, identity is not viewed as something stable that people possess, but rather something that is performed in a particular social environment. I view professional identity as the performing of an intelligible identity within specific professional discourses. For trainee physics teachers this would mean being able to gain recognition or making yourself meaningful as a physics teacher-to-be within the dominant discourses of the physics teacher training programme.

- I suggest that the culture of physics plays a pivotal role in the success or otherwise of creating good quality physics teacher education.

- I problematize the recommendations of the Task Force on Teacher Education in Physics (T-TEP) report, showing how they are unlikely to be implemented without taking the culture of physics into consideration.

- I demonstrate how an implicit assumption, that the purpose of teaching physics is to create physics experts, appears to unintentionally undermine and devalue physics teacher education within physics departments. This assumption leads to four "myths" about physics teacher education:
  - *The Goal Myth— The role of a school physics teacher is to create new physicists*
  - *The Content Myth— The content of school physics is simple, uninteresting and inherently unproblematic*
  - The *Student Myth— Students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists*
  - The *Teaching Myth— It is not really necessary to learn how to teach physics*.
  - I suggest that knowledge about these constructs has the potential to inspire physics faculty to examine their own assumptions about what the goal of their physics teaching is and proactively move to address the four tacit myths identified.

2 Previous research

Since my work is situated in Physics Education Research (PER) I start, with a general overview of physics education research and its main themes. Thereafter I situate my thesis in the main areas of interest, namely: teacher education in relation to teachers' professional identity, and critical perspectives in Physics Education Research

2.1 An overview of Physics Education Research

In many ways, modern Physics Education Research (PER), can be said to have started with the launch of Sputnik by the Soviet Union during the cold war in the 1950s. The threat of being scientifically and technically left behind prompted the West—in particular the United States—to channel resources into improving science education. The first main focus in this drive to improve science education was to reform the curriculum, making it less fact-based and more focused on inquiry and participation in the scientific process (McDermott, 2006). Following these changes, outcomes of the reforms were examined in order to make further improvements to these reformed curricula (De Jong, 2007).

Since physics was seen as being the academic discipline with the closest coupling to the "Space Race", it was natural that reforms were first implemented there. Initially the main issues of interest within PER were the difficulties students experienced when faced with learning particular parts of physics. Such difficulties were investigated by exploring conceptual understanding (Heron & Meltzer, 2005). Meanwhile, the societal need to increase the number of students completing their studies so they can enter the workplace led to efforts to find and implement effective approaches to what physics experts *anticipated* as being problematic for students. At this stage, understanding *why* students could be expected to experience such challenges was considered to be of lesser importance, thus, little or no research was taking place into why the proposed interventions may be effective.

In the time between 1990 and 1998, referred to by Cummings (2011) as the "formative years", research in PER developed rapidly. One example is the development of "Tutorials in Physics" (McDermott & Shaffer, 2002; McDermott, Shaffer, & Rosenquist, 1996) by the University of Washington PER group. These Tutorials proved to be extremely effective and became widely implemented in university physics education in the USA. The development of such research-based materials to improve learning outcomes was the main thrust of PER for many years. An interest in understanding *why* students learnt physics in a particular way also began to grow. Here seminal studies were undertaken in kinematics (see for example Trowbridge & McDermott, 1981). Forerunners such as Helm (1980) and Warren (1979) had already produced considerable compelling evidence that the ability to solve physics problems did not necessarily reflect good conceptual understanding. Then, after the production of the Force Concept Inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992) and a large cross-university study it became clear that many students still have poor conceptual understanding of Newtonian physics after successfully completing introductory courses in this area (Savinainen & Scott, 2002). Thus, PER established itself as an integral part of physics with physicists researching their own practice, their students' understanding of physics content, and the learning challenges associated with that content. As described earlier, the research tended to be atheoretical and practically orientated. Since the researchers were practicing physicists, the methodology they used tended to be chosen from the "toolbox of physics" and consequently, quantitative methods were preferred and valued (Heron & Meltzer, 2005).

From these beginnings, PER developed a rich and effective range of learning interventions and in what follows I describe the main themes of this work that are visible today. From a literature review that I carried out at the beginning of my PhD studies of all articles published in the American Journal of Physics, European Journal of Physics and Physical Review Physics Education Research between 2011 and 2013, I identified the following themes: conceptual understanding, problem solving, use of representations, expert-like thinking and assessment and development of curriculum. Interestingly, these themes, to a large degree, correspond to the topical areas reviewed by Docktor and Mestre (2014).[1] Docktor and Mestre, however, discuss "Representations" and "Expert-like thinking" in subsections under "Conceptional understanding" and "Problem solving". In contrast, I decided to give them their own headings. Docktor and Mestre also suggest the topical areas "cognitive psychology" and "attitudes and beliefs about learning and teaching". I chose to add the latter to my overview and to see "cognitive psychology" as a theoretical framework used in many PER areas, rather than a theme.

[1] Here "curriculum and instruction" correspond to the theme of development of education.

2.1.1 Conceptual understanding

In PER, the "conceptual understanding" construct characterizes concerns about how students construct their understanding of physics fundamentals and how they use this understanding across physics tasks. Much of the work in this area has been situated in introductory and intermediate physics areas, for example, classical mechanics (Trowbridge & McDermott, 1981), electromagnetism (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), quantum mechanics (Sadaghiani & Pollock, 2015), physics equations (Airey, Grundström Lindqvist, & Kung, 2019) and modern physics (Henriksen et al., 2014; Scherr, 2007). Conceptual understanding is one of the most original and thoroughly explored areas of PER, that started with the realisation that students have difficulties understanding basic concepts in physics, even when they pass regular examinations. The terms "misconceptions", "naive conceptions" and "alternative conceptions" have been suggested to describe conceptual understanding and often get used to refer to the understandings that students constructed from their everyday life experiences, typically before they entered physics classrooms (Docktor & Mestre, 2014). This kind of characterization has been criticised for labelling the everyday understanding of phenomena as "lesser than" the formal world of physics knowledge (Linder, 1993), see further discussion on this in section 2.1.3 (Attitudes and beliefs about physics learning).

An illustrative example of an area of conceptual understanding analysis and assessment is that of student understanding of measurement (Volkwyn, 2005; Volkwyn, Allie, Buffler, & Lubben, 2008). After finding that only a small fraction of students could demonstrate a coherent *understanding* of measurement after traditional instruction, these studies found that a significant improvement in student application of laboratory procedures related to measurement can be obtained through understanding how students think about certainty and uncertainty in measurement.

In general, the theoretical foundation of the research on conceptual understanding has to a large degree been loosely grounded in cognitive psychology thinking and this thinking brought the research focus onto individual students (see McDermott & Redish, 1999). The early PER investigations that assessed the conceptual understanding of students slowly shifted into new areas that called for stronger theoretical frameworks. Examples here are the connection between the teacher-reflected epistemology and conceptual challenges (eg, Linder, 1992), epistemic games "how students access the knowledge they have in the context of solving a particular problem" (eg, Tuminaro & Redish, 2007), epistemological reasoning of students and understanding of physics concepts (eg, Ding, 2014), and the connection between response time and understanding (eg, Miller, Lasry, Lukoff, Schell, & Mazur, 2014). Thus, in contemporary PER, theoretical foundations and their associated methodologies have become increasingly important. An illustrative example here is the "Knowledge in pieces" perspective (diSessa, 1988; for a recent example of using this perspective see Harlow, Bianchini, Swanson, & Dwyer, 2013).This perspective is grounded in the theoretical view that physics knowledge is constructed through the collection of a large number of small contextual parts that are referred to as “p-prims” (diSessa, 1988, 1993).

2.1.2 Problem solving and expert-like thinking

In the area of student problem solving, “novice” approaches to problem solving have been compared with that of “experts”. An early example from psychology is Chi, Feltovich, and Glaser (1981) who found that experts approached physics problems by focussing more on deep structural features, while novices did this by focussing more on surface features. A lot of research followed in the footsteps of this paper (Savelsbergh, de Jong, & Ferguson-Hessler, 2011), both in PER and in other fields, even though the original findings have been hard to replicate (Wolf, Dougherty, & Kortemeyer, 2012b, 2012a). In a seminal paper, Van Heuvelen (1991) discussed student use of “representations” (in the sense of semiotic forms) while solving problems in physics as a physicist would, and from here instructional goals were proposed for ways to encourage and support students learning to think and act like physicists (i.e., experts).

This way of connecting problem solving with representations and expert like thinking has since developed into a major strand in PER (for example, see Treagust, Duit, & Fischer, 2017). Typical questions here centre around how the use of different representations affects student learning and student approaches to problem solving.

2.1.3 Attitudes and beliefs about physics learning

This research area is based on the idea that “student epistemology” i.e. students’ attitudes and beliefs about learning and physics (Elby & Hammer, 2010, p. 409) affect how they learn in the classroom (Marton & Säljö, 1976; Mason & Singh, 2016; Prosser & Millar, 1989; Trigwell, Prosser, & Waterhouse, 1999). This research area in part started as a response to research on student “misconceptions”, offering a different perspective on why students fail to learn (diSessa, 1993; Hammer, 1996; Linder, 1993).

One way for teachers to approach student epistemology is through the concept of “epistemological resources” – “fine-grained knowledge elements that a student possesses, the activation of which depends on context” (Elby & Hammer, 2010, p. 410). A locally coherent network of epistemological resources is called an “epistemological frame”. One example of an epistemological frame could be the resource “knowledge as propagated stuff” together with the resource “learning as accumulation”. Thinking of epistemological frames rather than student beliefs about learning, puts the emphasis for teachers on the context dependency of student beliefs. (Elby & Hammer, 2010)

Another way student attitudes are often viewed, is in in relation to physicists attitudes to physics, science and knowledge (Hammer, 1994; Redish, Saul, & Steinberg, 1998). In the study of expert like epistemology and the impact of student epistemology on learning in physics (Bing & Redish, 2012) it is shown that learning epistemological skills, such as switching between epistemological resources depending on context, is an important part of learning physics. Helping students develop towards an expert-like epistemology is however not straightforward if there is a mismatch between the (naive positivist) epistemology often implicit in the teaching of physics and the social-constructivist epistemology implicit in the practice of physics (Sin, 2014).

Several tools have been developed to measure students' attitudes, beliefs and epistemology. One example is E-CLASS, that measures student epistemology and expectations in a laboratory context (Zwickl, Hirokawa, Finkelstein, & Lewandowski, 2014). In other work, McCaskey (2009) compares and discusses different ways of measuring student epistemology.

2.1.4 Representations in physics

A newer direction in PER seeks to explore how the communicative practices of physicists draw on different forms of representations such as graphs, diagrams, equations, gesture, written and spoken languages, etc. These representations form what is referred to as the "disciplinary discourse" of physics (Airey, 2009; Airey & Linder, 2009) that is, they both create and communicate physics knowledge. In this work, the physics that students meet in their classrooms is understood to be interwoven with, and inseparable from, the representations of the physics community.

There has been a great deal of work looking at the role of individual representations in physics. Research has been carried out into the use of Graphs (e.g. Åberg-Bengtsson & Ottosson, 2006; McDermott, Rosenquist, & van Zee, 1987; Volkwyn, Airey, Gregorcic, & Linder, in review), Equations (e.g. Airey et al., 2019; Hestenes, 2003; Sherin, 2001), Language (e.g. Airey & Linder, 2006; Brookes, 2006; Roth, 1996), Gesture (e.g. Gregorcic, Planinsic, & Etkina, 2017; Roth, 2001; Scherr, 2008), Diagrams (e.g. Heckler, 2010; Rosengrant, Van Heuvelen, & Etkina, 2009) etc.

Fredlund, Airey and Linder (2012) discuss the *disciplinary affordances* of these different representations—that is the functions that different representations fill for the discipline. Similarly, Airey (2015) has suggested the term *pedagogical affordance* which he defines as the aptness of a particular representation for teaching some educational content. Fredlund et al. (2014) show how the disciplinary affordance of a physics representation can be unpacked (in effect how teachers can increase the pedagogical affordance of a representation). Airey & Eriksson (2019) explain how such unpacking will of necessity decrease the disciplinary affordance of the representation.

A number of researchers have investigated how representations are combined in physics (see for example Dufresne, Gerace, & Leonard, 1997; Rosengrant, Etkina, & Van Heuvelen, 2007; Van Heuvelen & Zou, 2001). Here it has been suggested that there is a particular *critical constellation* of representations that are needed for appropriate construction of any given disciplinary concept (see Airey, 2009; and Airey & Linder, 2009). Recent work has also emphasised the importance of movement *between* the different representations—formally termed *transduction*—for the teaching and learning of physics. Here, it is claimed that the shifts in pedagogical and disciplinary affordance when moving between the different representations of the same concept allow students to notice aspects of physics concepts that they might otherwise have overlooked (Volkwyn, Airey, Gregorcic, & Heijkenskjöld, 2018, 2019)

The use of Social Semiotics (Jewitt, Bezemer, & O'Halloran, 2016) as a way of understanding learning through analysis of communication has become popular in recent years (see Airey & Linder, 2017 for an overview of this approach). One significant outcome of this research perspective is the suggestion that for each learning objective, there is a number of "Disciplinary Relevant Aspects" – DRAs (Fredlund, 2015; Fredlund et al., 2012; Fredlund, Airey, & Linder, 2015) that collectively could facilitate a holistic learning. Discussion emanating from this work suggests that a raised awareness of which of the DRAs each representation may provide direct access to, can significantly improve learning outcomes. Further, building on Eriksson et al. (2014b), Airey and Eriksson (2019) argue that for students to discern the DRAs in the HR-diagram, it is not enough to just *notice* them, students also need to reflect on and make meaning of what they have noticed. Eriksson, Linder, Airey & Redfors (2014a) suggest that this process can be referred to as *disciplinary discernment*.

In other work, Euler, Rådahl, & Gregorcic (2019) combine social semiotics and embodied cognition to discuss the meaning-making of two students' reasoning about binary star dynamics. They show how students' use of non-disciplinary resources, such as touch and movement, can support reasoning about physics phenomena. Another interesting example of this direction is the research on use of infrared cameras in physics and chemistry teaching. Here it has been shown that the use of such cameras makes it possible for students and instructors to focus on DRAs in a chemistry lab setting for example change in temperature (Samuelsson, Elmgren, & Haglund, 2019).

2.1.5 Assessment and Concept Inventories

A large range of conceptual inventories have been developed in PER to better understand the learning challenges in different areas of physics such as student understanding, problem solving ability, use of representations and student attitudes and responses to changes in teaching (see list at AAPT, 2019a). One of the first inventories developed was reported on by Helm (1978) who developed a twenty item test to explore students' understanding of a range of physical concepts that are fundamental to introductory physics. Helm built his work on the free response testing done by Warren (1979). However, because the dominant measure of understanding physics at the time was the ability to solve physics problems correctly, this early work had little influence on the wider PER community. In 1992 the first set of comprehensive results from an inventory was reported on. This inventory was called the Force Concept Inventory (FCI) (Hestenes et al., 1992) and it measured student conceptual understanding in introductory mechanics. The results shocked the PER and wider physics teaching community because they revealed how challenging these concepts were for students to come to appropriately understand. The FCI was revised in 1995 and went on to be given to thousands of students around the world, all with much the same result, and it is still widely used as a diagnostic tool today (Caballero et al., 2012; Traxler et al., 2018).

Today there are inventories for measuring understanding in many areas of physics, for example, electro-magnetism (Maloney et al., 2001), quantum mechanics (McKagan & Wieman, 2006), student understanding and use of graphs in physics (Beichner, 1994), student attitudes (MPEX, CLASS) (Adams et al., 2006; Redish et al., 1998) epistemology (E-CLASS) (Zwickl et al., 2014) and Student Representational Fluency (Hill, Sharma, O'Byrne, & Airey, 2014). For a list of published concept inventories and validation studies see (Docktor & Mestre, 2014, p. 24).

Besides their obvious use in terms of diagnostics for individuals and groups, in the literature these tools are typically used to assess the effects of different ways of teaching physics. In such work, large scale surveys are distributed to students before and after a teaching section, and the results are analysed using statistical methods. Today, the research on assessment is rich and complex, including "exploring correlations between inventory scores and other measures of performance, comparing scores across multiple populations (culture and gender), and exploring the value of complex models of student learning beyond pre-post scores" (Docktor & Mestre, 2014, p. 22).

2.1.6 Development of education in PER

The realization that many students leave introductory physics courses with the same (or even less!) conceptual understanding of physics than before taking their courses (Beichner, 2009) inspired a large number of projects giving practical guidance on how to address learning challenges in physics. An extensive list of resources can be found at https://www.physport.org (AAPT, 2019b). Below, I present some examples to give a flavour of this kind of work.

Just in time teaching. Web-based pre-class assignments seek to improve the quality of physics class and make it possible for teachers to adjust their lessons to their students. Class-time seeks to activate the students. The interaction in terms of student-student and student-teacher is seen as important (Novak, 1999).

- **Peer Instruction** (Mazur, 1997). It has been shown that students learn physics more effectively if they are active and engage with the course material. In Peer Instruction this is accomplished by collaboration between students. The lectures are structured around shorter presentations by the teacher followed by discussion of the core concepts among the students. This has been shown to be more effective than lectures when assessing conceptual understanding with the FCI (Crouch & Mazur, 2001). Peer Instruction is typically used together with just in time teaching. Also available for quantum mechanics (Singh, 2008).
- **Physics by Inquiry.** Two text-books aimed at introductory level physics by McDermott, Shaffer, and Rosenquist (1996) introduced physics starting with the students' own observations and focusing on scientific skill and reasoning.
- **Tutorials in introductory physics** is a set of materials that can be used as a supplement to lectures and a textbook in a course. The purpose of the tutorials is to develop conceptual understanding and scientific reasoning and the tutorials contain pre-tests, questions to discuss, homework and post-tests (McDermott & Shaffer, 2002).
- **Colorado learning assistant model.** Undergraduate physics majors work as teacher assistants together with a lecturer to implement new ways of teaching. This has improved the number of students interested in teaching and improved the quality of teaching (Otero, Pollock, & Finkelstein, 2010).
- **Scale-Up.** An interactive learning environment for introductory college courses in physics, chemistry and biology. There is no separate lab work but labs and lectures are integrated. Interaction between small groups of students are facilitated by smaller segments such as "Tangibles", "Ponderables" and "Real World Problems". Most noticeable is that the physical space of the classroom is restructured in a way that encourages non-traditional teaching. (Beichner, 2007)
- **Thinking Problems.** A large collection of physics problems designed for conceptual understanding, problem solving skills, and making real-world connections. (University of Maryland PERG, 2006)
- **Matter and Interactions.** A calculus-based textbook, focusing on fundamental principles, the atomic nature of matter and the modelling of physical systems (Beichner, Chabay, & Sherwood, 2010; Chabay & Sherwood, 2015).
- **PhET.** A collection of open ended game like simulations to be used in the learning of physics, chemistry, math, biology and earth science. (Wieman, Perkins, & Adams, 2008)
- **ISLE** (Investigative Science Learning Environment). Based on the principle of learning science by experiencing what scientists do. An

interactive method that guides students through the scientific process of pattern recognition, explanation, reasoning, and testing. (Etkina & Heuvelen, 2007)

- A more recent direction is **the use of technology in teaching and learning**. Some elements of this have been around for a long time (like open source tutorials) and some are more about how to make use of new technological development (Martínez, Naranjo, Pérez, Suero, & Pardo, 2011). See for example Euler & Gregorcic (2017) about the role of the digital learning environment Algodoo in aiding students move between the physical context and the formal mathematical context when solving problems, and Gregorcic, Etkina, & Planinsic (2018) about the use of interactive whiteboards in a High School physics classroom.

2.2 Situating the thesis

The previous section presented an overview of the wider field of PER within which this thesis is situated. This section focuses on presenting areas of particular interest for this thesis. These are teacher education, professional identity, and critical perspectives within physics education.

2.2.1 Swedish teacher education

The Swedish teacher education programme that is the focus of this Licentiate thesis was created in its current form in the 2011 Swedish teacher education reform (SOU 2008:109; Prop. 2009/10:89). Before this reform, the pedagogical part of Swedish teacher education was structured as one programme for all trainees, regardless of the age group they were preparing to teach. In the new model however, teacher education is now instead organised in separate programs for each age group. This was a return to an earlier teacher education model that was implemented between 1988 and 2001 (Sjöberg, 2019). This way of pivoting between opposite understandings of how teacher education should be organized can be said to mirror the relationship between teacher education and Swedish government. Teacher education is used as a means of affecting society and each new political constellation has had their own understanding of what this should look like. The historical organization of Swedish teacher education into separate teacher training colleges as opposed to academic institutions has resulted in teacher education having less strong academic traditions compared to other academic programmes. This phenomenon has been suggested as one reason why direct government intervention has been considered legitimate. (Sjöberg, 2014)

Because of the tradition of organizing education in teacher training colleges, the discourse of achieving practical knowledge through practice-based experience is pronounced in Swedish teacher education. Since 1950, other more theoretical academic discourses have been made available along with the gradual academization of teacher education. The two discourses of practical, experience-based knowledge versus theoretical academic knowledge now exist in parallel in Swedish teacher education. In general, the theoretical academic discourse is more dominant in programmes aimed towards older age groups whilst the practical experience-based approach is more pronounced in programmes aimed towards lower age groups. (Sjöberg, 2019)

One interesting direction in Swedish teacher education research is the exploration of constructions of the image of what a good quality teacher is, through analysis of the practice of failing trainees on the practicum part of education (Gardesten, 2016; Nordänger & Lindqvist, 2015). As of today, eligibility for teacher education in Sweden is based on academic performance only, but up until 1977 candidates needed to pass some version of a personal appropriateness test, assessing for example character and mental health. Today, passing the practicum part of the teacher education program can be considered to fill a similar function, however the practices of actually failing a student are complex (Nordänger & Lindqvist, 2015). In his thesis, Gardesten (2016) explored what he termed “the essential basis” i.e. the minimum competence required for trainees to pass their practicum. He found that the ability to be responsible and “mature” in relation to school pupils was considered an important baseline competency. Common grounds for failing students have been found to be exaggerated passiveness, inability to appropriately respond to social cues, and rigidity—the inability to change their behaviour according to their mentor’s suggestions. (Nordänger & Lindqvist, 2015)

2.2.2 Teacher education in PER

One early and important focus of PER was the dissemination of the knowledge of teaching and learning physics to the wider field of physicists, by focusing on demonstrating to the individual physics teacher the values of using new methods in their own classrooms (Henderson, Beach, & Finkelstein, 2011). For the K12 level, it was thought that making reformed materials and summer courses teaching new ways of teaching physics available to K12 teachers would be enough to spread these ways of teaching physics. This proved not to be the case and efforts to implement reformed curricula petered out after the initial initiatives (McDermott, 2006). Since then, large efforts focusing on the preparation of pre-service teachers have been made. What successful examples of US teacher preparation programs have in common is a local commitment in the physics department to high quality physics teacher education (Task Force on Teacher Education in Physics (T-TEP), 2012). I will now give a brief overview of some of these programs.

The Colorado Learning Assistant Program (Otero et al., 2010) at the University of Colorado shows how physics students working as learning assistants in undergraduate physics courses can improve the quality of teaching. This approach has proven to increase both the number of students interested in teaching and the level of engagement of the physics department in teacher training.

The University of Washington has developed courses for pre-service as well as in-service teachers, built on Physics by Inquiry (McDermott et al., 1996). Physics by Inquiry was designed with pre-service teachers in mind, with the argument that these students have particular needs, both because they will teach the physics they learn and because they often have different academic backgrounds than the other students (McDermott, Shaffer, & Constantinou, 2000).

The Physics Teacher Preparation Program at Rutgers University focuses on pedagogical content knowledge (PCK) (Shulman, 1986, 1987) as its theoretical foundation of teacher knowledge (Etkina, 2010). Apart from learning content knowledge, pedagogical knowledge and pedagogical content knowledge, pre-service teachers in the Rutgers program are also equipped with strategies on how to implement what they have learned in the program in practice. Through the development of productive habits, the program tries to support new teachers in making fast teaching decisions when pressed for time in the new complex school environment (Etkina, Gregorcic, & Vokos, 2017).

Finally, the Modeling Instruction Program at Arizona State University offers professional development to in-service physics teachers. The program is built around the Modeling Instruction method, where basic physics models are the entrance to learning physics. It offers courses in physics pedagogy, interdisciplinary science and contemporary physics (Hestenes, Megowan-Romanowicz, Osborn Popp, Jackson, & Culbertson, 2011).

The successful physics teacher preparation programmes mentioned above make use of both knowledge about the teaching and learning of physics of all students, and specific research focused on the learning of pre-service teachers. PER was from the start interested in the particular needs and differences between different groups of learners such as life science majors (Redish & Hammer, 2009) and pre-service teachers (Şahin & Yağbasan, 2012). Smith and van Kampen (2011) for example found that pre-service science teachers had difficulties with qualitative reasoning about circuits with multiple batteries while Fazio, Di Paola, and Guastella (2012) investigated pre-service teachers epistemological approaches to knowledge production. In such explorations, the focus has been on what distinguishes the physics learning of the pre-service teacher group, rather than on what pre-service teachers need to learn to become good physics teachers.

Another strand of research, more concerned with this later matter, uses the model of pedagogical content knowledge developed by Shulman (1986, 1987) to make a distinction between "content knowledge", "pedagogical knowledge" and "pedagogical content knowledge". PCK has evolved into a family of related concepts, pointing towards the complex interplay between disciplinary knowledge and what is needed to effectively teach this knowledge

(Berry, Friedrichsen, & Loughran, 2015). In physics education, the related concept Content Knowledge for Teaching (CKT) is preferred (Etkina et al., 2018; Loewenberg Ball, Thames, & Phelps, 2008). CKT has mainly focused on pre-service teacher learning of applications, metaphors, representations, common student misconceptions and strategies of dealing with them, and is also used as a tool to measure the learning gains of pedagogical efforts (Hiller, 2013; Milner-Bolotin, Egersdorfer, & Vinayagam, 2016; Thompson, Christensen, & Wittmann, 2011).

PCK, CTK and other conceptualizations about teacher knowledge put forward theories about what teachers need to be taught. One important question here is to consider the role of physics content courses (McDermott, 1990), what physics content do trainees need and why? Here, recent work has indicated that different stakeholders have quite diverse answers to this question (deWinter & Airey, 2019). The knowledge of the dynamics already in play in physics teacher education programs is however still small. In particular, the PER literature on teacher education tends to focus on how to make teachers teach physics better while presupposing views about the purpose and meaning of physics. Too little knowledge exists about how these views affect trainee teachers and what the result is of the interplay between the culture of physics and teacher education. A further exploration of the significance of the norms and culture of physics for teacher education is needed.

As discussed above, the fundamental direction in PER that is focussed on teacher education examines how to spread the developed knowledge of physics teaching and learning to teachers, both at the pre-service and in-service stage. Another focus that has been created through this path is on evaluating the success of such efforts, and of several well-functioning programs for pre-service teacher education. However, there are few exploratory studies on the process of becoming a teacher. Such exploratory studies do however exist in the fields of science education and teacher education. Such work often uses the identity concept to explore the student experience of becoming a teacher. This will be further discussed in section 2.2.5 (Teacher professional identity).

2.2.3 Physics content and the purpose of learning physics

Teacher education is an inherently political area, affected by both national political agendas, a number of academic disciplines and public opinion. In practice, it is the individual physics teacher who, as a professional, chooses how he or she will teach. However, this individual freedom is restricted by such things as national testing, grading standards and the curriculum (Lundgren, 1999; Sundberg & Wahlström, 2012).

The formation of a school subject has been generally discussed as a historical process where the subject strives to move closer to an academic form to gain some of the high status of the university subject (Goodson, 1993). In general, what content is included in school and the interpretation of that content “might be a result of struggling social forces giving way for different interpretations, interpretations that lean on different political and ideological visions” (Englund, 2010, p. 6). The school subject is also in practice enacted and implemented by each individual teacher. Physics teachers can to some extent be expected to form their understanding of what physics is and should be during their university years (Aikenhead, 2011). In Sweden, school physics has been described as a static, simplified version of university physics, that has failed to adapt both to new research in physics, pedagogical development and curriculum change (Engström & Carlhed, 2014; Löfdahl, 1987). Curricular development since the 1970s has brought a new direction to the Swedish school physics syllabus, with a larger focus on societal and equity aspects of physics, but actual introduction of new teaching practices in school to match these new aims seems to be slow and limited (Engström & Carlhed, 2014).

A range of ways of understanding the purpose of physics teacher education co-exist in the educational system, where each such purpose also casts a different light on the physics content that could potentially be included in the educational program. Different ways of understanding what is valuable and useful physics content in physics teacher education are closely connected to the understanding of the purpose of such educational programs. One way of considering such questions is described by Roberts (2007, 2011) as two *Visions of scientific literacy*. The two Visions are competing discourses around what constitutes good science education, each with a different purpose assigned to the learning of school science. Vision I envisions literacy within science itself. Here, the concepts, laws and theories of the discipline should be the main focus of the school science content. The purpose of teaching science is to make students literate for and within the scientific discipline. In vision I, then, this scientific knowledge is considered to automatically lead to students also knowing how to apply the scientific knowledge in contexts outside the discipline, such as for teaching.

Vision II envisions science literacy for society. Here, the scientific discipline is just one of many areas where reasons for students to learn science are to be found. This means for example that students should be able to apply their knowledge in everyday life or political contexts as citizens, and that the skill to do this needs to be taught. Translating these visions to physics, Vision I deals with physics for physics own sake, whilst Vision II deals with physics for society. In addition to the original two Visions, a Vision III has been suggested that includes a critical perspective on the scientific discipline itself (Aikenhead, 2007; Haglund & Hultén, 2017). The visions of scientific literacy provide tools that can be used to discuss what content should be included in physics education. Only a handful of students in school will become physicists and explicitly need Vision I physics. However, all students are becoming citizens, and it is the task of physics teachers to make physics relevant to these students.

Given this difference in emphasis, it is important to learn how physics teacher education handles these very different views about the purpose of physics. What are trainees actually taught? One especially interesting question is the distribution of responsibility between the education department, the physics department and school. Who is responsible for teaching trainees how to teach physics and what should be included in that part of the education?

2.2.4 Physics and social justice

Physics has well-documented challenges with underrepresentation, and this has spurred an interest in issues related to social categories such as gender, social class, ethnicity, etc. (Phoenix, 2006). The goal is to create physics education that provides equal possibilities to enter and work in the physics community. In Physics Education Research, questions concerning equal participation in science have traditionally been approached by using quantitative methods together with an understanding of gender as a fixed binary category (Danielsson, 2009; Traxler, Cid, Blue, & Barthelemy, 2016). For example, Hazari. et al. (2013) used survey data from 7505 college English students to statistically test the effects of five factors believed to encourage female participation in science. They found that only one factor—discussing the underrepresentation of women in physics class—had a significant positive effect.

In her PhD thesis, Danielsson (2009) searched through science education and PER journals for articles concerning physics and gender and concluded that the majority of studies taking a gender perspective at that time were quantitative in nature. The identified articles mainly dealt with aspects of what is called the gender gap, differences between men and women that can be measured with quantitative methods.

Some examples of how gender has been approached in PER are: Richardson and O'Shea (2013) who investigate the gender differences in a student response system in an introductory physics course, Miyake et al. (2010) who report on a suggested way to reduce the gender-gap in college science by value affirmations, and Potvin and Hazari (2016) who found gender bias in how physics college students rate their secondary school physics professors. The last study found that both male and female students rated male professors higher than female professors, and this difference was higher among students with a higher identification with physics. The authors discuss how this shows that gender bias is not solely a characteristic of older members of the physics community but is also evident in those students who are most likely to become new members (those who show high identification with physics). An interesting question in this context that is of particular interest for this Licentiate thesis is whether it could be that physics newcomers adapt to already existing gender biased discourses in the physics environment.

One way of interpreting this research area within PER is that questions of unequal participation in physics in the Western world have generally been handled within a so-called deficit model (Traxler et al., 2016). In its simplest terms, this approach means that the problem is formulated in terms of questioning why underrepresented groups fail to be more like the "standard successful physics student" who is stereotypically taken to be a white male. With this type of formulation, the problem of unequal participation in physics becomes a function of something that women and minorities lack. It is perhaps not surprising then, that solutions to these perceived problems usually consist of trying to change or help and support women/minorities in different ways. It has been pointed out that this approach risks reinforcing the existing bias against women and minorities in physics (Traxler et al., 2016). To avoid this problem, it has been suggested that Physics Education Research should focus on the practice of physics itself and how it reproduces both privilege and unequal structures, rather than on the perceived shortcomings of certain groups (Johansson, 2016, 2018b; Traxler et al., 2016) (see also Hussénius et al. (2013) for a similar argument in science education).

One interesting example that turns the gaze towards the structure of the education rather than the individual student is the study by Andersson and Johansson (2016). They problematize the traditional way of understanding achievement differences on a third-year electromagnetics course. The study was motivated by instructor concerns about differences in grades between male and female students. Qualitative analysis of interviews with the students taking the course showed that students approached their studies in two distinctive ways, *studying to pass* or *studying to learn*. Student approach was connected to how significant they perceived the course to be in relation to their program affiliation. The apparent gender gap that motivated the study, could in further analysis be re-framed as a program gap, where programs "further from the discipline pf physics had lower mean grades and also enrolled a larger fraction of female students" (p.1) In this way the gender gap was shown to be the result of a complex relationship between individual students, perceived meaningfulness of this particular course, and gendered patterns of study choice.

While endeavours to understand science and physics as a social practice have only just recently begun in PER (Johansson, 2016), this is not a new research theme in science education and science studies. In science studies, for example, Latour and Woolgar (1979) adopted an anthropological approach to science and the production of scientific facts in complex social networks. Similarly, in her work on epistemic cultures, Knorr-Cetina (2007; 1999) focused on the social processes of knowledge production. These studies within the sociology of science thus investigate the processes of science itself, while others have focused on the production of scientists. Hasse studied the "physicist institution as just another culture" (2002, p. 254) and described how visions for the future of physics inspired by science fiction affected how students saw physics as for them and their expressions of genuine interest in physics (Hasse, 2015). Similarly, in her seminal work, Traweek (1988) studied the high energy particle physics community and in her book describes how physics students are expected to walk the one legitimate path towards becoming a "timeless genius". Her discussion of physics as a "culture of no culture", a characteristic that works to hide the actual nature of the culture of physics under a supposed neutrality, has been taken up again and again by later studies (Gonsalves, Danielsson, & Pettersson, 2016). For example, Due (2012) found competing discourses of "physics being masculine" and "physics being understood as gender neutral" (see also Danielsson, 2009 and; Gonsalves, 2014b). When the discipline of physics is considered to be both gender neutral and masculine, the masculine becomes neutral (Gonsalves, 2014a) and bodies that are marked as female consequently become un-neutral – i.e. gendered (Beauvoir, 2002). Ong (2005) explores how these notions can affect *who* can be seen as ordinary in the community, and the amount of work done by women of colour to achieve that position. She shows how the culture of the physics discipline works to solidify barriers to non-traditional students' participation in physics.

The effect of physics-culture on women's participation in physics has also been investigated in the UK school context (Francis et al., 2016). Archer et. al. (2017) show how ideas of physics as masculine are internalized by girls (age 15/16), understanding physics as not for them. Furthermore, to be credible as physics persons, the girls who do chose physics are required to perform as exceptional physics girls. This position is not equally attainable for all girls and is for example difficult to combine with working class femininity.

These studies are all examples of the emergence of critical perspectives in physics education. They focus on the role that the culture of physics plays in creating and maintaining inequalities. What many of them have in common is that they make use of the identity concept from a post-structural, critical perspective. However, this line of research has typically tended to focus on the situation of particular groups and has not yet been used to problematize physics teacher education. This is not the case in science teacher education, see for example the work of Mensah (2009, 2013; Mensah & Jackson, 2018). While driven by a strong commitment to social justice, the work of this thesis is not directly concerned with questions of equal representation of specific social groups. Rather, the focus is on the consequences of the discourse of physics teacher education on the identity formation of *all* trainee physics teachers. The discourse of physics teacher education both limits and enables trainees in their work to be recognized as physics teachers. This, of course, includes gendered expressions, colour and differences in status between the various subfields of physics (Johansson, 2018a). However, it also includes investigating the understanding of the nature and purpose of the subject physics that trainees are exposed to and potentially bring with them to their own teaching. This understanding, when communicated to a new generation of physics students, in turn limits or enables who is able to see themselves as a future physics student/physicist/physics teacher. These questions can be approached through the concept of professional identity, which will be examined more closely in the following section.

2.2.5 Teacher professional identity

Although the concept of identity is regularly invoked in educational research, in the past it has rarely been explicitly defined. In this respect, the majority of published work appears to have taken the identity concept as self-explanatory and unproblematic (Sfard & Prusak, 2005, p. 15). However, this tendency has changed recently with authors giving more consideration to what they mean when they use the term. There are now several theoretical ways of understanding identity, often divided into more psychological approaches that view identity as an inner property of individuals, and constructivist approaches that view identity as constructed in social interaction. This Licentiate thesis is written in the intersection between PER, science education research, teacher education research and gender research. In all of these fields, the identity concept tends to be understood and used quite differently. This is not just in a theoretical sense, but also in terms of what questions identity is taken to be able to help to answer.

In presenting an overview of teacher identity research I have chosen to structure the section according to what I perceive that the each of the authors are trying to achieve by using the identity concept. As a start, I have built on three review papers written about teacher identity, that discuss what the identity concept is useful for when researching teacher education. The particular theoretical perspective on professional identity taken in this thesis is presented in section 3.3 (Performing an identity).

Studies approaching teacher identity as an empirical phenomenon

In their review of research on teacher professional identity published between 1988 and 2000, Beijaard, Meijer, and Verloop (2004) found that professional identity studies could be divided into three groups: studies focusing on the formation of professional identity, studies focusing on different characteristics of professional identity, and studies with a narrative approach, viewing professional identity as represented by stories told by teachers and students. This review paper seems to take the perspective that professional teacher identity is primarily an empirical phenomenon, and as such something that teachers have or possess. This is visible for example in how the authors in their discussion focus on how the included studies point towards "features that, in our view, are essential for teachers' professional identity." (Beijaard et al., 2004, p. 122). The purpose of using the identity concept according to these authors then, seems to be to find out more about it, i.e. to map features, or dimensions of professional identity. Although the included studies explore quite different questions with very different theoretical approaches towards the identity concept, their results are thus all taken to point to different important features of the same phenomena of professional identity. In this way, different definitions or theoretical perspectives on identity are understood as tools that give access to different dimensions of the empirical phenomena of professional identity.

This view of identity as something that is primarily empirical is also present in the second review paper on teacher identity by Beauchamp and Thomas (2009). They state that:

> A major hurdle in gaining an understanding of identity is resolving a definition of it, as a variety of issues surface in any attempt to reach a definition. One must struggle to comprehend the close connection between identity and the self, the role of emotion in shaping identity, the power of stories and discourse in understanding identity, the role of reflection in shaping identity, the link between identity and agency, the contextual factors that promote or hinder the construction of identity (p. 176)

Here then, different theoretical perspectives on identity are seen as giving access to different aspects of this empirical phenomenon.

Finally, in the main section of a more recent review paper on science teacher identity, Avraamidou (2014) similarly synthesized a number of empirical findings to answer the question "What do we know about science teacher identity?" She found that among the studies reviewed that use teacher identity there seems to be a consensus that:

> (a) teacher identity is socially constructed and constituted; (b) teacher identity is dynamic and fluid and constantly being formed and reformed; and (c) teacher identity is complex and multifaceted, consisting of various sub-identities that are interrelated (p.164)

These three characteristics of teacher identity again point towards how teacher identity in the literature in many contexts is used as a feature of teachers that in itself can be studied rather than a theoretical tool to study something else. These three review papers together imply that identity in the context of teacher education often seems to have been treated as an empirical rather than a theoretical concept, containing anything of interest for the study in question related to being or becoming a teacher.

Perhaps the most straightforward approach to the kind of work that views identity as an empirical phenomenon, is to explicitly ask teachers about their professional identity and let their answer define what it is that you are looking for (Beijaard, Verloop, & Vermunt, 2000). In this form, research on teacher professional identity explores what being a teacher is, as defined by teachers themselves. One interesting example of this perspective is Molander and Hamza (2018) who interviewed trainee science teachers about how they experienced their educational program. They saw four phases that the trainees went through during their program: Cautiously positive, Rejection, Acceptance and Complexity. This view has strong parallels with what is called

Expert-Like Thinking (Adams & Wieman, 2011) in Physics Education Research, where the practices and thinking of physicists are investigated and applied as a model for what students should learn or aim to emulate. Perhaps the use of the identity concept in this way could be called *expert-like identity thinking*.

Another area of research employing professional identity as an empirical phenomenon can be found in studies exploring what factors or mechanisms affect the professional identity of pre-service teachers. Timovstvsuk and Sikka (2008) interviewed 45 teacher students with a focus on their stories as statements about identity. They conclude that trainee's professional identity is affected by their social relations with university teachers, fellow students and supervisors and by the quality of communication in the education. Beijaard, Verloop, and Vermunt (2000) suggested that teachers' professional identity is formed mainly by three factors. These are: earlier experiences of being a teacher, biography-indicating former school experiences, and the context of the present social environment.

Studies utilising teacher identity as a theoretical tool.

As I have shown, viewing professional identity as an empirical phenomenon seems to be common in the fields of teacher education and science teacher education. However, the review paper by Avraamidou (2014) also asks another question: "In what ways have researchers used the construct of teacher identity to examine science teacher learning and development?" This second question implies a different understanding of teacher identity. Here identity is framed as a *tool* that can be used to investigate teacher learning and development rather than being the object of investigation per se. Examples can be found in the literature on reform-minded teaching (Luehmann, 2007; Saka, Southerland, Kittleson, & Hutner, 2013; D. C. Smith & Jang, 2011) and studies of teaching with a Nature of Science approach (Akerson, Pongsanon, Weiland, & Nargund-Joshi, 2014).

These two ways of using identity are of course not possible to separate in many studies. In a study by Stears (2012) for example, teacher identity is used to empirically examine why teachers learn some things and not others in a professional development course. Stears used the identity model by Beijaard et al (2000) to evaluate whether teachers taking part in an Advanced Certificate in Education program actually learned what was intended by the program and the new curriculum. Teacher professional identity was described as "teacher as subject specialist", "teacher as didactical expert" and "teacher as pedagogical expert". Similar to the study by Molander and Hamza (2018), participating teachers were found to be motivated by, and focused on subject matter and did not pay attention to the pedagogical and didactic aspects of the program. The authors attribute this to the teachers having professional identities as subject specialists. Professional identity is thus seen here as something that teachers *have,* and at the same time as something that can explain how they respond to professional development efforts. This approach to using professional identity is interesting as a way of connecting what teachers do to the context they are in. However, the implication here seems to be that this influence only goes in one direction, attributing what teachers learn to the identity they (already) possess. Thus, in this framework, there is no way of discussing the interplay between the professional context of the course and the different ways of being a teacher that are leveraged by the teachers in their everyday professional environment. There is the implication that identity is a stable property of a person that is not easily changed and that this might hinder the training and development of teacher skill. Thus, in this model, choosing the right kind of person with the right kind of identity to enter teacher training becomes important.

The study by Stears can be said to belong to a group of studies using identity constructs as a way of answering questions about why teachers act as they do: how teachers respond to policy reforms, why they chose to teach in a particular way, and what is needed to change this. Another example is the literature on reform-minded teaching (Luehmann, 2007; Saka et al., 2013; D. C. Smith & Jang, 2011) and on how to help students teach with a Nature of Science approach (Akerson et al., 2014). Saka, Southerland, Kittleson, & Hutner (2013) followed a new physics teacher during his first year in school. They use Gee's (2000) four ways to view identity together with the identity model of Carlone and Johnson (2007) to examine how the student's interaction with the teaching context shapes his possibility to implement reform minded teaching practices.

In the work on social justice, gender and culture in physics discussed in section 2.2.4 (Physics and social justice), the construct of identity is used as a way of exploring questions of power and equal participation in science. Here the identity construct is often used in a post-structural, critical understanding, and serves as a way of connecting who people are understood to be—often in terms of identity categories such as gender, race, socioeconomic status or sexual orientation—to their opportunities in science (Rosa & Mensah, 2016). As argued above, this line of research has not yet been used to problematize physics teacher education and there is a lack of studies that take a social critical perspective on the construction of physics teacher identities. There is a need to explore what is made possible in the educational program, not in terms of social categories, but in terms of who and what is included and excluded by the discourses of education.

Professional identity in this Licentiate

This thesis explores the context of physics teacher education where pre-service physics teachers move towards becoming physics teachers. I ask how the culture of physics and of teacher education has the potential to afford and constrain possible ways of becoming a physics teacher and what ways of understanding the subject of physics are afforded by the educational program. In both Publication II and Publication III, I use discourse analysis (Gee, 2005) to explore these questions. Professional identity is then used in Publication II as a way of understanding how the discourse models found in the analysis can be understood as enabling and limiting trainees in becoming physics teachers. I thus use professional identity as a theoretical tool to guide understanding of how the discourses of physics teacher education enable and limit becoming a physics teacher. To make this possible, I adopt an understanding of identity as socially constructed in discourse. In contrast to a "psychological" perspective on identity, in this view identities are seen as constructed in interplay with the social context. Thus, the construct of professional identity that I am using is fluid, rather than fixed and exists between people in language rather than being an intrinsic property of an individual. I follow Archer et al and conceptualize identity in term of celebrated identity performances (Archer et al., 2017; Butler, 1990; Davies, 2006). This concept is discussed further in section 3.3 (Performing an identity).

3 Creating a theoretical framework

Through its intimate connection to the discipline of physics and the wide experience of learning and teaching physics that has been built over the years, PER contributes in a unique way with discipline-specific knowledge about learning and teaching. PER researchers often have a firm base in physics, and therefore a good grasp of the quantitative tools used in the discipline. Contemporary questions asked in PER, however, often call for a range of qualitative methods and theoretical underpinnings to be used. The challenge of learning and adapting to a new set of research skills and what constitutes a valid knowledge claim in such circumstances has been taken up by countless PER-researchers, myself included. This together with the current methodological diversity found in PER has reinforced the need for agreement about which methods can be considered valid and what standards of evaluation are appropriate (Robertson, McKagan, & Scherr, 2018). Recently the growing interest within PER for questions of equal representation and equity has further raised the need for adopting new methodologies that can take for example, issues of power into account.

Traditionally in the past, cognitive and atheoretical frameworks have often been called on to generate understandings of students' learning challenges in physics (Redish, 2004). However, questions relating to the social experience of learning physics, how becoming a physicist involves learning to think, act like, talk like and see yourself as a "physics person" (Johansson, 2016) increasingly call for the adoption of new theoretical tools. A recent example of this is Andersson & Johansson (2016) who show how a constructionist discursive understanding of social identity makes possible new understandings of gender inequality in physics.

In section 2.2.5 (Teacher professional identity) I argued for a focus on the system of physics teacher education rather than on individual trainee physics teachers. Now in this section, I will describe the theoretical tools I have chosen to implement this shift in focus. In the order they appear in the following sections these are: the discourse analytical framework put forward by Gee (2005, 2011, 2014) in particular Gee's notion of Discourse models, the concept of disciplinary literacy (Airey, 2011b), the categorization of Disciplinary Knowledge Structures according to Bernstein (1999, 2000), Celebrated Identity Performances adapted from Archer et al. (2017) and the Culture Model of Schein (2010).

3.1 Discourse and discourse analysis

The term "discourse" is often used to mark an understanding of language as structured in patterns that regulate how and what can be said. Discourse analysis is the analysis of these patterns (Jørgensen & Phillips, 2002). In this Licentiate I have chosen to draw on the work of Gee, who defines discourse as the ways in which meaning is made through language, that is, how language is used to say, do and be certain things (Gee, 2005). I do not, however use Gee's conceptualization of identity and a discussion of why this is the case can be found in section 3.3 (Performing an identity).

Gee (2014, p. 8) differentiates between two ways of defining discourse. First, discourse can be thought about as a sequence of sentences put together according to grammatical rules. This more functional linguistic understanding puts the focus on the structure of language, the grammar. Second, discourse can be thought of as language-in-use. Here the focus is on how language in a particular context is being used to create meaning. In my work, the emphasis is on this latter understanding, and I use discourse analysis to explore the ways in which language is used to make meaning in specific contexts. This does not mean that grammar is taken to be unimportant. To access the meaning being made, an analyst needs to be fluent in the structural ways in which the language works.

Gee draws on ideas from a range of influences and describes his approach as being critical discourse analysis. By this Gee is suggesting that discourse analysis should always be critical since it always is political (Gee, 2014). This is because discourse ascribes values to things and distributes what Gee calls social goods. Gee (2005, p. 8) also insists that discourse analysis is not about describing how language works, but rather it is about "contributing, in terms of understanding and intervention, to important issues and problems in some "applied" area (e.g., education) that interests and motivates the researcher."

Gee chose to denote language-in-use (that is written or spoken language) as discourse with a small d. This is to make the distinction between a limited language-based perspective and the *wider text* that involves whole meaning making practices. This includes all practices around language that bear meaning, such as gestures, facial expression, tools, clothes, etc. Gee refers to this wider view of text as Discourse with a big D. When doing discourse analysis, it is practical to record interviews and then, in the analysis stage, work with a transcribed record of that conversation. This way of working tends to make the researcher focus on spoken language. When carrying out an interview however, many other things than what is actually said carry meaning, this wider Discourse cannot be ignored by the researcher. When listening to a recording or reading a transcript of an interview that you yourself carried out you thus bring with you a layer of interpretation depending on things that are not captured in the recorded material. This is the case for the analysis for the second Publication of this Licentiate thesis, where I carried out the interviews.

Here, the analysis thus in part includes Discourse aspects, rather than just the words (and tone of voice) that were used. For Publication III some of the interviews were conducted by my supervisor John Airey, and in that case the analysis of those interviews uses mainly what was actually said. This makes interpretation more difficult and the need for checking interpretations greater.

In my Licentiate work I have taken a very pragmatic approach to discourse analysis, choosing to use the tools of Gee because they seem to give valuable results in relation to my research questions. Gee says:

> this book is meant to 'lend' readers certain tools of inquiry, fully anticipating that these tools will [be] transformed, or even abandoned, as readers invent their own versions of them or meld them with other tools embedded in different perspectives. (Gee, 2005, p. 5)

Discourse analysis according to Gee can mean many things, and Gee proposes several different tools that may be used to carry out discourse analysis. One technique involves dividing transcripts into lines and stanzas, looking at the details of what each line says. In the analysis of the material in this project, I have not worked with the text at this micro level, which might entail either Systemic Functional Linguistics or conversation analysis. Rather I have chosen to use one of the macroscopic tools of inquiry put forward by Gee, the notion of discourse models. In what follows, I describe Gee's discourse models together with my own interpretation and implementation of this notion. In section 4.4 (Coding and analysis) I will go deeper into the way in which I have employed discourse models as a tool when doing discourse analysis.

3.1.1 Discourse models

I have chosen to use Gee's (2005) concept of discourse models as a way of describing and analysing the discourses in play in interviews with teacher educators. In Publication II, discourse models function as both a tool of inquiry, guiding me through the analysis, and as a specific way to characterize and describe the discourses in play in the interviews. Discourse analysis is theory and method in one, and I will not try here to clearly separate these two functions that I believe are inseparable. I will however return to discourse models as a tool of inquiry in the analysis section of this thesis when I give practical examples of how I have used this construct.

In Gee's terms, discourse models are "images or storylines or descriptions of simplified worlds in which prototypical events unfold. They are our 'first thoughts' or taken-for-granted assumptions about what is 'typical' or 'normal'" (2005, p. 71). Another way of describing discourse models is that they are conscious or unconscious theories or heuristics about the world that are used to understand it—put simply, they help us choose what meaning to ascribe to certain things. These theories or heuristics can be unconscious, personal and informal, but they can also be formalised, well-defined and shared between people. One good example of such shared, formal and well-defined discourse models are theories in physics. Physics theories tell us how to interpret observations in particular contexts. In geometrical optics for example, the discourse model explaining the meaning attached to light is different to the corresponding discourse model attached to light in the context of particle physics (Gee, 2005, p. 64). In physics these two competing ways of viewing the nature of light fill different functions and are used in different contexts. It is this contextualized use of discourse models that is key in my work. In physics there is a formalised understanding of when one discourse model applies and when another is appropriate. In most other situations, however, such an understanding is lacking—often a number of competing discourse models can be identified, and it is not uncommon for discourse models to be inconsistent and used outside of the context in which they were formed.

Gee proposes a number of questions that can be asked of a transcript to identify discourse models, many of which can be summarized in the following quote:

> For any communication, we want to ask what typical stories or figured worlds the words and phrases of the communication are assuming and inviting listeners to assume. What participants, activities, ways of interacting, forms of language, people, objects, environments, and institutions, as well as values, are in these figured worlds? (Gee, 2014, p. 90)

Note that in this quote Gee uses the term figured worlds (Holland, Lachicotte, Skinner, & Cain, 1998) as a synonym for the term discourse models, something I will come back to later. Identifying discourse models involves trying to understand what the speaker needs to assume for what they are saying to make sense in a particular context, this is done from the basic assumption that all people make sense within their own frame of reference.

One question that can be asked is whether discourse models are real—do they exist independently out in the real world? Gee certainly writes about them as real, saying "'Discourse models' are 'theories' (storylines, images, explanatory frameworks) that people hold, often unconsciously, and use to make sense of the world and their experiences in it." (Gee, 2005, p. 61). This would imply that discourse models are properties of people, perhaps existing inside their mind. However, Gee also states that discourse models along with concepts such as situated meaning and discourses are invented theoretical constructions or "thinking devices". It is in this latter way that I approach discourse models in my work. Discourse models certainly do *represent* real analytic things, identifying and interpreting patterns existing in how the interviewees talk. But at the same time, the discourse models that are the results of my analysis are my own *analytical constructions*, and they represent just one way of dividing up reality so that it makes sense. As such, these constructions are dependent on my research questions and my understanding of what is going on in the interview.

A note on the use of terminology. Gee introduced the concept Discourse models in the second edition of his book *Introduction to discourse analysis* (Gee, 2005). From the third edition (2011) he instead use the term figured worlds for the same theoretical construct. Gee comments on his of change of terminology in the following way:

> The term 'figured world' has the advantage of stressing that what we are talking about here is ways in which people picture or construe aspects of the world in their heads, the ways they have of looking at aspects of the world. We humans store these figured worlds in our heads in terms of stories, ideas, and images. We build little worlds, models, simulations—whatever term we want to use—in our heads in terms of which we seek to understand and act in the real world. (Gee, 2011, p. 76)

While I in part agree with this description, saying that discourse models characterize ways of looking at the world, to me suggests too large an understanding of what discourse models encompass. Holland et al. (1998, p. 51) describe figured worlds as "all those cultural realms peopled by characters from collective imaginings: academia, the factory, crime, romance, environmental activism, games of Dungeons and Dragons" In my work, I use discourse models as a way of characterizing the discourse of teacher educators. The way I use this term does not denote whole realms such as academia, but rather quite *local* understandings or explanations that one needs to understand (either tacitly or explicitly) to be fluent in the discourse. Another aspect is that I hope to avoid an understanding of discourse models as something existing *inside* the heads of teacher educators. Using Gee's own suggestion to transform or discard his tools as necessary I have chosen to use the word "discourse models" to denote what I am looking for. For my purposes, I believe it is better to point to this understanding rather than using the concept of "figured worlds".

3.2 Developing disciplinary literacy

Publication I explores physics lecturers disciplinary learning goals for their students and discusses the contexts of physics teacher education from a Bernsteinian disciplinary knowledge structure perspective. The theoretical framework used in Publication I quite different from the one used in Publications II and III and should be understood as a complementary view of the system of physics teacher education. In this section I will briefly summarize the theoretical tools used in the chapter. These are based in literacy research and draw on work done in the area of academic and disciplinary literacy. Rather than repeating the whole theoretical framework that can be found in the chapter here, in what follows I will focus on presenting the two major terms used in the discussion that have bearing on physics teacher education. The first is the concept of disciplinary literacy and the second is Bernstein's classification of disciplines according to their knowledge structures.

3.2.1 Disciplinary literacy

In its original meaning, literacy means the ability to read and write and is close to the meaning of the Swedish word "läskunnighet". This understanding has been broadened in the literature and literacy is now often used in a very wide sense, meaning the ability to communicate or function in the ways that are important in a particular context. In the context of the academy, academic literacy can in its original sense mean the ability to read and write academic text, but also the extended competences needed to participate in the differing practices of the academy. In this respect, disciplinary literacy for trainee physics teachers can be thought of as similar to mastering the discourses of the environments students meet, and as such connects to Publications II and III. Following Airey (2011c) disciplinary literacy is defined as

> The ability to appropriately participate in the communicative practices of a discipline. (Airey, 2011c, p. 3)

This involves appropriately using a number of communicative practices which to some extent are unique to the discipline, but naturally also changing in meaning and use across a discipline. This could be compared with what Gee has termed "pulling off a discourse" (Gee, 2005).

One way of making this differentiation is to separate disciplinary communication aimed towards the academy, the workplace (outside of academia), and society. Figure 1 shows the disciplinary literacy triangle that illustrates these three sites for disciplinary literacy. A discipline can be positioned in the triangle depending on its relative emphasis on developing literacy for each setting.

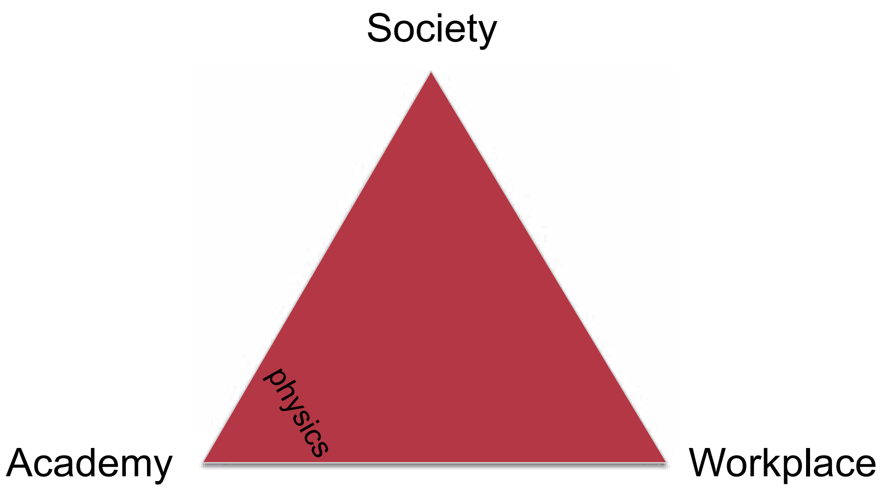

Figure 1. The disciplinary literacy triangle. Here, the discipline of physics is placed in the left corner. This represents the focus on teaching for the academy that was reported by the physics lecturers that were interviewed for Publication I.

The disciplinary literacy triangle can be used as a way of representing the relative degree to which a course or degree programme puts emphasis on developing communicative practices for the three sites: society, workplace and academy. Different disciplines prioritize differently between the three sites, and this can be expected to be mirrored in the disciplinary literacy goals of lectures. For example, in publication I, the physics lecturers interviewed all report that they direct their teaching towards the academy, placing physics disciplinary literacy in the bottom left-hand corner of the disciplinary literacy triangle (Figure 1).

3.2.2 Knowledge structures

Bernstein (1999) organizes systems of knowledge in discourses through two sets of categories. The first division is between vertical and horizontal discourses. Horizontal discourses are fragmented, local languages that lack formal organization. Vertical discourses are organized structures of knowledge with specialized rules for the inclusion or exclusion of knowledge. The academic disciplines can all be said to be versions of vertical discourses. In turn, these vertical discourses can have different disciplinary knowledge structures and these can be more hierarchical or more horizontal in nature. Disciplines with hierarchical knowledge structures organize knowledge into a coherent, integrated system, where each new piece of knowledge has to fit with the rest of the structure. Bernstein proposes that the sciences are examples of such knowledge structures and that the discipline of physics is the most hierarchical of the science disciplines.

Disciplines with horizontal knowledge structures organize knowledge in a series of independent specialized “languages”, these are in Figure 2 named L_1, L_2, L_3 etc. Each of these languages introduces a new perspective and allows us to focus on particular aspects whilst other aspects move into the background or are not present at all. Note that these disciplinary languages do not need to be consistent with each other. In fact, it is their very incompatibility that is key since each language gives us a new perspective on a particular phenomenon. The knowledge of such disciplines is extended both through the development and growth of existing languages and through the introduction of new languages. In figure 2, the differences between hierarchical and horizontal knowledge structures are illustrated though the use of triangles, inspired by Martin (2011).

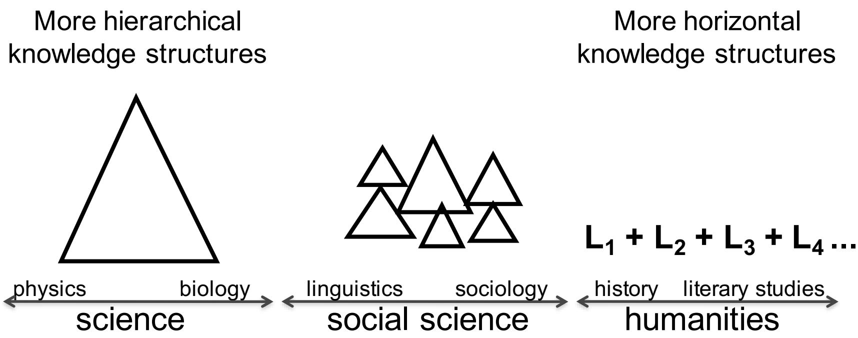

Figure 2. The difference between horizontal and hierarchical knowledge structures. Picture adapted from (Martin, 2011).

Another way of characterizing disciplines is in terms of Singulars and Regions (Bernstein, 2000). Singulars are disciplines with a sense of strong intrinsic value, where developing the knowledge in the discipline is a strong motivation in itself. Regions, on the other hand, are disciplines where knowledge that has been developed in a number of singulars is brought together and recontextualized for use in society. Bernstein (2000) suggests that educational science is a horizontal region while physics is a hierarchical singular. In Publication I it is argued that this difference in how knowledge is viewed creates unique challenges for trainee physics teachers when moving between the education department, and physics department. This will be further discussed in section 5.1 (Findings Publication I).

3.3 Performing an identity

I have approached the context of physics teacher education by interviewing teacher educators who teach pre-service physics teachers. My interest in these interviews is how teacher educator discourse can be understood as a part of the context that limits and enables trainee physics teachers in their becoming of physics teachers. The teacher educators are of course constructing their own identity (as teacher educators, researchers, physicists or teachers) inside and outside of the interview situation. However, I am not focusing on the professional identity of the teacher educators themselves (like Jonker, März, & Voogt, 2018; and Trent, 2013). Rather in this thesis I focus on the educators as a major formative influence—as an important part of the context within which pre-service physics teachers create their own professional identities. I use identity as an analytical tool to allow me to understand the conditions for being recognized as a legitimate physics-teacher-in the-making in the context of the training environment. This is one way of connecting individual practice with more general, overarching structures, addressing the interplay of individual agency and sociocultural context (Sfard & Prusak, 2005, p. 15). Although the question of structure vs. agency has been generally addressed theoretically, it has been suggested that empirically there has been an overemphasis on the individual student or teacher, leaving out the *context* that structures this individual agency (Shanahan, 2009, p. 44). In her review of research on science teacher identity, Avraamidou (2014) similarly found that the contexts where science teacher identities are formed are often overlooked: "In general, we are told little about the nature and characteristics of the contexts in which these studies took place and how these contexts may (or may not) have impacted upon the participants' identities." (Avraamidou, 2014, p. 165; see also Vähäsantanen, 2015, p. 3 for an explicit discussion of structure and professional agency of teachers).

One way of shifting the focus from individual identities to the structures within which these identities are played out is by choosing to view identity through the lens of discourses (Søreide, 2007, p. 538). This is a common way of understanding identity in social constructionism, that rejects psychological ideas where the individual is seen as existing independently of social structure, or where mastering language is framed as a tool for self-expression. Rather, in social constructionism a person is understood as being created through and within discourse (Burr, 2003). Different variations of this view are rapidly becoming the dominant way of understanding identity in science education, where identity is understood as socially constructed, dynamic, fluid and multifaceted (Avraamidou, 2014; Shanahan, 2009). This way of describing identity is however still at odds with common, everyday understandings of what identity means. A common-sense way of understanding identity is as something that a person *is* or *has*. People tend to experience a certain feeling for who they are, as one person with an identity with a coherent narrative sustaining this (Holmegaard, Ulriksen, & Madsen, 2012). One way of bringing the common-sense view into line with a discursive understanding of identity is to think of identity as the process by which a person constructs an image of themselves as coherent and making sense. This construction is however dependent on context and is therefore influenced by the ways of being that are recognizable and valued within the dominant discourses the person encounters (Watson, 2009).

I have chosen to view identity in terms of identity performances (Archer et al., 2017; Butler, 1990; Davies, 2006) and in the remainder of this section I will discuss this specific identity construct. Before this however, a discussion of the choice of this specific construct is in order. Since the main part of the work reported in this Licentiate kappa builds on discourse analysis following Gee (2005) and since the analytical framework proposed by Gee puts identities in the foreground, it might be expected I would also use the identity concepts developed by Gee when talking about professional identity. In Gee's account, language-in-use always seeks to position people as something, identities or roles, and a way of doing discourse analysis is to focus on how meaning is constructed through the kinds of "who" that are saying something and who is supposed to be listening. However, to ask of a text what identities are being created and how that affects meaning is just one way of doing discourse analysis proposed by Gee and in my use of Gee's work, I have chosen not to focus on identities but rather to use the construct of "discourse models". The most important reason for this is perhaps that my primary interest is the discursive structure of physics teacher education rather than the professional identity of teacher educators. I am thus not interested in the professional identities of the teacher educators that are being constructed in the interview situation. Instead in the first stage of analysis for Publication II, the focus was the "ways of being" for trainee teachers that are tacitly encouraged and discouraged by the discourses of the teacher educators. Subsequently, I analysed the ways in which the identified discourses could be understood as limiting and enabling the professional identity of trainee teachers. Here, and this is another reason why I chose to not use Gee's identity concept, I did not find tools for conceptualizing how the individual subject is produced in discourse in the identity concept Gee proposes. Here, the way Butler (1997) uses the concept of subjectification proved to be very useful.

Butler (1997) uses subjectification as a way of discussing the relationship between individual subjects and discourse. Becoming *someone* in the discourse, a subject with agency, requires using the positions available in the discourse in an acceptable way and thus involves submitting to the discourse. It is this submission that makes agency possible, ”Subjection consists precisely in this fundamental dependency on a discourse we never chose but that, paradoxically, initiates and sustains our agency" (Butler, 1997, p. 2; cited in Davies, 2006, p. 426). What is possible in the discourse thus limits the ways of being a subject with agency, and agency is severely limited by structure.

Agency lies in that the subject is created together with the discourse, at the same time shaping it and being shaped by it. This is in line with a Foucauldian understanding of power that claims that "power relations are a precondition for our subjectivities, individuals cannot exist outside them." (Danielsson, Berge, & Lidar, 2017, p. 168).

In her discussion of gender identity, Butler (1990) argues that gender is not a consequence of particular biological properties of bodies, but something created in on-going performances of gendered/gendering acts. These performances create the impression of a coherent gendered self, a stable gender identity: "the 'coherence' and 'continuity' of 'the person' are not logical or analytic features of personhood, but, rather, socially instituted and maintained norms of intelligibility" (Butler, 1990, p. 23). To perform in an intelligible way is to conform to, or be coherent with, established norms. Identities that fail to do so are rendered impossible, they "cannot exist" and appear as "logical impossibilities" inside the discourse (p.24). Butler's work has mainly been seen as pertaining to the construction of gendered identities. However, Butler's conceptualization of identity has also been taken up and used in the wider context of education research (see for example Davies, 2006).

In Publication II, I follow Archer et al. (2017) and use Butler's (1990) concept of identity performances to understand the training environment as a context for becoming a physics teacher. In order to be "intelligible" or achieve recognition (Carlone & Johnson, 2007; Gonsalves, 2014b) an identity performance has to both align with the dominant discourse and be valued on the basis of the taken-for-granted assumptions within that particular discourse. Note that the term recognition here not only implies both comprehensibility or understanding, but also appreciation—being valued. In Publication II, I use the term celebrated identity performances (Archer et al., 2017) to include both of these meanings, asking what are "intelligible" and "valued" ways of performing a trainee physics teacher identity in the discourses of the physics teacher education.

When talking about professional identity in my work, the professional implies a professional *context* rather than a special, professional kind of identity. Thus, the theoretical construct of identity itself does not change for personal and professional use, rather, it is the professional context that distinguishes a professional identity from any other kind of identity.

> A 'professional identity' can be theorized as arising in the subject positions available within a specific historically and socially situated dominant articulation of the discursive field. In order to perform a 'professional identity' the subject must be positioned within this articulation. (Watson, 2009, p. 471)

Being a professional physics teacher means performing an intelligible identity within specific professional discourses. In physics teacher education this means being able to gain recognition/making yourself meaningful as a physics teacher-to-be within the dominant discourses of the physics teacher training programme. It is thus these dominant discourses that are of interest in this thesis.

3.4 Schein's culture model

In Publication III the object of interest is defined as departmental physics culture as it pertains to physics teacher education. The main reason for this is that "physics culture" is a well-used and known term in the physics education community, which is the audience for publication III. Additionally, the publication discusses the situation for physics teacher education and how this needs to change. Here, research on discipline-based education has shown that the success of interventions is to a great extent dependent on taking the culture of the organization into account—creating change demands an understanding of culture (Henderson et al., 2011). Publication III thus connects the findings of the empirical study as an example of physics culture, to international discussions of problems with physics teacher education and ways to foster change.

Publication II uses discourse analysis as an analytical tool in a similar way to Publication III. However, an additional layer of physics culture was added in the final step of analysis, in order to see the findings as an expression of local physics culture. To define culture, I used the *culture model* by Schein (2010). In Publication II this model was combined with the discourse analytical tools described by Gee (2005) (see section 3.1).

Schein (2010) developed the culture model as a tool within organizational theory. In his model, culture is defined as what is created in a group that shares a history of joint problem solving. Culture in this conceptualization is thus:

> A pattern of shared basic assumptions learned by a group as it solved its problems of external adaptation and internal integration, which has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems. (Schein, 2010, p. 18)

The culture of a group is changeable, it is fluid and complex, but the definition also implies a degree of stability. Culture is something transferred to new members of a group and therefore reproduced, and is therefore in many cases quite resistant to change. As a pattern of shared assumptions, culture is not necessarily explicitly expressed, but rather implicitly inherent in how members of the group speak and behave and can even be encoded in physical artefacts within the group environment.

Schein writes about culture on three levels: Artefacts, Espoused Beliefs and Values, and Basic Underlying Assumptions. The first two levels are made up of things that are more or less explicit in the organization, such as departmental rules, how classrooms are designed and what is talked about in the coffee room. The last level—basic underlying assumptions—is implicit and not immediately apparent to an outsider. These basic underlying assumptions affect how the group understands a situation and are often seen as self-evident to group members. They are therefore difficult to identify.

In Schein's definition, culture is the result of what has been perceived as fruitful for solving the problems of a group in the past. These solutions are therefore reproduced or transferred to new members of the group. In the context of Publication III, the problems referred to would be the creation of and participation in high quality physics [teacher] education. The focus of analysis is shared assumptions in physics departments pertaining to physics teacher education. Finding such implicit shared assumptions gives us a key to understanding what the explicit cultural expressions of the group mean.

In the analysis for Publication III, the culture model of Schein was combined with discourse models to create explicit tools to "see" physics culture. As discussed in section 3.1.1 (Discourse models), discourse models are "images or storylines or descriptions of simplified worlds in which prototypical events unfold. They are our 'first thoughts' or taken-for-granted assumptions about what is 'typical' or 'normal'" (Gee, 2005, p. 71). In Publication III, I suggest that discourse models tell us about the last level of Schein's culture model—the Basic underlying Assumptions.

4 Methodology

When choosing how to carry out the research in this thesis I have aimed to let the questions asked steer the methodological choices made. In this chapter, I start with my research questions and present a line of reasoning from these questions to my chosen methods. I do this in order to explain to the reader why I believe my methodological choices are an appropriate match to the questions I wish to answer. In section 4.4 (Coding and analysis) I give a detailed description of how the data generation and analysis was carried out in practice. In order to give a coherent picture of the research, much of the text in this section is similar to relevant sections of the publications, however I have taken the opportunity to extend and explain the methodological descriptions in more detail.

4.1 The questions I ask and how to find answers to them

In this section I will go through my publications one by one, beginning with the research questions and motivating the methodological choices I have made. Note however that the research questions were of course formulated in the language of the particular theoretical stance taken. As such, the research questions are already charged with meaning, suggesting an appropriate design. For a more general discussion of my original research aims and their connection to the research questions, see section 1 (Introduction).

Publication I has three main parts. The first presents and explains the theoretical framework of disciplinary literacy (Airey, 2011c, 2013) combined with the concept of disciplinary knowledge structures by Bernstein (1999, 2000). This chapter strives to make a theoretical contribution and as such is discussed in the theory section (3.2). In the second part of the chapter the disciplinary literacy goals (Airey, 2011c, 2011a, 2013) of undergraduate physics lecturers in Sweden are discussed. This discussion is based on a comparative study of physics lecturers in South Africa and Sweden where I was not involved in data collection or analysis. The third part of Publication I presents an argument that using Bernstein's constructs of hierarchical and horizontal knowledge structures (1999, 2000) can give valuable insight to the specific difficulties of physics teacher education. This argument uses interview data from interview round a and the question asked is:

1. Can Bernstein's constructs of hierarchal and horizontal knowledge structures in a fruitful way be used to understand the specific difficulties of combining physics and educational science in a physics teacher education programme?

This question is discussed and tentatively answered using data from interview round a. The theoretical ideas in the chapter were developed in parallel with work on Publication II. Initially the chapter was planned to be entirely theoretical but the first author and I discovered that both interview round a and the bigger set of data that interview round b is part of took on new and interesting meaning when viewed through the theoretical lens of the chapter. The transcripts from interview round a were preliminarily analysed, looking for ways in which differences in knowledge structure between physics and education are expressed in the interviews.

In Publication II the following questions are asked:

1. What discourse models (here ways of making sense of the education of physics teachers) can be identified in the talk of the teacher educators that trainee physics teachers meet during teacher training?
2. What physics teacher identity performances might we expect to be recognised and valued within these discourse models?

To get access to how physics teacher educators talk about the education and the creation of physics teachers, I chose to do qualitative, semi-structured individual interviews with teacher educators. When using a discursive understanding of identity and sense-making, cases of everyday speech or reasoning are the central material for analysis, and interviews are a useful way of collecting this kind of data (Gee, 2011).

I interviewed nine teacher educators, these interviews are referred to as interview round a. Choosing to do nine interviews could be considered a very small sample. However, in this study, the aim was not to provide a generalisable description of the state of physics teacher education in Sweden, but rather to investigate the discourses of one physics teacher education programme. As such, Publication II can be thought of as a case study chosen on the basis of information (Flyvbjerg, 2006). This means that the case was chosen because of its specific potential to reveal important information, rather than to be a typical instance of the phenomena studied. Earlier work has highlighted the problem of integrating subject matter, educational theory and school practice into one coherent programme, suggesting fragmentation and competing discourses are often inherent in teacher education (Danielsson & Warwick, 2014b, 2014a; Hökkä & Eteläpelto, 2014; Sandifer & Brewe, 2015; Scherr, Plisch, & Goertzen, 2015; Sjølie, 2014). In the particular educational programme studied in Publication II, these parts are physically separated, located on different campuses. The geographical context of Publication II presents an extreme rather than typical case and this is a particularly fruitful arrangement for studying the competing discourses and fragmentation of physics teacher education.

A more ethnographically inspired data collection was considered at the beginning of the project. This would have entailed doing participant observation in the classrooms of educators or following trainee physics teachers when they moved between the environments in the educational programme. I decided against this because the aim was to get educators to talk extensively about physics teacher education, and I did not expect such discussions to spontaneously arise to any large extent in the classroom. It could however be argued that what educators actually say when interacting with students is very important when identifying identity performances that are recognized in physics teacher education. Choosing to interview teacher educators rather than observing the actual education happening in classrooms has the disadvantage of putting an extra layer between me and the experienced reality of pre-service teachers. However, the interview situation can "be used to gain purchase on interpretive practice relating to matters that may not be casually topical" (Holstein & Gubrium, 1995, p. 17). By interviewing educators, and getting them to talk about what they do in a much more direct way than they would ever do in the classroom, I am able to better elicit the tacit assumptions and norms about the educational program. I can then use these more elaborated descriptions to create discourse models that I would expect to be hidden or expressed in much more implicit ways in the classroom. Time constraints made it impossible to do both observations and interviews without losing depth in the analysis. However, I do believe that following up my interview study with classroom observations would be very fruitful.

In Publication III the following research questions are asked:

1. What properties of physics culture with respect to physics teacher education can be identified in the talk of physicists?
2. What effects might these aspects of physics culture have on physics teacher education?

These questions were asked on the basis of the four discourse models and celebrated identity performances that were presented in Publication II. In particular, in Publication III I wanted to look more closely at the physics expert model as an expression of local physics culture as it pertains to teacher education. I chose to add eight interviews with physics lecturers to the original data set of nine interviews with physics teacher educators. These eight new interviews were originally conducted by my supervisor John Airey for a project concerned with scientific literacy, and will in this text be referred to as interview round b.

The intent of using interview round b in the analysis for Publication III was to broaden the original findings by exploring whether a group of physicists teaching in different settings use the physics expert model, and if so, in what way. The work thus checks the findings of Publication II, while at the same time expanding them. Can the physics expert model be shown to have explanatory value when applied to a new interview context, with a different original purpose? It is, of course, a disadvantage that the new round of interviews was carried out with another purpose, but this was balanced by the possibility to both broaden and test the findings in Publication II.

4.2 Interviews

In semi-structured interviews, an interview guide is used but the researcher allows the interview to be organically steered by what may come up or seem important in the moment. Questions are open which gives the participant room to show the interviewer what is significant and important from their point of view. This allows for flexibility to let interesting things happen during the interview and for interviewer and interviewee to explore these things together (Robson & McCartan, 2015). One strategy is to ask questions about the *how* of things rather than the *why*. The goal is to get the interviewee to describe rather than to offer their own analysis of, or answer to, the research questions. Follow-up questions can ask for clarification, steer the conversation in an interesting direction, or try to catch what is important to the interviewee. There is no single way of carrying out an interview and starting with the same interview guide, each interview is expected to develop in a unique direction. (Kvale, Brinkmann, & Torhell, 2009)

Interviews are a standard method of choice in qualitative research but the validity of this method has been questioned (Robson & McCartan, 2015). The discussion of validity of interviews however, has to be held on the basis of the kind of knowledge the interview is used to gain (Kvale et al., 2009). If the interview is understood as a way of probing deeply into the experiences of interviewees (Kvale, 1996) where "subjects are basically conceived as passive 'vessels of answers' [… and] repositories of facts and the related details of experience" (Holstein & Gubrium, 1995, p. 7) then validity is about getting those facts in an objective way. However, in a post-modern understanding, researcher and interviewee construct knowledge together (Kvale et al., 2009) and I have chosen to view the interview as a co-construction of meaning between researcher and interviewee (Holstein & Gubrium, 1995). However, this does not mean that interview knowledge is entirely contextual. The interaction of course draws on and therefore a source of knowledge about active outside discourses (Kvale et al., 2009).

4.2.1 Interviews, power and positioning

Even in the most convivial and casual of interview situations, the interview must be understood as asymmetric. The researcher is in most cases the initiator of the interview, has a set agenda and an understanding of what constitutes a successful interview. The sharing is one-sided, and the interview has a clear gain for the researcher (Kvale et al., 2009). The power dynamics between researcher and interviewee are further skewed by the researcher's intention to interpret what the interviewee has said and publish this interpretation. In my case, I also take a critical stance in my research and there is a possibility that interviewees will not agree with my outsider interpretations.

In social interactions, including the interview, we position ourselves in relation to each other and the context. The interviewee's answers to a question are entirely dependent on the position they take, and their understanding of my position as researcher. Are they answering as an expert, a fellow academic, an interested stakeholder or perhaps even a perpetrator being accused? (Gee, 2011; Holstein & Gubrium, 1995) Making good quality use of interviews involves not trying to avoid such positionings, but rather to use positioning in a conscious way. This also includes being aware of what these positionings say about the material during analysis. When I interview a teacher educator, the formal framing is the practice of a research interview and when speaking, I generally aim to position myself as a researcher and the interviewee among other things as a willing participant. However, these positions constantly change during the interview, which also changes the situated meaning that the interviewee and I create together (Gee, 2005). During the interviews I sometimes tried to adopt the position of a novice PhD-student with less knowledge than the interviewee, framing the interviewee as a more experienced and benevolent colleague who will help me by telling me exactly how things are. This was a way to frame my questions as innocent and information seeking and was also an attempt to avoid the interviewees feeling they had to defend the system of teacher education rather than sharing their own understanding of it as sometimes flawed. These positionings define the meaning of what is being said (enacted) in the interview situation.

I have myself completed physics teacher education, which implies close familiarity with the practices and discourses of the educational programme. This is, of course, both a strength and a weakness. As Mercer (2007) argues, being an insider in relation to a research site should be considered a continuum where the degree of insiderness can vary not only between interviews but also during an interview. In this case, being part of the physics department, having completed the physics teacher-training programme and doing educational research are all things that made the environments of the interviewed educators familiar. This provided the possibility to interpret the interviews drawing on a common frame of reference and also allowed easy access to the system. On the other hand, this kind of familiarity may, of course, lead to blindness to shared frames of reference and difficulties in appreciating different perspectives on the system. On balance, I believe this is a strength rather than a weakness of the study.

4.2.2 Interviews Publication II

In interview round a, I interviewed a total of nine teacher educators from the three environments of physics teacher education: three physics lecturers, three education lecturers and three mentors. Henceforth, these interviewees will be collectively referred to as the educators. Thus, there were three educators from each of the three environments.

In choosing the education lecturers, I made sure that they all had experience of teaching introductory and advanced courses. Similarly, the physics lecturers teach major physics courses, taken by both trainee physics teachers and bachelor students. The education and physics lecturers were recruited using contacts within the university system.

The practicum mentors were found using a list of all local mentors. Typically, mentors have very full timetables and do not receive extra time to work with trainees. This made it difficult to find mentors who would prioritise participating in the study. In the end, the first three mentors on the list to agree to be interviewed were selected. Fortunately, these mentors did have varying experiences of teaching and mentoring. One of the mentors was quite new both as a teacher and mentor, whilst the other two were more experienced.

The interviews were carried out in Swedish, lasted between 60 and 90 minutes and took place in an environment chosen by the educator. The in-depth, semi-structured interviews were guided by three themes designed to explore the ways in which the educators construed physics teacher education as more or less valuable for creating professional physics teachers. The interview guide can be found in Appendix A.

The most relevant theme for this study became "What new physics teachers need to take with them from the educational programme." Here, I asked about the practice and purpose of the teaching that the educators were involved in, as well as the other parts of teacher programme. The educators also talked about the purpose of the educational programme in general, its most important parts and whether something was missing. The second theme, "The general physics teacher", involved questions around ideal pictures of a physics teacher as well as worst case scenarios. The last theme, "Choosing to become a physics teacher" involved discussions around what motivates trainees to become physics teachers contrasted against other choices such as a teacher of another subject or a physicist.

4.2.3 Interviews Publication III

For Publication III, a second round of interviews was added to the data set created by interview round a described above. The second round of eight interviews were conducted by my co-author and supervisor for a study concerned with the disciplinary literacy goals of physics lecturers (Airey, 2011c). The interviews lasted between 60 and 90 minutes and were held in English. The interviews were guided by a disciplinary literacy discussion matrix and included questions about what goals the physics lecturers have for their different groups of teachers (see Airey, 2011c). Physics lecturers were selected from a further three universities across Sweden. At two of these universities, trainee physics teachers are taught physics in their own separate groups. Thus, introducing the round b data set made it possible to not only explore the physics expert model in three new university programs, but also to evaluate the applicability of the model when dealing with settings where trainee physics teachers have their own dedicated physics courses.

In summary, the 17 interviewees for Publication III consisted of three education lecturers, three school physics mentors and 11 physics lecturers. The physics lecturers work at four different Swedish universities. At two of these universities, trainees take physics together with other program students, whilst at the other two universities trainees take physics in trainee physics teacher only groups. In the findings section (5.3), the 14 physics lecturers and school physics teachers will be collectively referred to as "physicists". For an overview of all the 17 interviewees, their context and teaching situation, see Table 1.

Table 1. A summary of all 17 interviewees along with information about their context and teaching situation. In brackets after each interviewee is shown an upper case L for large or S for small university and a lower case a for interview round a, or b for interview round b.

Interviewee code	**Context**
Mentor 1 [La] Mentor 2 [La] Mentor 3 [La]	Upper secondary school physics teachers who function as mentors during school placement. Large university. Interview round a.
Education lecturer 1 [La] Education lecturer 2 [La] Education lecturer 3 [La]	Education lecturers who teach educational theory at a large university teacher education. Interview round a.
Physics lecturer 1 [La] Physics lecturer 2 [La] Physics lecturer 3 [La]	Physics lecturers who teach physics for mixed groups of students at a large university. Interview round a.
Physics lecturer 4 [Sb] Physics lecturer 5 [Sb] Physics lecturer 6 [Sb] Physics lecturer 7 [Sb] Physics lecturer 8 [Sb] Physics lecturer 9 [Sb]	Physics lecturers who teach physics in groups with trainee teachers only, at smaller universities. Interview round b.
Physics lecturer 10 [Lb] Physics lecturer 11 [Lb]	Physics lecturers who teach physics for mixed groups of students at a large university. Interview round b.

4.3 Transcription

The interviews in rounds a and b were transcribed verbatim by me in the language in which they were held. Since analytically I was interested in meaning making rather than in grammar, I did not pay attention to details of *how* things were said, like pauses and hesitation, but focused on the *content* of the interviews. All quotes that appear in this Licentiate thesis and in the publications have been edited to enhance understanding. Repetitions and false starts have been removed and the quotes from interview round a that was held in Swedish have been translated into English. In the translation process, care was taken to keep the original meaning of the quote rather than literal word-for-word translations.

The transcribing of interviews from rounds a and b were quite different processes. In interview round a, I had conducted the interviews and they were all in Swedish which is my first language. Transcribing here means putting in text, my interpretation of what is being said, and transcription can therefore be viewed as the beginning of the analysis (Kvale et al., 2009). Having conducted the interviews and being fluent in the language in which they were held, this interpretative process was straightforward in a way. When transcribing interview round b, where some interviews were in English and not conducted by me, transcribing was a slower process. I checked the text repeatedly against the audio recordings and discussed what was being said with my supervisor who is a native English language speaker and who also conducted the interviews. This step of course in a different way also served as a way of starting the analysis process.

4.4 Coding and analysis

Here I will discuss the analytical processes employed in publications II and III. Since the book chapter included in this thesis is more theoretical in nature this is discussed in section 3.2 (Developing disciplinary literacy).

As stated in the theory section, in the work of this thesis, discourse analysis is understood as theory and method in one. Because of this I chose to start the discussion of the theoretical framework of discourse analysis and how it is applied to my work in the theory section (3.1). I will here briefly summarize the main points from that section before moving on to the more practical details of my analysis.

Gee (2005) defines discourse as the ways in which meaning is made through language, that is, how language is used to say, do and be certain things. I use discourse analysis to explore the ways in which physics teacher educators use language to make meanings about the physics teacher programme. I am interested in the "ways of being" that are tacitly encouraged and discouraged by the discourses educators engage in. To do this I have chosen to work with one of the macroscopic tools of inquiry put forward by Gee, the notion of discourse models. In my work discourse models function both as a way of doing analysis and as a way to characterize and describe the discourses in play in the interviews. One way of understanding discourse models is as conscious or unconscious theories or heuristics about the world that are used to understand it. They are things we need to take for granted for our understanding to fit together. To find discourse models, Gee proposes asking what the interviewee needs to assume for their talk to make sense in their frame of reference.

Discourse models are used continuously when creating meaning, adapting our understanding of what words or phrases mean or what is being communicated. They are thus not fixed and there is not one single understanding of a concept, for example the concept of a physics course. Rather, a physics course can mean very different things in different situations, and these discourse models can be inconsistent and not fit together. This means that an individual can be expected to be inconsistent when moving between contexts, even within the same conversation. In an interview, the word physics can be used to denote "school physics" and invoke a complex understanding of what that is, that might be connected to experiences of school. Just moments later, the word physics might mean the physics discipline and invoke a totally different discourse model of universities and experimental research. In general, not every discourse model is appropriate in every context, and for meaning to be communicated, what is said needs to be understood within the particular discourse in play.

When doing discourse analysis, I take an approach that is concerned with the actual meaning created in communication, rather than the structural ways language has been used to create this meaning. My main interest is what is possible to say, or be, in the contexts I am studying. The grammar of language in this context is naturally important, since it shapes how these possibilities are created. But doing discourse analysis presupposes that you are fluent in the language being analysed, that you understand the potential for meaning-making residing in the grammar being used. In the end, when interviewing, transcribing and doing analysis the researcher needs be confident to be fluent enough in the local language to ascribe good meaning.

4.4.1 Analysis Publication II

To begin analysis, the transcripts were read through in their entirety and then in the first round coded very generally and associatively, sorting the material into tentative categories of repeating themes, thoughts, differences and similarities. This first open coding (Strauss & Corbin, 1998) served as a way of moving from viewing the interviews as separate units towards getting a feel for the material as a whole. It was also a way of distancing myself from the very familiar material (Jørgensen & Phillips, 2002).

In the second round of coding, the text material in each tentative category from round one was collected in a document and printed. Examples of categories at this stage were "the subject physics", "said about knowledge", "the choice to become a teacher" and "stuff to think more about". The printed documents were read through, discussed and re-sorted, still in an open way, keeping all themes that seemed potentially interesting.

Then, I focused on how each category could contribute to an understanding of how the different parts of teacher education were comprehended as relevant to the goals of the educational programme. For example, in the quote below, one of the lecturers at the education department is discussing what the physics courses should ideally cover.

> I think that [the physics courses] should adjust to the goals of schooling [...] in practice this means what is in the curriculum. With some elaboration. So to a large extent [...] secondary teacher education should adjust to the demands, values, and directives of the school physics curriculum.

This statement was understood as judging the value of university physics courses in terms of their suitability for preparing trainees to teach what is set out in the school curriculum. Gee (2005) suggests that when carrying out analysis we should ask ourselves what discourse models have been used to make value judgments. Here, the physics courses are judged as a means to a particular end—the implementation of the curriculum. This statement was initially coded as *subject according to syllabus* and later became part of the curriculum implementer discourse model.

The second round of coding was very open and resulted in a comprehensive revision of the categories, where some categories were recognised as more significant, whilst others were decided to represent side-tracks that would not be the focus of further analysis for now. The significant categories were then refined and merged into larger categories in an iterative process resulting in four separate systems of meaning, the discourse models. What the coded quotes in each discourse model had in common was that they all, more or less explicitly, indicated the same system of underlying understanding about the goal of physics teacher education. To make this structure visible in analysis, quotes were connected to nodes of meaning using a visual information environment VUE (Educational Technology Services at Tufts University, 2015). For an early version of the visual representation of the structures of meaning that in later iterations became the physics expert model, see figure 3.

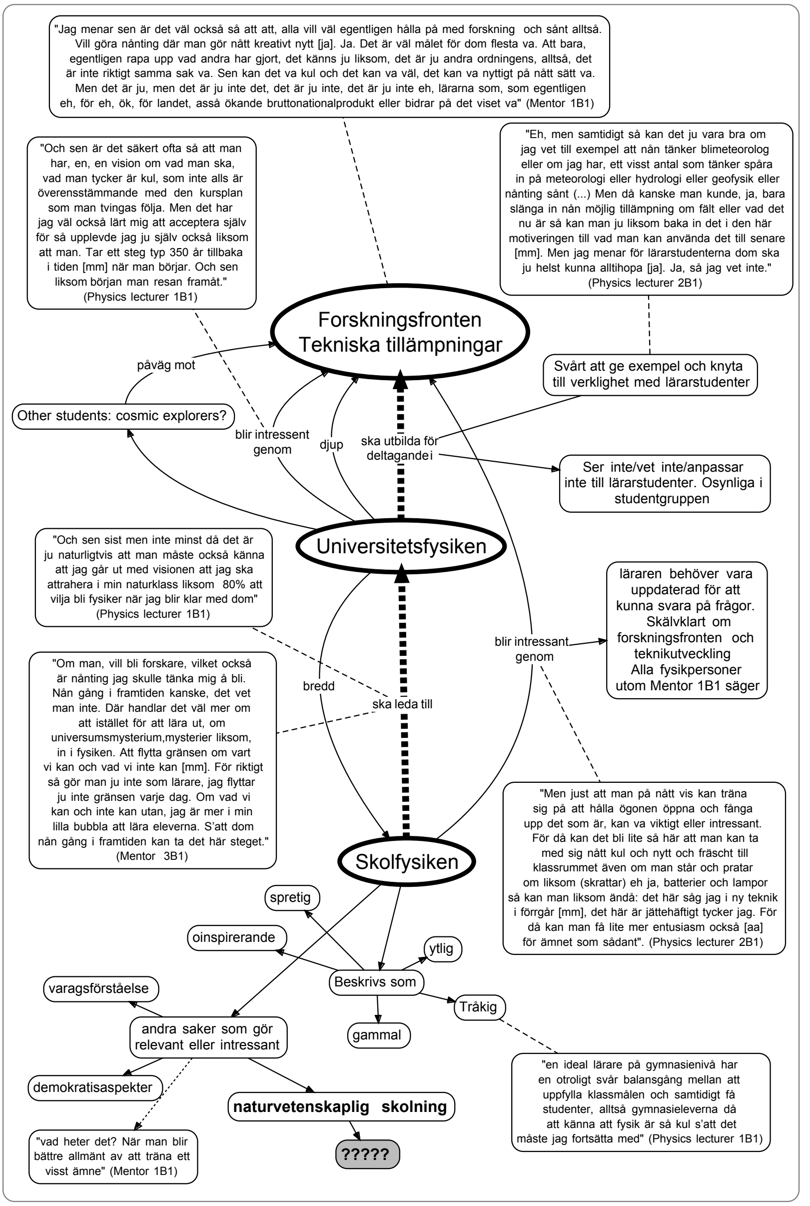

Figure 3. An early version of the visual representation used in analysis to make visible structures in meaning around physics teaching. In later iterations the particular representation depicted here became the physics expert model.

Using the visual representations as a support, the material as a whole was then read through again and recoded, now with the models as a starting point. Quotes were further connected to the models in the visual representation that was then used as the starting-point for discussions with my co-authors, testing and refining each model to reflect what we were seeing in the transcripts.

4.4.2 Analysis Publication III

In publication III, the earlier findings of the four discourse models and in particular the physics expert model were used as a lens to look at the combined data from interview rounds a and b. I did the analysis and at each stage I discussed my findings with the third author. The findings were then presented to and discussed with the second author, checking that the current interpretation was true to the experience of him doing the round b interviews.

The analysis was initially guided by the questions proposed by Gee, which meant reading through each transcript and asking what this physics lecturer must assume for this piece of talk to make sense. The physics expert discourse model is organized according to a particular goal of the education, the implied professional future of the student group. The intent was to use the model in analysis without taking for granted its applicability to this partly new context. Because of this, in the first analytical iteration, all 17 transcripts were gone through with an open focus on what assumptions about student professional future were visible in the material. A qualitative analysis software package, QRS NVivo 10 was used for coding and analysis.

In the first iteration, the material was organized around four themes of student futures, the “physics expert future”, the “physics teacher future”, the “engineering future” and “other futures”. For an example of what the analysis software looked like at this stage, see appendix B. The four themes were then gone through again and merged into two assumed futures, the physics expert future and the physics teacher future. Large parts of the “engineering future” theme at this stage became part of the physics expert future theme. In a second iteration the ways in which the assumed futures became visible in the material was further explored. For both assumed futures this resulted in three themes describing how the assumed futures became visible in the talk of teacher educators. These were *the description of physics*, *the description of the student,* and *learning to teach physics*. In the last step of the analysis, Schein’s (2010, p. 18) definition of culture was used, asking if and how the emerging structure could be understood as “A pattern of shared basic assumptions” guiding the “correct way to perceive, think, and feel in relation to” physics teacher education.

The analysis builds on close reading and re-reading of the transcripts while trying to make visible what is not apparent at first glance. Care was taken to catch what was not being said as well as what was being said, that is what was excluded from the talk of educators. In general, the findings are based on an understanding of the material as a whole rather than on straightforward analysis of particular pieces of educator talk. This means that when quotes are used in the findings section, they simply illustrate the findings and should not be understood as the single origin of any particular result.

4.5 Trustworthiness

When discussing criteria for excellent qualitative research, Tracy (2010) challenges the researcher to show rather than tell. In earlier sections I have aimed to show the reader the ways in which I have worked, to ensure that the findings presented can be trusted. This with the hope that the reader will find them trustworthy enough to act on their implications (Tracy, 2010 p. 837). This section is also a form of telling, where I discuss how criteria for good qualitative research can be applied to my work.

In traditional *quantitative* research, the quality of research is judged on validity, reliability, generalizability (or external validity), and objectivity. It is now close to forty years since Guba and Lincoln (1982) highlighted how these criteria, belonging to the rationalistic (scientific) paradigm, were unsuited to judge the quality of naturalistic inquiry, the study of the world of people using qualitative methods and case study design. They proposed four questions responding to the trustworthiness criteria traditionally used in rationalistic research (or the scientific paradigm). These questions are concerned with *truth value* – the establishment of confidence in the truth of findings, *applicability* – the degree to which findings are applicable in other contexts, *consistency* – how to determine whether findings could be consistently repeated in a different context, and *neutrality* – how to establish to what degree findings are free of "biases, motivations, interests, perspectives, and so on, of the inquirer" (Guba & Lincoln, 1982, p. 246). In response to these "rationalist" truth questions Guba and Lincoln proposed four criteria better suited to guide research in the naturalistic paradigm. These are *credibility*, *transferability*, *dependability* and *confirmability*.

Credibility is concerned with the assumed relationship between research findings and the realities being investigated. These realities, according to Guba and Lincoln, reside in the minds of people. One way of testing for credibility is by member checking, asking participants if they recognize, and agree with the findings. In this project, I have investigated the discursive practices of teacher educators and it is thus not the realities residing inside the minds of educators that are of interest, but rather the structure or meanings made by their talk. In this case, establishing credibility is about showing that the conducting of interviews, the recording of talk, the transcription and analysis all can be trusted to make sense in relation to the research questions and findings. Tracy suggests that credible research makes "readers feel [the findings are] trustworthy enough to act on and make decisions in line with" (2010, p. 843).

Credibility is about whether the findings are plausible and reasonable and enough details need to be provided that the reader can judge if this is the case. This might be called a "thick description" (Geertz, 1973) but note that this concept is usually used to denote a detailed description of the research data, allowing the reader to judge findings on their own value, rather than the thorough description of the research process referred to here.

Transferability, according to Guba and Lincoln, is about offering the reader enough information to make reasonable judgment about contexts that the findings could be transferred to. In the process of "naturalistic generalization" (Stake & Trumbull, 1982), each reader will judge for themselves if the described case context is similar enough to their own, to warrant the findings applicable in some way to their personal context (Mills, Durepos, & Wiebe, 2010). Tracy (2010) discusses transferability in terms of usefulness, a study being valuable "across a variety of contexts or situations." (p. 845) In this Licentiate thesis, I strive to provide the information needed for the reader to have tools to judge both the direct application, and the value of the findings in a wider context. The knowledge produced should be judged on meaningfulness i.e. does it help solve some problem, is it for example useful to teacher education professionals in their context? Hopefully, the discourse models can work as tools for professionals to see more clearly the meaning-patterns surrounding their own practice. In Publication III, adding the second round of interviews can also be seen as a test of transferability. Here the physics expert discourse model proved to be a working and useful construct in the new context of interviews made with a different purpose.

Dependability is the response to the rationalist criteria of reliability—the ability of a study to be replicable if the research design is repeated. In research dealing with humans, or in complex macroscopic situations, the exact context under which a study is carried out can of course never be recreated. Even so, it is important to provide a detailed description of research design, to enable a reader to assess the process leading to the research findings. In an interview project, each interview is unique and the researcher's accumulating understanding of the research context can further be expected to make the later interviews of a project very different from the first. I have documented this process by keeping notes in changes in my interview approach as well as my general reflections around each interview situation. These notes were used in the analysis when needed.

Confirmability is Lincoln and Guba's response to the rationalist criteria of objectivity. All scientific endeavour is contingent on the values of the researcher and the context, and objectivity in the traditional rationalist sense can therefore not be reached. Lincoln and Guba (1982) discuss inquiry being value bound in the choice of problem and framing, in the paradigm selected, in the choice of theories and methods used, in the interpretation of findings and in the values inherent in the context being investigated (p. 238). To generate confirmability, they suggest a clear path from result through analysis back to raw data. This is similar to Tracy's (2010) suggestion to strive for meaningful coherence, where the purpose of research, research question, chosen theory and methods, analysis and findings, all fit together meaningfully. It is the task of this Licentiate thesis to illustrate such a coherent line in research execution.

Another means to achieve confirmability is self-reflexivity or sincerity: "that the research is marked by honesty and transparency about the researcher's biases, goals, and foibles as well as about how these played a role in the methods, joys, and mistakes of the research" (Tracy, 2010, p. 841). Self-reflexivity involves being conscious of the impact of the research, both on the self and the informants, and to "think about which types of knowledge are readily available, as well that which is likely to be shielded or hidden." These questions are addressed partly in the introduction and partly in section 4.2 (Interviews).

4.6 Ethics

Throughout the research project, I have followed the guidelines for good research practice drawn up by the Swedish research Council (2002, 2017). However, simply following legislation and guidelines is not enough to ensure ethical conduct in research (Johnsson, Eriksson, Helgesson, & Hansson, 2014). Procedural ethics need to be practiced together with situational ethics, relational ethics and exiting ethics (Tracy 2010, p. 847). This means ethical considerations cannot be confined to the research design stage, but should follow the researcher through each stage of the project. One such issue where the required ethical procedures risk producing other ethical problems is the use of consent forms. During and after an interview, participants have the right to withdraw participation, to refuse to answer questions and to ask that the material recorded is not used. But by signing a piece of paper with formal formulations, there is a risk of the participant feeling legally bound to follow through, even if they change their mind or feel uncomfortable with where the interview is going. To minimize the risk of participants having this understanding, I made sure to go through the consent form with participants and to stress that by signing the consent form they do not promise to participate but simply agree that they are informed of what participation entails.

Since my research design did not require the processing of any "sensitive information" as defined in The General Data Protection Regulation (GDPR) and did not involve any physical interference with participants or bear any risk of harming participants, it did not require approval by the Swedish regional research ethics board.

In interview round a, participants were initially contacted by me through phone or email and asked whether they were interested in participating in the study. If they agreed, they were sent an email with written information about the study, asking again whether they wanted to participate and if so to specify a time and place that suited them. Attached to the email was a consent form that the participant was asked to look at in beforehand. The consent form originally used (see Appendix C) focused on the recording and use of research material. At the start of the interviews I added information about the aim of the study and what participation entailed. After the first three interviews, this information was instead added to a reworked consent form that was used in the remaining six interviews (see appendix D). The information given to the participants remained the same irrespective of which consent form was used.

Participants were informed that the interview would be recorded and that they could chose to terminate the recording at any time during the interview. If the participant chose to not be recorded or wanted to end the interview, I would ask what (if any) of the already recorded material I could use. The recorded material would be used to do research at the Uppsala PER group and would also be discussed with my supervisors from outside the research group. This includes using the transcribed material in future publications and presentations. All participants are professional adults with a higher education degree. As such they can be expected to be able to understand the information about their participation in the study.

In interview round b participants were recruited through contacts at the universities where they teach. The interviews were conducted by my supervisor John Airey. All interviewees were informed of the purpose of the study and agreed to participate. They signed a consent form granting permission to use the interview for research purposes, and informing them that their name and the material would not be shared with anyone outside the research group. The consent form used in interview round b can be found in Appendix E.

All research should be judged in terms of the risks associated with the study compared to the expected gains. This project aims to provide information that can be used to create a physics teacher education that better provides for the educational needs of trainee physics teachers. This is a gain to the field of teacher education in general but also to the specific contexts of the educators participating in the study. The risks for participants can be considered minimal. The educators are professional adults and do not belong to any vulnerable groups.

Regarding the confidentiality and storing of data, the consent forms used in interview round a stated that personal information will not be recorded in any transcripts (see Appendix C and D). This includes personal number, name, address, or telephone number or other information that could easily be used to find the identity of the interviewee. A pseudonym has been used in transcripts and parts of the transcript that clearly risk exposing the identity of the interviewee will not be quoted in any publication. When not being directly used, data will be stored in a safe way, encrypted or in a locked space, only accessible by members of the Uppsala PER research group. When not actively used in my work, audio files and transcripts are stored on two hard drives in a locked drawer in a locked room, at Uppsala University.

5 Findings

In this section I present a summarized version of the findings for each publication.

5.1 Findings Publication I

In Publication I the concept of disciplinary literacy combined with a way of categorizing disciplines in terms of disciplinary knowledge structures provides the means for reasoning about what the movement between the physics department and education department might entail for trainee physics teachers. The concepts of disciplinary literacy and knowledge structures are further described in section 3.2 (Developing disciplinary literacy).

Disciplinary literacy is defined as “the ability to appropriately participate in the communicative practices of a discipline” (Airey, 2011c, p. 3). For trainee physics teachers this means mastering the communicative practices in order to be considered competent students and later, competent physics teachers. This is another way of understanding the need to be recognized as legitimate as discussed in Publications II and III, but differs from the framework used in those publications in that it is the particular ways of using semiotic resources in the discipline that is examined. The line between these different ways of understanding legitimacy is of course fluid, and the distinction is a theoretical rather than empirical one.

Earlier findings (Airey, 2012) imply that physics lecturers tend to have the same literacy goals, regardless of the student group they teach. In Publication II it is argued that lecturers having the same disciplinary literacy goals for physics students and trainee teachers would mean that trainee physics teachers do not get the chance to develop the specific skills-set involved in teaching physics. When trainee teachers participate in labs for example, they fail to learn how to talk about and use this experiment for the particular purpose of teaching someone else physics. Another example that is also discussed in Publication III, is the experience of learning university physics through the medium of English when the goal is to teach school physics in Swedish. There is thus a risk of trainee teachers failing to learn the specific set of skills associated with teaching physics. Viewed through the lens of the findings of publications II and III, the lecturers can be said to focus on the literacy goals relevant to a becoming a physics expert, while not considering, or finding irrelevant, the particular things a trainee teacher needs to learn in order to teach physics.

In Publication I, the environment of teacher education is also discussed in terms of knowledge structures. Physics is categorized as a hierarchical singular, where meaning is taken to be unchanged across contexts. Knowledge is constructed through integration into the larger existing hierarchical structure and the discipline is seen as an end in itself. This is contrasted with the horizontal region of education, where knowledge is created in a number of specialized "languages", each suited to a particular context, and where knowledge from a number of disciplines is recontextualised for educational purposes, see Figure 1.

When moving between the disciplines of physics and education, trainee teachers can be expected to experience a radical change in communicative practices. If students spend their first year at the physics department, internalizing an understanding of knowledge as unchanged across contexts, they might be particularly less prepared to handle this change. In a similar way, different ideas about what counts as knowledge in the disciplines of physics and education have the potential to cause problems. Students who are steeped in the epistemological commitments of a coherent, hierarchical, positivist, physics knowledge structure may experience the contingent nature of educational science as disjointed, incoherent and unscientific.

5.2 Findings Publication II

The research questions for Publication II were:

1. What discourse models (here ways of making sense of the education of physics teachers) can be identified in the talk of the teacher educators that trainee physics teachers meet during teacher training?
2. What physics teacher identity performances might we expect to be recognized and valued within these discourse models?

For research question 1, the analysis of the interviews resulted in the construction of four discourse models: *The practically well-equipped teacher model*, *The critically reflective teacher model*, *The curriculum implementer model* and *The physics expert model*. The discourse models are analytical devices (Jørgensen & Phillips, 2002) that delineate the different and sometimes incompatible ways of making sense of the educational programme that were identified in the talk of the educators. All four models are depicted together in Figure 4.

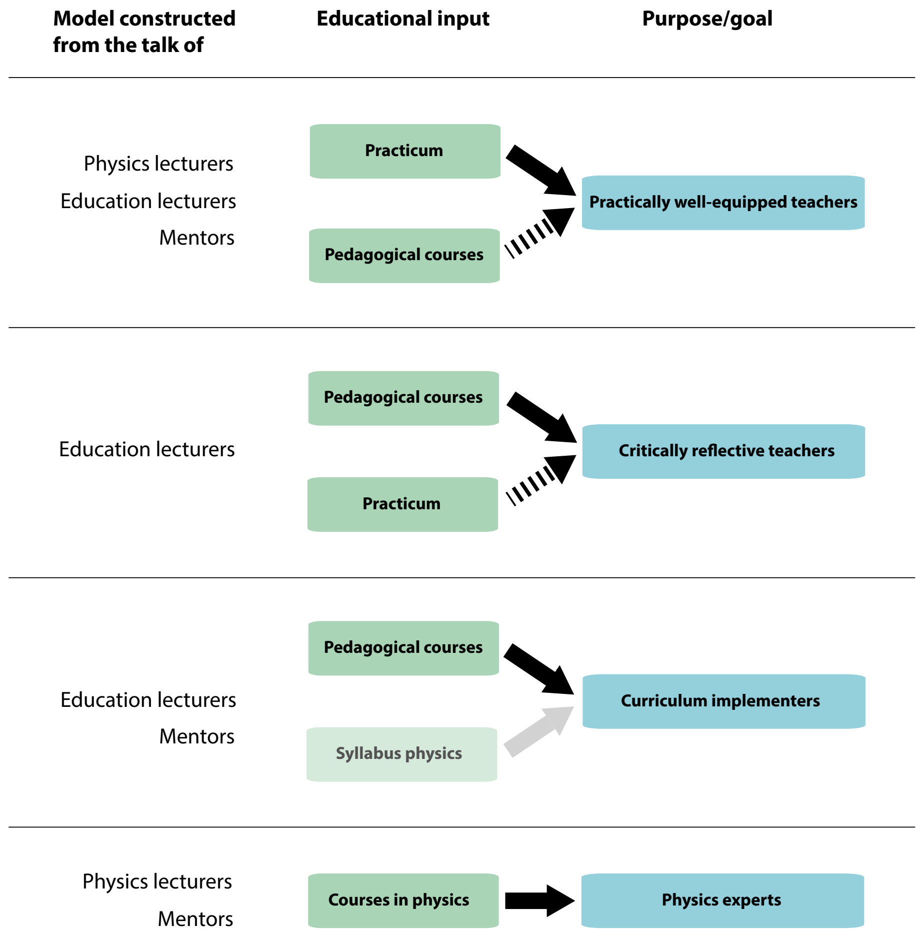

Figure 4. The four discourse models. In each model, the educational programme is understood in relation to the goals represented by blue rectangles on the right. The different educational inputs represented by green rectangles in the middle column are understood in varying ways as contributing to the goals of the educational programme. A solid arrow means contributing to the goal and a broken arrow means not contributing despite the potential to do so. The models were constructed from the talk of the various groups of educators listed on the left.

Each model frames physics teacher education in terms of a goal—a particular kind of professional. These different goals mean that the various parts of the educational programme appear more or less relevant—depending on the model being used at the time. The models thus represent logical systems of meaning where practice is understood with reference to what the educational programme is striving to achieve. In some cases a given discourse model offers no ways of understanding the relevance of a particular part of the programme at all. This means that in order to make sense of that part of the educational programme, another model would need to be used. The same educational input can therefore be interpreted in quite different ways depending on which discourse model is being invoked. In the figures accompanying the models, goals are represented by blue rectangles and educational input by green rectangles.

In answer to research question 2, each model is associated with a celebrated identity performance. For each model I will briefly summarize the goal of the model and how different identity performances are recognized and valued.

5.2.1 The practically well-equipped teacher model

In this model the goal of the educational programme is to create physics teachers who can do the work of a teacher on a day-to-day basis. This goal is assumed to be reached by teaching practical skills. In this model, identity performances on the theme of a well-prepared teacher would be valued. This would entail demonstrating knowledge about the practical nuts and bolts of the job that teachers are expected to perform in schools. However, since the model frames the educational programme as not providing the tools needed to reach this goal, it is probably difficult to "pull off" (Gee, 2005) this practically well-equipped teacher identity performance (at least on the basis on the programme). A much less valued, but probably more easily accomplished identity performance within this model, would be that of a practically *ill-equipped* teacher. Here the trainee would be seen as entering the teaching profession without important knowledge needed to do the job and probably understanding most of the time spent in teacher education as wasted.

5.2.2 The critically reflective teacher model

In the *critically reflective teacher* model, the goal is to give trainees the theoretical tools they need to critically reflect upon their own practice. To be recognised as professional within the critically reflective teacher model, trainee teachers should reflect on questions such as: How was physics created? Why is it normally taught in this way and what are the consequences of that? In this model, the traditional, accepted ways of doing things need to be questioned from all possible angles. Thus, the *critically reflective teacher* model values identity performances based around trying to change the education system for the better.

5.2.3 The curriculum implementer model

In the *curriculum implementer* model the goal of teacher training is to create "civil servants" whose mission is to implement the curriculum. Here a teacher's job is both to teach the specific content set out in the syllabus and also to meet a long list of demands that can be found in policy documents. In this model, identity performances where a teacher is framed as a public servant are valued. Performing a public servant identity allows the trainee to draw on large parts of the teacher programme and involves playing a relatively well-defined role. However, there is a risk that this position may be disempowering since the responsibility for what is learned lies, not with the teacher, but with the writers of the curriculum.

5.2.4 The physics expert model

The *physics expert* model differs from the other three models in that it has a very different goal. Whilst the *curriculum implementer*, *practically well-equipped teacher* and *critically reflective teacher* models all refer directly to a kind of professional teacher stereotype, the *physics expert* model focuses on the creation of physics experts. At first glance a discourse model that does not aim to create any kind of teacher, but rather has the production of physics experts as its goal, appears totally unrelated to physics teacher education. However, in our analysis the *physics expert* discourse model was repeatedly used to frame the relevance of physics teacher education.

In the *physics expert* discourse model, the choice to become a physics teacher is understood as a deviation from the obvious path to become a physicist, taken by everyone who is talented enough. A valued professional identity performance might for example be an expressed desire to work in physics research as a physics expert. However, the choice to become a teacher involves movement away from the research front and teachers are therefore likely to be understood as unsuccessful or deviant. It appears that there are no highly-valued ways of performing a physics teacher identity within the physics expert model.

5.3 Findings Publication III

The research questions for Publication III were:

1. What properties of physics culture with respect to physics teacher education can be identified in the talk of physicists?
2. What effects might these aspects of physics culture have on physics teacher education?

The analysis of the 17 interviews of rounds a and b together resulted in a system of basic underlying assumptions about physics, physics teaching and trainee teachers. Note that the results of Publication III are partly a corroboration of the findings of Publication II. In particular, the assumption of the *physics expert* model, that the goal of physics teaching is to create physics experts, came to play a significant role in the analysis for Publication III. Here, the analysis of the new compiled material provided a deepened and more nuanced understanding of how the physics expert assumption is part of physics culture and, more importantly, an extended exploration of what the consequences of this are for physics teacher education.

For the purpose of Publication III, culture is defined as a pattern of shared basic assumptions that I saw as recurring in the analysis. In what follows, I first present the underlying assumption that *the purpose of teaching physics is to create physics experts*. Then in the following three sections, I present the patterns of assumptions following the physics expert assumption, together with their logical implications. Each section is devoted to one of the main themes that came up in the analysis: *school and undergraduate physics*, *the trainee physics teacher* and *learning to teach physics*.

The physics expert assumption holds that the *purpose of teaching physics is to create physics experts*. One example of how this assumption became visible in the analysis for Publication III was in the interview with physics lecturer 11Lb who teaches physics at a large university and has around 10 % trainee teachers in his student groups. When discussing the group he teaches, physics lecturer 11Lb describes the different paths students take after leaving the program. Here, working as a physics teacher is not mentioned as one of these paths. In fact, throughout the whole interview with 11Lb, the teaching of physics to trainee teachers is curiously absent— even though when asked directly he is aware that trainee teachers are taking his course. It is not until the interviewer explicitly asks: "and do any of the people who take a degree here, do they go on and teach later on?" that the only short discussion of trainee teachers in relation to university physics takes place. In this short exchange, the interviewer asks if it might be a problem for trainees that they learn high-level university physics in English when physics teachers need to go on to teach lower-level school physics in Swedish. The interviewer thus makes trainee teachers visible as a group and suggests that their particular future as physics teachers might create particular needs and problems for teaching. However, 11Lb re-constructs this question as being about physics itself, that the teaching language might be a problem for "keeping physics in Swedish alive" and then turns the discussion to a general one, leaving the subject of trainee teachers: "both Swedish and English are equally important in Sweden. [At] *any workplace* I would imagine." By turning the discussion towards what is needed at "any workplace" rather than what trainee teachers in particular might need, trainee teachers are made "invisible" and the question of whether physics teachers might have special needs in terms of physics teaching is left unanswered.

The physics lecturer discussed above teaches physics at a large university where trainee teachers take physics together with other student groups. In such a context it is possible to let the *physics expert* goal set the agenda for the whole student group. This is not true of the interviews with physics lecturers who teach trainee teacher-only groups, where it would be strange to explicitly state that trainee physics teachers should have the goal of becoming physics experts. However, even though the idea that lecturers were creating physics experts was not explicitly stated in these interviews, this assumption could still be implicitly inferred from the talk of the lecturers. The following quote from a second-round physics lecturer illustrates this:

> Physics lecturer: (…) to me it's important that I'm not a physics teacher, but I'm a teaching physicist. [mm]
>
> Interviewer: I think that's a good way of putting it actually.
>
> Physics lecturer: Because otherwise, I'm not so curious about the physics itself. I want to stay curious and learn more about physics [mm] and use all the tools of, as a physicist. Yes and that's also a very important aspect. When I, when I teach even high school students. It's important for me that what I teach about is reality, it's not just part of school reality. I teach because this has to do with the real world. So that's why I want to be a teaching physicist rather than a physics teacher. Just doing my job.
>
> Physics lecturer 7Sb

There are several things that can be unpacked from this quote. First, the physicist is careful to not take on an identity of physics teacher. To be recognized as a physics teacher is obviously undesirable, even when teaching physics to high-school students. The position of physicist is preferred and is also framed as coming with some advantages for teaching physics. In contrast to a physics teacher, a physicist is construed as curious and wanting to learn more about physics. At the same time, being a physics teacher is associated with the opposites of these things. As implied by the counterpoint structure of his argument, a physics teacher is thus not curious and not interested in learning more about physics. Further, being a physicist seems to exclude being a physics teacher. In the second part of the quote, the physicist contrasts teaching physics that is about the real world, with teaching physics that is "just part of school reality". Unfortunately, it is not possible to further unpack the meaning of this statement based on this single quote, and this theme was not expanded on later in the interview. What can be said is that the talk of this physicist implies that the difference between teaching physics about the real world and school reality is important and is put forward as an argument for why it would be a disadvantage to identify as a physics teacher when teaching physics: "So that's why I want to be a teaching physicist rather than a physics teacher".

This line of reasoning illustrates how the assumption about creating physics experts, even in trainee teacher only groups, implicitly influences what is considered to be desirable. This assumption also seemed to transfer over to how physicists talked about school physics. For example, physics lecturer 1La discussed how the goal of physics teachers when teaching school physics, should be to lead students towards expert physics.

> And last, but not least of course, [as a physics teacher] you have to feel that you have the vision to make at least 80% of your students want to become a physicist after taking your class.
>
> Physics lecturer 1La

Thus, in the interviews, the overarching goal of a school physics teacher was not expressed as for example to contribute to a more scientifically literate society, but rather the role of a school physics teacher is to create more physicists. In the discussion of Publication III, this is framed in terms of the *goal myth*.

5.3.1 School and undergraduate physics

Under the assumption that the purpose of teaching physics is to create physicists, school physics becomes meaningful as a bridge that leads students towards undergraduate physics. In the talk of physics teacher educators, school physics was constructed as uninteresting and without inherent meaning. It was described as predictable, unchallenging and inherently boring.

For undergraduate physics, a difference was constructed between "real" or "ordinary" physics taught to students who can be assumed to have a physics expert goal, and trainee physics taught to trainee teachers. In the interviews with mixed-group lecturers, the purpose of undergraduate physics was constructed as forming a stable base that enabled the next level of physics. This stable base was described as very mathematical and one early goal of a physics degree should be to develop the mathematical tools needed to describe the different theories in physics. In the interviews with physicists who teach trainee only groups, the physics lecturers implicitly relate to this notion of "real" undergraduate physics as difficult and mathematical, compared to what they teach to trainee physics teachers that is constructed as simple, conceptual and un-mathematical.

To summarize the theme of school and undergraduate physics the analysis resulted in a collection of assumptions connected to the physics subject: *"Real" or "ordinary" undergraduate physics is mathematical and difficult. Specialized physics for trainee teachers is not real physics. The content of school physics is simple, uninteresting and inherently unproblematic.* In the discussion of Publication III, this is framed in term of the *content myth*.

5.3.2 The trainee physics teacher

In what ways did physics lecturers talk about trainee physics teachers in the interviews? First of all, one common response throughout the interviews with lecturers teaching at larger universities with mixed groups of students, to any question regarding trainee teachers was a "I don't know". Despite having trainee teachers taking their physics classes, these physics lecturers demonstrate an unawareness of, and indifference to, the existence of these trainee teachers. In this way the implicit assumption that all students have another goal, to become physics experts, was seen in the analysis. Trainee physics teachers are striving towards something that is assumed not to be desirable, and therefore they are either overlooked or marginalized.

In this structure of meaning, trainee physics teachers are rendered different from the "ordinary", "normal" or "real" physics students. This also became clear in the analysis of the talk of the lecturers who only taught trainee teacher groups. This assumption about who the "normal" physics students are fits well with the construction of school and undergraduate physics discussed in the previous section. Students who are not taking "real" physics cannot be considered to be "real" physics students. We interpret this to point towards a shared, tacit assumption across our interviews that the "normal", or "real" physics student is one who wants to become a physics expert.

When trainee teachers were discussed explicitly, they were described as less talented or not as smart as "ordinary" physics students. Connected to this construction of the trainee teacher as less able than the "ordinary" physics student is the idea that choosing to become a physics teacher is something you do in the absence of other better alternatives or the ability to cope with "real" physics. When trainee teachers are constructed as differing from an ordinary physics student by not having what it takes to continue with physics, the "ordinary" physics student is at the same time constructed as talented and having what it takes. A difference in status is thus constructed where the trainee physics teacher is placed below a "real" physics student, and the teaching of school physics is seen as trivial.

To summarize the theme of the trainee physics teacher, the analysis resulted in a collection of assumptions around who trainee physics teachers are, all based on the assumption that "ordinary" physics students aspire to become physics experts. The trainee physics teacher is assumed to be less talented in physics than the "ordinary" physics student. Moreover, *students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists.* In the discussion of Publication III, this is framed in terms of the *student myth*.

5.3.3 Learning to teach physics

Finally, in the analysis, the *expert goal* assumption was seen to be implicit in educator talk about what is needed to teach school physics. In the interviews, learning to teach physics was above all connected to gaining *enough* physics knowledge, "*it is subject knowledge always that is important*" (Mentor 1La). However, the assumed link between mastering undergraduate physics and teaching school physics was not problematized. Becoming a good physics teacher was constructed as something not requiring great effort to achieve. One aspect of physics culture here thus seems to be the assumption that *a* *genuine interest in physics and in teaching is enough to become a good physics teacher*.

In the interviews with lecturers who teach trainee-only groups, learning to teach physics was surprisingly little discussed considering that this should be the goal of all their students. When learning to teach does come up, the focus is to a large degree on talking about and explaining physics. Across the interviews, a shared picture of the physics teacher as a lecturer, or performer on a stage was constructed, while other possible ways of talking about physics teaching were absent. For example, ideas of science for society were excluded from the discussion of a physics teacher's role.

To summarize the theme of learning to teach physics, the analysis resulted in a basic underlying assumption that *it is not really necessary to learn how to teach physics*. Physics knowledge and interest in physics combined with an ability to talk about physics is enough. In the discussion of Publication III, this is framed in terms of the *teaching myth*.

6 Discussion and looking forward

The aim of the research I present in this Licentiate thesis is to investigate the differing ways to perform a professional physics teacher identity, that are made available in the discourses of educators in Swedish physics teacher education. I connect these available performances to trainee learning, arguing that *what* trainees find significant to learn is dependent on *how* they can be recognized as professional physics teachers. Physics teacher education is one of the main ways to impact school-level physics teaching and learning, and this teaching and learning has the potential to affect both who wants to pursue physics and how physics is perceived by non-physicists in Sweden. The quality of physics teacher education can further be an important tool to inspire ambitious students to choose physics teaching in a climate of negative discourse around the teaching profession.

As an initial way to theoretically approach the discourses of physics teacher education, in Publication I my co-author and I used the theoretical constructs of disciplinary literacy together with a Bernsteinian disciplinary knowledge structure perspective, as a lens to look at physics teacher education. The research question was

1. Can Bernstein's constructs of hierarchical and horizontal knowledge structures be used in a fruitful way to understand the specific difficulties of combining physics and educational science in a physics teacher education programme?

Following Bernstein's classification, physics would be categorized as a hierarchical singular, while education would be classified as a horizontal region. In Publication I, it is suggested that this difference in knowledge structures and especially the different ideas about what counts as valid knowledge in the two environments, risk causing problems for the learning of trainee physics teachers. When transitioning between the physics department and education department students who are steeped in the epistemological commitments of a coherent, hierarchical, positivist, physics knowledge structure may experience the contingent nature of educational science as disjointed, incoherent and unscientific. Through this theoretical argument, that was supported by preliminary analysis of educator interviews, Publication I points towards how the learning of trainee physics teachers could potentially be negatively affected by the discourses of what counts as knowledge in the environments trainees participate in.

To further investigate the discourses of physics teacher education, for Publication II, I interviewed nine teacher educators in the three different environments that trainee physics teachers move between during their education. The research questions for publication II were

1. What discourse models (here ways of making sense of the education of physics teachers) can be identified in the talk of the teacher educators that trainee physics teachers meet during teacher training?
2. What physics teacher identity performances might we expect to be recognised and valued within these discourse models?

The analysis resulted in the construction of four discourse models: *The practically well-equipped teacher model*, *the critically reflective teacher model*, *the curriculum implementer model* and the *physics expert model*. The discourse models are four different ways that educators were found to make sense of the educational programme, where each model frames physics teacher education in terms of a default goal—a particular kind of professional. In the *practically well-equipped teacher model*, the goal of the educational programme is to create physics teachers who can do the work of a teacher on a day-to-day basis. In this model, identity performances on the theme of a well-prepared teacher would be valued. In *The critically reflective teacher model*, the goal is to give trainees the theoretical tools they need to critically reflect upon their own practice. In this model, the traditional, accepted ways of doing things need to be questioned from all possible angles. Thus, the critically reflective teacher model values identity performances based around trying to change the education system for the better. In the *curriculum implementer model*, the goal of teacher training is to create "civil servants" whose mission is to implement the curriculum. In this model, identity performances where a teacher is framed as a public servant are valued. Performing a public servant identity allows the trainee to draw on large parts of the teacher programme and involves playing a relatively well-defined role. However, there is a risk that this position may be disempowering since the responsibility for what is learned lies, not with the teacher, but with the writers of the curriculum. Last, the *physics expert model* differs from the other three models in that it has a very different goal. Whilst the curriculum implementer, practically well-equipped teacher and critically reflective teacher models all refer directly to a kind of professional teacher stereotype, the physics expert model focuses on the creation of physics experts. This goal means that the choice to become a teacher is difficult to understand and it appears that there are no celebrated ways of performing a teacher identity within the physics expert model.

The four models represent logical systems of meaning where practice is understood with reference to what the educational programme is striving to achieve. In some cases, a given discourse model offers no ways of understanding the relevance of a particular part of the programme at all. This means that in order to make sense of that part of the educational programme, another model would need to be used. In publication II, my co-authors and I interpret this as a sign of the fragmentation of the education, where in the analysis, no coherent way of viewing the whole system as a coherent whole could be found.

In answer to research question two, each model was associated with a celebrated identity performance. In a way that mirrors the discourse models, these performances offer no coherent way of depicting yourself as a competent physics teacher while at the same time drawing on the whole of the education as valuable to your professional knowledge.

Noticeable in the results of Publication II was the physics expert model, where the goal of teaching physics is understood to be to create physics experts. This discourse model was prevalent in some way in all interviews for Publication II. In this discourse model, there does not appear to be any way of performing a celebrated physics teacher identity. For Publication III, I chose to investigate this notion further in a wider context of physics departments in Sweden. I added eight interviews with physicists from three more Swedish universities. These interviews were originally part of the data-set for Publication I. The research questions for Publication III were:

1. What properties of physics culture with respect to physics teacher education can be identified in the talk of physicists?
2. What effects might these aspects of physics culture have on physics teacher education?

The analysis of the 17 interviews for Publication III suggested that one facet of the culture of Swedish physics departments is the basic underlying assumption that the purpose of all teaching of physics is to create physics experts. This assumption leads to four 'myths' about trainee physics teachers and school physics: The *Goal Myth,* the *Content Myth,* the *Student Myth* and the *Teaching Myth*. The first of these myths is a reformulation of, and therefore in substance very similar to, the physics expert model. However, while the main point of the *physics expert* model is that the purpose of university physics teaching is to create physics experts, the Goal Myth focuses on the teaching of physics in school.

The Goal Myth: *The role of a school physics teacher is to create new physicists.*
The Content myth: *The content of school physics is simple, uninteresting and inherently unproblematic.*

The student myth: *Students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists.*
The Teaching Myth: *It is not really necessary to learn how to teach physics.*

In Publication III, my co-authors and I argue that these four myths together work to unintentionally undermine and devalue physics teacher education.

In summary, the results of the three publications suggest that the discourses around physics and teaching that are present in physics teacher education seem to present problems to the identity performances and learning of trainee physics teachers. These problems will be further discussed in Section 6.2 and 6.3. For the purpose of this discussion I will refer to the results collectively as discourses of physics teacher education. But first I will examine the limitations in my findings. To what extent do my results illustrate the differing ways to perform a professional physics teacher identity, as made available in the discourses of educators in physics teacher education?

6.1 Limitations

The findings of publications II and III are based on discourse analysis of interviews with teacher educators. As such, the data naturally says a great deal about the educators themselves and the local systems of education they work in. One question that may be asked is how exhaustive this description of physics teacher education discourses is. To what extent have all available discourses in this system been described? The short answer to this question is, not at all. It is impossible to gain access to, or describe all discourses in play in an environment by interviewing a limited number of central actors. However, the four discourse models and the description of physics culture as it pertains to teacher education presented in this Licentiate thesis *do* represent how the educators in my interviews talked about physics, teaching physics, and teacher education. As such, the description of the discourses represents aspects of what is present in this educational program. Further, I argue that the discourse models I identify are worthwhile describing and considering in the context of creating a better (physics) teacher education programme. There may indeed be other important discourses that speak to my research questions. However, this possibility does not diminish the value of the discourses that I have described.

Another related question deals with the extent to which discourses identified in the talk of teacher educators can say anything about the discourses trainees meet and participate in. Participating in an interview is a very different context to teaching physics for example, and the experience of being interviewed automatically puts the interviewee in a very different position (performing a different identity) than when they are teaching. Clearly, it is not certain that the discourses created from what educators say in an interview are also enacted in the classroom (cf. Säljö, 1997). However, it would also be very surprising if there were no relationships between the discourses identified in the interview situation and how educators talk about the education and content when meeting trainee physics teachers. Discourses are not individual traits, rather they are repertoires shared and repeated between people (Jørgensen & Phillips, 2002). During the interviews, the educators draw on the discourses available in their environment. I thus expect that the discourses, whilst constructed from the interview situation, are available in the wider institution. As such it is reasonable to expect these discourse models to also be available to trainees and that they will thus be part of the discursive structures that trainees need to negotiate when learning to become teachers.

Finally, there is the question of transferability. To what extent are the discourses I present relevant in other contexts, for example for teacher education in other institutions both in and outside Sweden? The discourses constructed reflect properties of the particular system of physics teacher education in four institutions in Sweden, and may not necessarily apply to the reality of physics teacher education in other countries. However, I believe that the discourses presented can be valuable as a lens that researchers and educators in physics teacher education can use to view their own training programme. Perhaps they can work as a contrast that can make visible what is excluded and included in their own practice. Further, since the organization of physics teacher education (divided between three different environments) is common both in Sweden and internationally, it is likely that similar patterns may well appear in other educational programmes.

6.2 Trainee physics teachers' identity performances

The large amount of research on trainee identity and teacher education has resulted in a call for explicit discussion within educational programmes of the kinds of negotiations needed to create a professional teacher identity (Danielsson & Warwick, 2014b; Olsen, 2008; Saka et al., 2013; Varelas, House, & Wenzel, 2005). This Licentiate takes up this call, suggesting that such a discussion cannot be carried out in a vacuum. I argue that in order to give trainees possibilities to openly negotiate their professional identity, the training programme needs to be problematised as a context that steers and limits professional identity performance.

In the analysis of Publication II, there was no single way of performing a professional physics teacher identity that would be simultaneously recognised and valued within all four discourse models. In the practically well-equipped teacher model, the well-prepared teacher is valued, but this identity performance is difficult to pull off due to the model's framing of the educational programme as lacking (in fact a more credible identity performance based on this model is that of the practically ill-equipped teacher—someone entering the teaching profession without the practical skills needed for the job). In the curriculum implementer model, public servant identity performances are valued where teachers work towards the overarching goal of implementing the curriculum. However, in contrast, the critically reflective teacher model is partly about challenging that same curriculum, framing oneself as an agent for change. Finally, and perhaps most surprisingly, in the physics expert model, becoming a physics expert is the ultimate goal, which offers no valued way of performing a professional physics teacher identity.

What can be said about how these potential identity performances and professional discourses of educators in physics teacher education that I have presented can be expected to affect trainee physics teachers? In Publication II, my co-authors and I suggest that when progressing through their programme, moving between the different educational environments, trainees will meet the four discourse models and thus have to respond to the incoherence in the discourses of the educators. Which, if any, physics teacher professional identity should they be performing? One approach would be for trainees to adapt to and participate in each model as it arises, performing different physics teacher professional identities in different contexts. However, it is unclear how this could be achieved.

Another question is which model or models trainees take with them from the education—what sticks? Can students develop the ability to see their educational experience through a number of perspectives, or will trainees adopt just one model, choosing to understand what it means to become a physics teacher through that particular lens? As I have shown, this would be problematic since each model unintentionally undermines and devalues the others. This risks trainees viewing large sections of their education as a waste of time. A goal for any physics teacher education programme should be to present a coherent way of understanding how each part of the programme is meaningful in creating new physics teachers. However, no such coherence could be found in the analysis of interviews I conducted. Elsewhere, such efforts have been made, one example is the literature on reform-minded teaching (Luehmann, 2007). In this work, science teacher education has been designed with a particular identity performance in mind. However, presenting trainees with one single coherent discourse in this way has been shown to be insufficient for trainees to be able to perform this identity in school (Saka et al. 2013).

Being recognised as a professional teacher in school means being able to perform teacher identities that are intelligible within the context of the school. It is thus not enough to present trainees with a single coherent discourse within which to perform their teacher identities during the training programme. To be useful to trainees after their education, such identity performances also need to be valued in school.

In the particular educational programme studied in Publication II, practicum forms part of the education. The two discourse models that were primarily constructed from the talk of mentors, the practically well-equipped teacher model and the physics expert model, would thus appear to be more relevant to school reality than the other two models. It is perhaps these two ways of viewing the educational programme that are most likely to render students recognisable as professional physics teachers in school.

In the results of Publication III, the physicists and mentors expressed ideas indicating that a "normal" expected progression in physics is to go from school physics, through undergraduate physics and on into expert physics. In the analysis I came to see the culture of physics as it pertains to teacher education as being built around this assumption. In a system where the goal of all students learning physics is implicitly assumed to be becoming future expert physicists, choosing to become a teacher means diverting from the expected path to go back to school physics. In such a system, trainee physics teachers can be understood to be incomprehensibly "swimming against the tide" by wanting to return to school physics. This relationship is illustrated below in Figure 5.

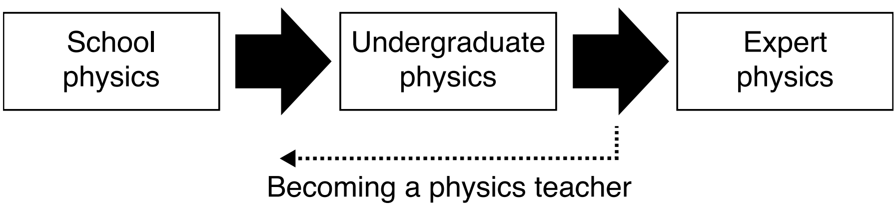

Figure 5: Trainee teachers "swimming against the tide" of the physics expert assumption.

In the introduction I asked why anyone, in the light of the negative discourse associated with the teaching profession, would choose to become a physics teacher? In the findings of Publication III, this question is addressed in what is termed the student myth: *Students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists.* In the analysis for Publication III, this myth was identified as a consequence of the default assumption that the purpose of teaching physics is to create physics experts. In the light of the student myth, anyone striving to be something other than a physics expert is viewed with suspicion. It is hard to understand why a good student would "waste their abilities" by choosing to teach school physics.

In the culture around physics teaching presented in publication III, advanced physics knowledge is what is primarily needed to be a physics teacher, whilst the rest of teacher education goes unnoticed. Further, the choice to become a teacher is a suspect one, calling into question the overall competence of the trainee teacher. The practically well-equipped teacher model on the other hand values practical knowledge, but at the same time understands the educational programme as not really giving this to trainees. If these discourses, or some combination of them, are the way of understanding the physics teacher programme that trainees take with them, the picture of a competent physics teacher painted is really just someone who is well-organised and not good enough to do "real" physics. In the introduction I asked why one of my interviewees, a physics teacher in school, was so eager to distinguish himself as a physicist rather than a physics teacher. One tentative answer is that the discourses around being and becoming a physics teacher enable only limited ways of performing a celebrated professional identity.

6.3 Trainee learning – Becoming a good physics teacher?

Another important question is how the educator discourses may affect the learning of trainee physics teachers. In general, as trainees move through their educational programme, the recognisable ways of performing professional teacher identities described in Publication II would bring some course content to the foreground, whilst other content is framed as less important (or even a waste of time). In the special case of trainees learning physics, the content myth from Publication III presents the content of school physics as simple, uninteresting and inherently unproblematic. However, physics is generally viewed as a very difficult subject and the content of school physics is experienced as problematic by a large number of students (Angell, Guttersrud, Henriksen, & Isnes, 2004). This means that a trainee physics teacher needs to understand the problems that school students may have with physics—and these problems are almost certainly quite different to those faced by future physicists. Simply *understanding* school physics is not enough because this is not the same as understanding how children tend to view school physics and how it can best be taught. This is not a trivial project. However, if the content of school physics is depicted in a trivial way (as in the content myth), and if learning to teach physics is further presented as just being about learning enough physics as in the teaching myth, then it is unlikely that trainee teachers will put their heart to learning the particular complexities of teaching school physics.

A further issue pertains to the differences between the disciplines of physics and education in terms of Bernstein's disciplinary classifications. As described in the findings of Publication I, physics is classified as a hierarchical singular, where meaning is taken to be unchanged across contexts. This is compared with the horizontal region of education, where knowledge is created in a number of specialized "languages". Each language is suited to a particular context, and knowledge from a number of disciplines is recontextualised for educational purposes. These differences between physics and education can potentially give rise to difficulties when trainees have to repeatedly move between environments deeply rooted in the different disciplines. Trainee physics teachers learn physics within a singular that has a strong disciplinary identity and this identity then needs to be renegotiated into a teacher identity. In particular, it is possible that some trainee physics teachers who have taken the understanding of knowledge in physics to heart, may struggle to see the validity of other types of knowledge. If this is the case, trainees risk having difficulties valuing and learning from the educational science content of teacher education (Guilfoyle, McCormack, & Erduran, 2017). Recent research suggests that this is indeed the case. Molander and Hamza (2018) found that trainee teachers who already had a PhD in a science related subject had great difficulty accepting the significance of educational theory during the first part of their teacher training program. The trainees started out with a strong focus on content knowledge and its explanation. During the program, this focus transformed to an understanding of teaching as complex and a "cautious appreciation" of the theoretical aspects of teacher education. However, they still experienced educational science as too disconnected from practice.

The assumption that the purpose of teaching physics is to create physics experts, as discussed in Publication III, comes with a very one-sided, Vision I understanding of the role of physics (Roberts, 2011). The Vision II aspect of physics teaching (i.e. science for society) goes unnoticed. However, only a handful of all the students in compulsory school that physics teachers meet over the years will become physicists. The potential risk here is that trainee physics teachers will not learn physics in a way that prepares them for their main role of teaching physics for everyone, if they have only ever met this narrow "physics for physics sake myth" in their educational program. If trainees learn this narrow understanding of the purpose of physics teaching, they risk reproducing unequal patterns of participation in physics in their own classrooms (Archer, 2019; Francis et al., 2016). If physics teaching in school has a role to contribute to the breaking of unequal patterns in physics, trainee teachers need to be equipped with the tools to make this happen. One such tool could be to learn a multitude of ways of reflecting on and understanding the purpose of teaching and learning physics, and I argue that this is something that a trainee physics teacher should learn in the physics department. Further, trainee teachers cannot be expected to present an image of physics as something other than connected to exclusivity, smartness and nerdiness (Johansson, 2018a), if their own relationship to physics contains struggling against notions of choosing to become a physics teacher as a less desirable or less challenging path than choosing to become a physicist.

6.4 Implications

For teacher educators, an understanding of the four models could be used to facilitate the negotiations needed to create a common understanding of what the physics teacher programme is trying to achieve. Such an understanding could also enable educators to make conscious, informed decisions about their own teaching practice. In addition, even though the discourse models described in Publication II might be familiar to some people working in systems similar to the one of the study, these discourses have not yet been described in the literature. The discourse models in this case contribute with an overview perspective, potentially affording educators the possibility to navigate between different perspectives of their programme (something that the educators that I interviewed were not able to do with ease).

Further, knowledge of the four discourse models presented in Publication II could help trainee physics teachers entering the system with an understanding of the motivations and goals of the different parts of their programme and allow them to question which aspects are relevant for their desired future professional identity. Knowledge of the models, then, potentially empowers trainee physics teachers to understand the different goals of their educational programme and from there make informed choices about their own particular approach to becoming a professional physics teacher and the identity performances this entails.

For physics departments, my co-authors and I suggest in Publication III that physics departments should examine their assumptions about what the goal of physics teaching is, and if needed, widen their definition of physics expert to include physics teachers. If we want the best physics teachers possible, then any tacit attitudes to physics teacher education similar to the ones signalled by the four myths need to be challenged. Physics students who want to become teachers should not need to “swim against the tide”.

6.5 Future work

Moving forward, one interesting path is to examine if and how the discourses presented in Publications II and III can be found to be significant in the actual professional identity performances of trainee physics teachers as they move through the educational programme. The results presented in this Licentiate thesis suggest a number of challenges that trainees might have to negotiate when learning to become physics teachers. However, no conclusions can be drawn about the realities of these problems without talking to trainees themselves. Going forward, I intend to examine whether the discourses of teacher education that I have identified can be recognized as significant from a trainee point of view. If this proves to be the case the next question would be: In what ways do trainees negotiate these discourses? I also want to investigate the extent to which the ability to deal with the four discourse models is equally distributed. Are certain groups of students at an advantage/disadvantage compared to their peers? What are the consequences of the four discourse models for the professional identities trainees can perform, and how can those performances be understood to influence their learning?

An interesting perspective to take on this problem is to explore how trainee identity performances can be understood as gendered in relation to the discourses of physics. Here, theoretical constructs of masculinity could be used as a lens to look at trainee physics teachers' experience of becoming a teacher. I am interested in how masculine associations connected to physics (Gonsalves et al., 2016), such as nerdiness and smartness, are negotiated in relation to stereotypically feminine qualities that are sometimes connected to teaching (Hjalmarsson & Löfdahl, 2014). In Sweden, teacher training is a study choice dominated by women, 77% of new teachers graduated year 2017/2018 were women[2] (Swedish Education Authority, 2019). At the same time, the *physics* teacher study programme has the largest amount of men (70%) of all teacher education study programmes (Swedish Education Authority, 2019). What does it involve for trainee teachers to make the choice to become a physics teacher in the intersection of these discourses? And more specifically with respect to my future work: can this be found to affect the learning of trainee physics teachers? Going forward, I want to investigate trainee physics teachers' negotiations around learning skills stereotypically associated with women, such as caring for students, caring for society etc., in relation to the physics subject they are learning to teach.

A possible way of doing this could be to interview trainee physics teachers and ask them about how they understand the task of using these skills in the context of teaching physics. Here, I believe it is important to avoid comparing male and female students, but rather explore how *all* students need to negotiate masculine notions of physics in relation to the goals of physics teaching.

Another worthwhile path to explore is the extent to which discourses similar to the discourse models and physics-culture described in this Licentiate thesis, can be identified in other physics teacher-training programmes outside Sweden. This could be done in a number of ways. However, close attention needs to be paid to what the purpose of such an exploration would be. I have argued in this Licentiate thesis that the primary value of the discourses I describe are that they can be used as tools for educators to examine their own practice. It is not obvious that further evidence of these discourses existing in other institutions would make them more useful tools. However, the case for using these tools could of course be made much more convincing, and I believe this is especially the case for the description of physics culture as it relates to teacher education presented in Publication III. These results indicate a

[2] The distribution is however less dramatic when only considering the upper secondary school teacher program where 56% were women 2017/2018.

serious problem, and further work is needed to investigate this issue. To make a convincing case to the physics community, a large-scale survey could be distributed to physicists in a number of countries, exploring physicists' assumptions about physics teacher education. However, designing such a survey to capture the assumptions around physics teacher education among physicists would be a very difficult task. One way could be to design questions corresponding to the four myths identified in Publication III. However, having respondents simply react to the myths explicitly stated would probably not be useful. In the discourse analysis that is the basis for the four myths, implicit meanings and silences are an important source of information. It is difficult to capture such data in a survey. The advantages of such a survey are however potentially large since statistically significant results are typically taken very seriously and acted upon by the PER community.

Another potentially fruitful way of approaching further exploration of the discourse models is to do so in close collaboration with physics teacher educators. Working together with educators, the usefulness of the discourse models could be explored. The goal of such a project would be to simultaneously explore and change, physics teacher education for the better together with educators.

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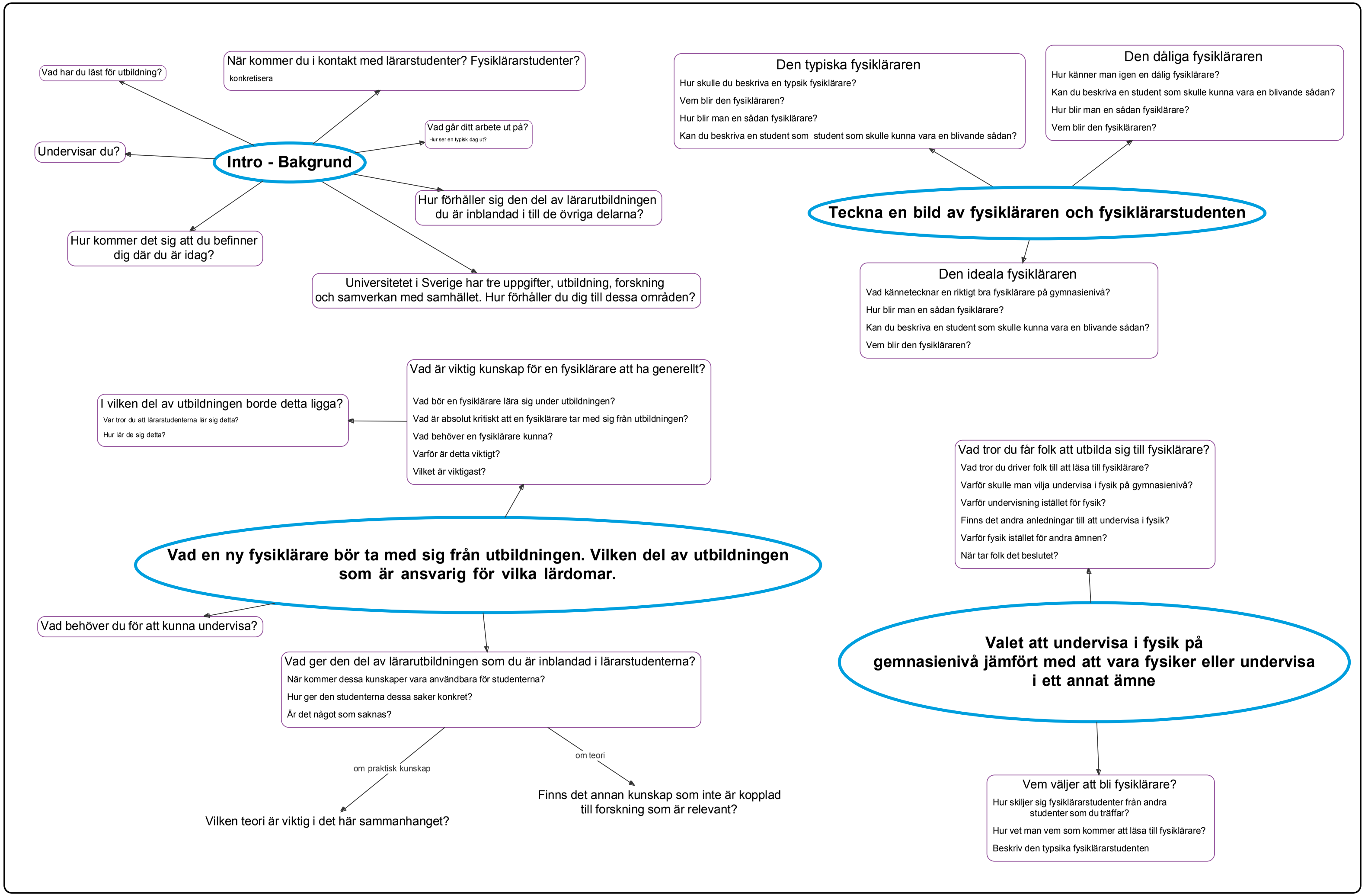
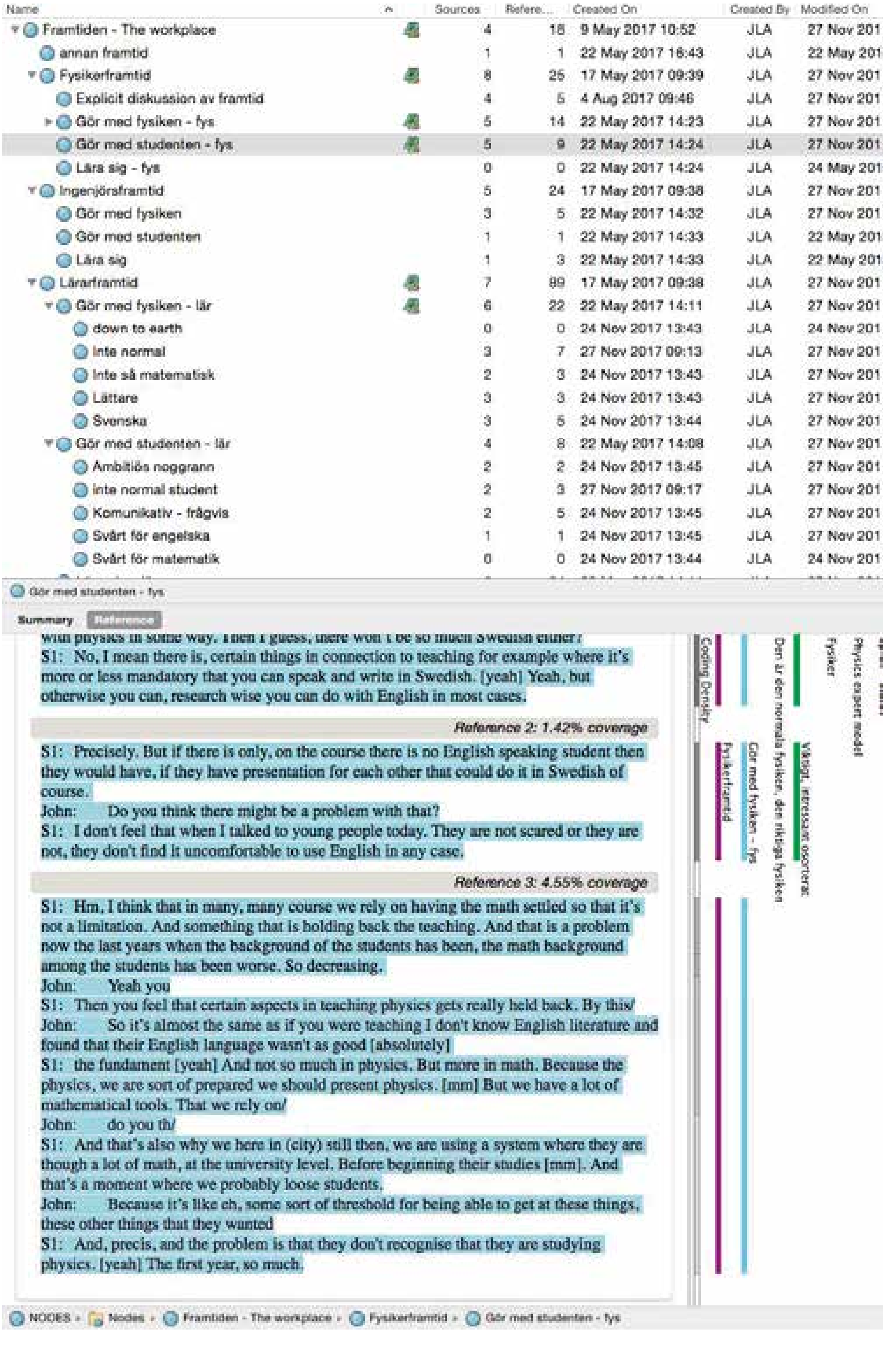
Appendix A

Interview guide used for interview round a


Intro - Bakgrund
Vad har du läst för utbildning?
När kommer du i kontakt med lärarstudenter? Fysiklärarstudenter?
konkretisera
Vad går ditt arbete ut på?
Hur ser en typisk dag ut?
Undervisar du?
Hur förhåller sig den del av lärarutbildningen du är inblandad i till de övriga delarna?
Hur kommer det sig att du befinner dig där du är idag?
Universitetet i Sverige har tre uppgifter, utbildning, forskning och samverkan med samhället. Hur förhåller du dig till dessa områden?
Teckna en bild av fysikläraren och fysiklärarstudenten
Den typiska fysikläraren
Hur skulle du beskriva en typsik fysiklärare?
Vem blir den fysikläraren?
Hur blir man en sådan fysiklärare?
Kan du beskriva en student som student som skulle kunna vara en blivande sådan?
Den dåliga fysikläraren
Hur känner man igen en dålig fysiklärare?
Kan du beskriva en student som skulle kunna vara en blivande sådan?
Hur blir man en sådan fysiklärare?
Vem blir den fysikläraren?
Den ideala fysikläraren
Vad kännetecknar en riktigt bra fysiklärare på gymnasienivå?
Hur blir man en sådan fysiklärare?
Kan du beskriva en student som skulle kunna vara en blivande sådan?
Vem blir den fysikläraren?
Vad en ny fysiklärare bör ta med sig från utbildningen. Vilken del av utbildningen som är ansvarig för vilka lärdomar.
Vad är viktig kunskap för en fysiklärare att ha generellt?
Vad bör en fysiklärare lära sig under utbildningen?
Vad är absolut kritiskt att en fysiklärare tar med sig från utbildningen?
Vad behöver en fysiklärare kunna?
Varför är detta viktigt?
Vilket är viktigast?
I vilken del av utbildningen borde detta ligga?
Var tror du att lärarstudenterna lär sig detta?
Hur lär de sig detta?
Vad behöver du för att kunna undervisa?
Vad ger den del av lärarutbildningen som du är inblandad i lärarstudenterna?
När kommer dessa kunskaper vara användbara för studenterna?
Hur ger den studenterna dessa saker konkret?
Är det något som saknas?
om praktisk kunskap
Vilken teori är viktig i det här sammanhanget?
om teori
Finns det annan kunskap som inte är kopplad till forskning som är relevant?
Valet att undervisa i fysik på gymnasienivå jämfört med att vara fysiker eller undervisa i ett annat ämne
Vad tror du får folk att utbilda sig till fysiklärare?
Vad tror du driver folk till att läsa till fysiklärare?
Varför skulle man vilja undervisa i fysik på gymnasienivå?
Varför undervisning istället för fysik?
Finns det andra anledningar till att undervisa i fysik?
Varför fysik istället för andra ämnen?
När tar folk det beslutet?
Vem väljer att bli fysiklärare?
Hur skiljer sig fysiklärarstudenter från andra studenter som du träffar?
Hur vet man vem som kommer att läsa till fysiklärare?
Beskriv den typiska fysiklärarstudenten

Appendix B

Example of how the analysis software was used during the first iteration of analysis for Publication III


Name
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Framtiden - The workplace 4 18 9 May 2017 10:52 JLA 27 Nov 201
annan framtid 1 1 22 May 2017 16:43 JLA 22 May 201
Fysikerframtid 8 25 17 May 2017 09:39 JLA 27 Nov 201
Explicit diskussion av framtid 4 5 4 Aug 2017 09:46 JLA 27 Nov 201
Gör med fysiken - fys 5 14 22 May 2017 14:23 JLA 27 Nov 201
Gör med studenten - fys 5 9 22 May 2017 14:24 JLA 27 Nov 201
Lära sig - fys 0 0 22 May 2017 14:24 JLA 24 May 201
Ingenjörsframtid 5 24 17 May 2017 09:38 JLA 27 Nov 201
Gör med fysiken 3 5 22 May 2017 14:32 JLA 27 Nov 201
Gör med studenten 1 1 22 May 2017 14:33 JLA 22 May 201
Lära sig 1 3 22 May 2017 14:33 JLA 22 May 201
Lärarframtid 7 89 17 May 2017 09:38 JLA 27 Nov 201
Gör med fysiken - lär 6 22 22 May 2017 14:11 JLA 27 Nov 201
down to earth 0 0 24 Nov 2017 13:43 JLA 24 Nov 201
Inte normal 3 7 27 Nov 2017 09:13 JLA 27 Nov 201
Inte så matematisk 2 3 24 Nov 2017 13:43 JLA 27 Nov 201
Lättare 3 3 24 Nov 2017 13:43 JLA 27 Nov 201
Svenska 3 5 24 Nov 2017 13:44 JLA 27 Nov 201
Gör med studenten - lär 4 8 22 May 2017 14:08 JLA 27 Nov 201
Ambitiös noggrann 2 2 24 Nov 2017 13:45 JLA 27 Nov 201
Inte normal student 2 3 27 Nov 2017 09:17 JLA 27 Nov 201
Komunikativ - frågvis 2 5 24 Nov 2017 13:45 JLA 27 Nov 201
Svårt för engelska 1 1 24 Nov 2017 13:45 JLA 27 Nov 201
Svårt för matematik 0 0 24 Nov 2017 13:44 JLA 24 Nov 201
Gör med studenten - fys
Summary
Reference
with physics in some way. Then I guess, there won't be so much Swedish either?
S1: No, I mean there is, certain things in connection to teaching for example where it's more or less mandatory that you can speak and write in Swedish. [yeah] Yeah, but otherwise you can, research wise you can do with English in most cases.
Reference 2: 1.42% coverage
S1: Precisely. But if there is only, on the course there is no English speaking student then they would have, if they have presentation for each other that could do it in Swedish of course.
John: Do you think there might be a problem with that?
S1: I don't feel that when I talked to young people today. They are not scared or they are not, they don't find it uncomfortable to use English in any case.
Reference 3: 4.55% coverage
S1: Hm, I think that in many, many course we rely on having the math settled so that it's not a limitation. And something that is holding back the teaching. And that is a problem now the last years when the background of the students has been, the math background among the students has been worse. So decreasing.
John: Yeah you
S1: Then you feel that certain aspects in teaching physics gets really held back. By this/
John: So it's almost the same as if you were teaching I don't know English literature and found that their English language wasn't as good [absolutely]
S1: the fundament [yeah] And not so much in physics. But more in math. Because the physics, we are sort of prepared we should present physics. [mm] But we have a lot of mathematical tools. That we rely on/
John: do you th/
S1: And that's also why we here in (city) still then, we are using a system where they are though a lot of math, at the university level. Before beginning their studies [mm]. And that's a moment where we probably loose students.
John: Because it's like eh, some sort of threshold for being able to get at these things, these other things that they wanted
S1: And, precis, and the problem is that they don't recognise that they are studying physics. [yeah] The first year, so much.
Coding Density
Fysikerframtid
Gör med fysiken - fys
Den är den normala fysiken, den riktiga fysiken
Viktigt, intressant osorterat
Fysiker
Physics expert model
NODES › Nodes › Framtiden - The workplace › Fysikerframtid › Gör med studenten - fys

Appendix C

Consent form used for the first
three interviews of interview round a

Avtal avseende användningsbegränsning av forskningsmaterial

Detta avtal är ett medgivande till materialanvändning från den som deltagit vid en ljudupptagning med avsikt att ge råmaterial till forskning, primärt vid Institutionen för fysik och astronomi, A*vdelningen för fysikens didaktik vid Uppsala Universitet.*

Allmänt användande av materialet

Allmänt användande av materialet avser t.ex. analys av deltagarnas interaktion med såväl varandra som med maskin- och mjukvara. Det innebär att materialet ej sprids utanför de inblandade forskargrupperna.
□ Jag medger
□ Jag medger ej
att upptaget ljudmaterial där jag medverkar får användas i forskningssyfte och datorbehandlas, förutsatt att det hanteras i enighet med vedertagen svensk forskningsetik.

Utdrag ur materialet för användning vid presentationer

Det huvudsakliga syftet med att använda utdrag ur materialet är att kunna visa på specifika situationer där beteenden exponeras som bedöms vara relevanta i relation till forskningen.
□ Jag medger
□ Jag medger ej
att utdrag ur upptaget ljudmaterial där jag medverkar får användas vid presentationer anknytande till forskning, förutsatt att mitt namn döljs.

Utdrag ur materialet för användning vid elektronisk publicering

Elektronisk publicering är en möjlighet att sprida kunskap om forskning vid Uppsala Universitet, primärt till andra forskare men även till allmänheten. Bilder och videoutdrag underlättar förståelsen för sampresenterat skriftligt material och är ett ypperligt sätt att visa intressanta exempel.
□ Jag medger att utdrag ur upptaget *ljudmaterial* där jag medverkar får användas vid elektronisk publicering anknytande till forskning, förutsatt att mitt namn döljs.
□ *Inget* ljudmaterial där jag medverkar skall användas vid elektronisk publicering.

Utdrag ur materialet för användning vid tryckning

Forskningsmaterial publiceras oftast i tryckt form och fotografier eller utvalda stillbilder ur videosekvenser kan förtydliga budskapet. Publicering sker mestadels i vetenskapliga tidsskrifter och i samband med forskningsrelaterade konferenser.
□ Jag medger
□ Jag medger ej

att utdrag ur upptaget ljudmaterial där jag medverkar får användas vid publicering i tryckt form, förutsatt att mitt namn döljs.

Ångerrätt

Jag förbehåller mig rätten att vid senare datum ändra mina nuvarande medgivanden, varvid jag insänder en uppdaterad version av detta avtal till nedanstående kontaktperson. Det uppdaterade avtalet träder i kraft när det mottages av kontaktpersonen och gäller ej retroaktivt avseende publicering utför i enighet med tidigare avtal.

Kontaktperson:

Postadress: Johanna Larsson
Box 530
751 21 UPPSALA

Besöksadress: Ångströmlaboratoriet
Lägerhyddsvägen 1
Å:81407

E-post: johanna.larsson@fysik.uu.se

Underskrift:

Namn (textat)	Personnummer
Ort och datum	
Underskrift	

REFERENCE

Rundgren, C.-J. (2008). *Visual Thinking, Visual Speech - a Semiotic Perspective on Meaning-Making in Molecular Life Science.* PhD thesis, Linköping University, Norrköping.

Appendix D

Consent form used for the
later six interviews of interview round a

Information om deltagande i intervju om utbildningen av fysiklärare

Detta är en informationsbrev och en samtyckesblankett där du informeras om vad det innebär att delta i min studie och hur dina personuppgifter kommer hanteras under forskningsprocessen. Det är viktigt att du läser igenom informationen noggrant innan du samtycker till medverkan i studien och vi börjar intervjun.

Ditt samtycke innebär att du 1) deltar i en intervju som tar runt en timme. 2) att intervjun får spelas in (om du vill, annars kommer jag att anteckna), 3) godkänner att materialet från intervjun används i forskningssyfte så som anges nedan.

Innan du tackar ja till att bli intervjuad så vill jag be dig försäkra dig om att du förstår syftet med intervjun och att du har fått tillräckligt med information om studien. Jag beskriver nedan närmre vad forskningen går ut på men om du har några frågor så tveka inte att kontakta mig.

Vad syftar forskningen till?

Vid avdelningen för fysikens didaktik studerar vi många olika aspekter av fysik ur ett lärandeperspektiv. Forskningen har stor betydelse för kvalitets- och utvecklingsarbete både vid vårt och andra lärosäten.

Mitt doktorandprojekt, som är ett samarbete mellan avdelningen för Fysikens didaktik och Centrum för genusvetenskap, handlar om ämneslärarutbildningen med inriktning fysik. Jag är intresserad av vilka förutsättningar för att forma en professionell identitet som lärarstudenterna möter under sin utbildning. För att få bättre förståelse för vad som händer under lärarutbildningen är jag intresserad hur lärarutbildare inom utbildningens olika delar ser på vad det är att vara fysiklärare och fysiklärarstudent.

Vad innebär deltagandet för dig och hur används materialet?

Att delta i intervjustudien innebär att du deltar i en intervju under ungefär 1 timme. Med ditt godkännande spelas intervjun in, men om du inte vill det tar jag anteckningar istället. Intervjun utgår från en intervjuguide med olika teman och frågor, men det är viktigt att din berättelse får ta stor plats under intervjun. Du bestämmer själv vilka frågor som du vill och inte vill svara på och det kommer jag att respektera.

Din medverkan är helt frivillig. Du kan alltid, både före, under och efter intervjun välja att avbryta din medverkan utan att ange särskilda skäl. Om du avbryter intervjun kommer jag att fråga dig om det intervjumaterial som hittills har samlats in kan användas eller inte.

Att du väljer att delta innebär att du godkänner att materialet används i forskningssyfte vid avdelningen för fysikens didaktik. Materialet kommer att kodas och ingen utanför forskargruppen får veta vad just du har gjort eller sagt. Du kan när som helst be att få ut den information vi har om dig eller, innan forskningsresultaten publicerats, välja att dra tillbaka din medverkan. Dessutom innebär ditt deltagande ett ovärderligt bidrag till vår forskning!

Efter intervjun kommer jag göra en utskrift (en transkribering) av delar av eller hela intervjun, och detta kommer att vara den text som jag främst använder för att vetenskapligt analysera intervjun. De anonymiserade texterna kommer att diskuteras i forskningsgruppen på avdelningen för fysikens didaktik och främst med mina handledare John Airey, Anna Danielsson och Eva Lundqvist, alla verksamma vid Uppsala universitet.

Det är viktigt att du förstår hur din integritet och dina personuppgifter är skyddade genom hela forskningsprocessen. Med personuppgifter menas ditt personnummer, namn, adress, telefonnummer eller andra tydliga uppgifter som kan spåra dig som person. Dessa uppgifter kommer inte att finnas med i de utskrifter som jag gör av intervjuerna. Du kommer att få ett annat namn, en pseudonym och om det finns en risk att du skulle kunna bli identifierad vid en återgivning av en enskild episod i intervjuberättelsen så kommer den inte att återges i detalj i någon publicering.

Enligt arkivlagen måste statliga myndigheter arkivera forskningsmaterial, detta gäller såväl ljudfiler som utskrifter. Dina uppgifter kommer att arkiveras på ett säkert sätt, krypterade eller inlåsta, och ingen obehörig kommer att ha tillgång till materialet. Resultaten kommer att publiceras i vetenskapliga tidskrifter och i en avhandling, i form av en bok. Studien kommer också diskuteras på vetenskapliga konferenser före publicering. Alla personuppgifter kommer att vara anonymiserade i samband med publikationer och diskussioner vid seminarier och konferenser. När publikationerna är klara skickar jag dig en kopia.

Kontakt

Har du frågor om projektet eller något annat får du gärna höra av dig!

Johanna Larsson
Doktorand i fysikens didaktik
Johanna.larsson@physics.uu.se
018-471 5879

Underskrift

Ja, jag vill delta i studien och är införstådd med vad det innebär enligt ovan:

Namn	Namnförtydligande	Ort och datum
___________________	_________________	________________

Appendix E

Consent form used in interview round b

Permission to use Interview Material

I herby grant permission for the use of this interview for research purposes. I understand that ***only transcripts*** will be used and the recording will not be shared with anyone outside the research group.

The anonymity of all interviewees will be maintained in any subsequent presentation of research findings.

Date ______________________________

Signed ______________________________

Name in block capitals ______________________________