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Trainee teacher identities in the discourses of physics teacher education

Going against the flow of university physics

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Abstract
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This thesis investigates what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher programme. Drawing on in-depth, qualitative interviews with 17 physics teacher educators and 17 trainee physics teachers, this thesis sees learning to become a physics teacher as a process of performing professional identities. It demonstrates aligning discourses of educators and trainees, and outlines a number of challenges that trainees have to negotiate when learning to become physics teachers.

The first part of the project analyzes the discourses of teacher educators. Four discourse models are identified which demonstrate how the talk of physics lecturers portrays the default goal of learning physics as becoming a researcher. Choosing to become a teacher in this system, means diverting from the expected path of a physics student, and moving backwards towards school physics. In such a system, trainee physics teachers are described as less competent and ambitious than other physics students, and can be understood to be incomprehensibly "going against the flow" of university physics by aiming towards school physics.

The second part of the project shows how physics courses are experienced by the trainee physics teachers as primarily meeting the needs of other student groups. The educators' talk about trainee teachers as less competent and ambitious is mirrored by trainees who see no incentive to try hard for good results. The analysis shows a physics study culture that emphasises brilliance and nerdiness, resulting in a passive classroom culture and high stress. Deepened analysis of the identity negotiations of three female interviewees shows how trainee teachers are resourceful in navigating this study culture. Combining positions of feminine woman, trainee teacher, and physics student, these students create practices of relaxed and constructive physics learning that challenge the elitist physics discourse.

The education of physics teachers is important for many reasons. There are projected shortages of trained teachers, and physics teachers have the power to affect how physics, a field that is lacking diversity, is perceived by young people. By exploring how becoming a physics teacher is entangled with discourses of competence, femininity, and the status of the physics discipline this thesis takes a novel approach to the education of physics teachers. The findings suggest that physics faculty in their role as teacher educators examine assumptions about physics teacher education and trainee physics teachers, and can be used to empower trainee physics teachers to challenge norms of brilliance and masculinity in physics.

Keywords: physics, physics teacher education, preservice teacher training, professional identity, identity performances, femininities, discourse analysis, qualitative interviews, educational relevance, gender

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For Tekla, Ture, and Henning

List of Publications

This thesis is based on the following publications, which are referred to in the text by Roman numerals. Reprint of Publication II is made with permission from Springer. The other publications are reprinted under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

- *I* 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
- *II* 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.
- *III* Larsson, J., Airey, J., & Lundqvist, E., (in press) Swimming Against the Tide: Five Assumptions about Physics Teacher Education Sustained by the Culture of Physics Departments. *Journal of Science Teacher Education.* https://doi.org/10.1080/1046560X.2021.1905934
- *IV* Larsson, J., & Airey, J., (in review) On the periphery of university physics: Trainee physics teachers' experiences of learning undergraduate physics. *European Journal of Physics*
- *V* Larsson, J., & Danielsson, A. T., (in review) Crafting constructive positions of learning physics: Trainee teachers' negotiations of femininity in a traditionally masculinized learning space. *Gender and Education.*

Author contributions

The contributions of the respective authors for each paper are detailed below.

- *I* For Publication I, 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* For Publication II, I proposed the idea, collected the data, did the analysis, and wrote the first draft. Each stage was discussed with my co-authors.
- *III* For Publication III, I proposed the idea and did the analysis. Part of the data was collected by me, and part of the data was collected by the second author. I wrote the first draft together with the third author.
- *IV* I proposed the idea, collected the data, and did the analysis. I wrote the first draft.
- *V* I proposed the idea, collected the data, and did the analysis. I wrote the first draft.

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

> Two students from the Bachelor in physics programme emailed me now during the exam period and asked me to help them, with nuclear physics, which I didn't even take myself, so that was funny (laughing). But I think it's perhaps because they're too afraid to ask the others [physics students] for help, because that would mean showing weakness, so it's kinda easier to ask a trainee teacher (laughing) for help.
>
> Ellen, trainee physics teacher

In this thesis, I explore what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher programme. In the quote above, Ellen[1], a trainee physics teacher that I interviewed in her third year of teacher education, describes her experiences of learning physics together with students who are enrolled in the Bachelor programme in physics. When the Bachelor students ask her for help, Ellen is recognized as someone who is competent enough to help others with physics. At the same time, Ellen gathers that the real reason she gets asked for help, even though she has not taken nuclear physics, is because she is a trainee teacher. As such, she is positioned outside the mainstream student culture of learning physics, where asking for help often means risking exposing yourself as weak or not smart enough.

Ellen belongs to a group of trainee physics teachers who are studying physics as part of the Secondary School Physics teacher programme, which will qualify them for teaching physics and mathematics in upper-secondary school in Sweden. In the programme, trainee teachers encounter three quite different teaching and learning environments. At the physics department, trainee teachers take physics courses taught by physics lecturers. At the education department, trainees take pedagogical courses, given by educational lecturers. During school placement, trainees observe and try out physics teaching in practice. Here they are supervised by a mentor, usually an upper secondary physics or mathematics teacher. This educational programme, and the way it is perceived and shaped by both educators and students, is the focus of my thesis project. I have used interviews with physics lecturers, education lecturers, school mentors, and trainee physics teachers, to explore this educational programme as a context where trainees perform identities as physics students and future physics teachers.

[1] All interviewee names throughout the thesis are pseudonyms.

While moving between the physics department, the education department and school environments, Ellen meets the educators who are responsible for her courses, and has to navigate their framing of what becoming a physics teacher is all about. Her identity performances are, thus, made possible within, and simultaneously limited by, the discourses at work in the educational environments. These discourses, as they are expressed by physics teacher educators, are the focus of the first part of the project. In the second part of the project, the focus is on how trainee physics teachers like Ellen negotiate their identities as physics students and trainee teachers, in relation to the subject of physics that they are learning to teach.

At the physics department, Ellen reads physics courses together with bachelor students and engineering students. Here, she is a physics student among others, and while she is studying mechanics, thermodynamics, and electromagnetism, she is also forming an image of the physics discipline. Ellen is coming to understand the nature and purpose of the subject she is preparing to teach, shaped by her courses, other students, and the physics lecturers she meets. She is also forming an image of who belongs within the physics discipline, while simultaneously coming to understand herself as a physics professional. Further, as a trainee physics teacher, Ellen is not only subject to the influence of the physics discipline. She is also moving towards a future as a physics teacher, where she will have influence over how physics is perceived by many students in school. This nexus of influence means that trainee physics teachers are of particular importance for the role of physics in the future: in school, university, and society.

The discipline of physics has well documented problems with underrepresentation of women and minorities (OECD Publishing, 2017b; Skibba, 2019). About 20% of students enrolled in undergraduate physics courses in affluent countries are women. This fraction decreases beyond the graduate level, where on average 16% of physics faculty are women in the US and European countries. (Skibba, 2019) In Sweden, 30% of general bachelor and master physics degrees[2] were awarded to women the academic year of 2019/2020 (Universitetskanslersämbetet, 2021). At the faculty level, 20% of Swedish physics faculty are women and for professors, this number is 12% (Statistiska Centralbyrån, 2021). Physics is thus a subject with a clear male dominance, and historically it has been associated with both masculinity and brilliance (Leslie et al., 2015; Traweek, 1988). Educational science on the other hand, has a pronounced female dominance and is not usually associated with brilliance (Leslie et al., 2015). Ellen is learning to become a physics teacher in the intersection between these two disciplines, and thus needs to negotiate these gendered discourses when performing her identity as a physics teacher-to-be. The

[2] This is calculated without including the engineering physics programs. The numbers for that program are even lower.

opening quote also hints at this relationship between physics and physics education, since helping other physics students is an unproblematic part of Ellen's positioning as a trainee teacher. According to Ellen, this position is not as readily available to other physics students, as they hesitate to ask each other for help while struggling to appear sufficiently "brilliant".

The gender-imbalanced participation in physics is also significant for physics teacher education in another way. It points towards the importance of how physics is portrayed by physics teachers in school. Images of physics as connected to smartness, nerdiness and for elites (Johansson, 2018a) and notions such as the "effortlessly clever physicist" (Archer, 2019) have been shown to discourage in particular female students from continuing with physics (Archer et al., 2020). Physics teachers can potentially affect these images, and consequently, who is able to see themselves as a potential future physicist. Furthermore, teachers are responsible for providing those students who will not go on with physics with the means for taking ownership of physics knowledge. It is important that these students see physics as relevant to their lives, and as something that can enable informed decision-making about socio-scientific issues (Fensham, 2011). This means that the ways in which Ellen, and her fellow trainee teachers, understand the nature and purpose of physics is an important factor in reproducing or changing patterns of unequal participation and engagement in physics (Archer, 2019; Francis et al., 2016).

Physics teacher education has large problems with recruiting and retaining trainee physics teachers. Few students attend physics teacher education both in Sweden and internationally, despite a documented need for new physics teachers and a close-to-guaranteed job at the end (Swedish national audit office, 2014; Woolhouse & Cochrane, 2010). In addition, the discourse around teacher education in Sweden is predominantly negative (Edling & Liljestrand, 2020). 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. These discussions reflect on trainee teachers, whose competence and suitability are questioned. (Aftonbladet, 2011; Dagens Nyheter, 2019; Dagens Samhälle, 2019) In this discourse, choosing physics teacher education can be understood as a choice that is "going against the flow" of what is expected of someone who is interested in, or good at, physics. To understand why students choose physics teacher education, and what can make them stay, it is important to understand how they navigate these discourses. In particular, in what ways can trainee teachers be understood as successful within the educational system, and what does this mean for trainee physics teachers' identities? If a dominating contemporary picture of trainee teachers is one of failure or incompetence, and if such ideas are allowed to define how physics teachers think of themselves, then this will affect both the physics teaching going on in secondary schools and who chooses to become a physics teacher.

Up until now, the Swedish discussions on how to improve the quality of, and recruitment to, teacher education have primarily concerned the educational science and school placement parts of teacher education. One example of this is the suggestions put forward in 2021 to ease the present regulations on the subject matter parts of the post-graduate teacher degree, whilst regulating both the educational science and school placement parts more tightly (Regeringskansliet, 2021). The attention paid to the specifics of what trainee teachers need in terms of subject matter courses thus seems to be low. I suggest that there is a need for an academic discussion of the role of physics content courses (as well as other subject matter courses), and how they interact with the other parts of teacher education. This PhD thesis forms part of that discussion in two ways. First, by investigating how teacher educators conceptualize physics courses as significant to teacher training. Second, by investigating how trainee teachers experience and negotiate their physics courses as connected to their future in teaching physics.

While the topic of becoming a teacher has been extensively explored in the literature, the specifics of the interaction between the system of physics teacher education and trainee physics teachers' identities are less well known. In particular, the role of physics courses in the system of teacher education and how they become significant in the identity negotiations of trainee physics teachers, has remained very sparsely researched. As I have argued above, this is important knowledge, as it will almost certainly inform the efforts to recruit more trainee physics teachers to teacher education and efforts to get them to stay. It is also important due to the special situation of trainee teachers, because they are moving towards a position where what they learn and how they see themselves in relation to the discipline has the power to affect a new generation of students. In physics, this is of particular significance due to the pronounced problems of underrepresentation of women and minorities, problems that have been shown to have their roots in the school physics classroom (Archer et al., 2020)

In this thesis, I take the perspective that learning to become a physics teacher is a process of becoming fluent in a number of new discourses, that is, learning to function within a number of locally, socially agreed systems of talking and acting. In physics teacher education, these systems need to be negotiated in the physics department, the education department, and school, and each of these environments has its own particular stance on what is considered important knowledge and good physics teaching.

The overarching aim of this thesis is to investigate what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher programme. I do this from two perspectives. In the first part of the project, from the perspective of the education that is offered to trainees, with a focus on the discourses that trainees need to negotiate to be recognized as legitimate physics teachers. Here, I analyze how educators talk about teacher education, asking which ways of being recognized as a professional physics teacher are made available by the discourses in the different parts of the programme. Second, in part two of the project, I investigate physics teacher education from the perspective of trainee physics teachers. Here I analyze how trainee physics teachers negotiate their experiences of learning physics in relation to the gendered discourses of the physics discipline.

The thesis aim engages in issues connected to several fields of research. First, due to its focus on the experiences of trainee teachers learning university physics, this thesis is situated in Physics Education Research. This line of research explores a "rich array of cognitive and social phenomena" (Beichner, 2009a, p. 3) related to the teaching and learning of (university level) physics. Methodologically, this thesis is situated within a qualitative strand of PER that uses identity frameworks to "explore how gender interacts with constructs like power, privilege, agency, discourse, positionality and inequity and how these are tied up in identity construction and trajectories into and out of physics." (Gonsalves & Danielsson, 2020a, p. 3) As is common in this strand of research, I draw on theory from gender studies, to allow for nuanced analysis of discourse and identity. With its focus on the system of physics teacher education, and on what it means to become a good physics teacher, this thesis also draws from the field of science teacher education, and research on teacher professional knowledge.

1.1 Research questions and publications

To investigate what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher programme, the thesis project consists of two parts. In the first part, I ask which ways of being recognized as a professional physics teacher are offered by the discourses of physics teacher education. The first three publications build on interviews with teacher educators and explore the system of teacher education through the discourses of these teacher educators. The research questions for publication I 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 recognized and valued within these discourse models?

In Publication II, I hold up a theoretical lens to the problem of becoming a physics teacher within the context of physics teacher education. This chapter explores physics lecturers' disciplinary learning goals (Airey, 2011b) for their students and discusses the contexts of physics teacher education from a Bernsteinian disciplinary knowledge structure perspective (Bernstein, 1999, 2000). As this publication is a theory-driven discussion of physics teacher education, it is not guided by an explicitly defined research question. However, in relation to my aim of exploring a Swedish physics teacher programme, a question could be formulated as follows:

> 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 III uses one part of the results of Publication I, the notion 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 question for this publication is:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

In the second part of the project, I investigate how trainee physics teachers navigate the discourses of physics teacher education, with a particular interest in trainee experiences of learning physics in relation to the gendered discourses of the physics discipline. Publications IV and V build on 17 interviews with trainee physics teachers. The research question for Publication IV is:

> How do upper-secondary trainee physics teachers experience the purpose and goals of their undergraduate physics learning, when studying physics together with other programme students?

In Publication V, I focus on the experiences of three trainee physics teachers and how they negotiate the discourses of physics teacher education, with a particular focus on gender. The research question is:

> How do female trainee physics teachers negotiate their positioning as women and physics experts to create spaces for themselves as learners of physics?

Together, the five publications thus provide a multifaceted view of what is involved in becoming a physics teacher in the system of physics teacher education, by combining the perspectives of educators and trainees.

1.2 Structure of the thesis

The thesis is divided into seven chapters that present and give a wider background to the findings of the five publications it builds on. In this Introduction, I have introduced the main empirical themes of importance and the aims of my thesis work. In Chapter 2 (Background: Teacher education in Sweden) I describe the Swedish system of physics teacher education that this case study is situated within. In Chapter 3 (Previous research) I give an overview of the fields of research that have informed my work and that I contribute to with my findings. In Chapter 4 (Theoretical framework) I introduce the theoretical foundations I have used, starting by placing my work within a discursive understanding of learning and identity, and describing the theoretical tools I have used for analysis. In Chapter 5 (Methods and methodology) I continue the discussion of what my theoretical stance means for data collection and analysis, and describe in detail what this means in practice for doing interviews and analysis. Chapter 6 (Findings) is a summary of the findings of each publication and finally in Chapter 7 (Discussion and looking forward) I discuss the findings, their implications for physics teacher education, my contributions to the field of Physics Education Research, and directions for future work.

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

The comprehensive summary of the thesis is written in such a way that it can be read as a standalone work from start to finish and is intended to make sense without needing to refer to the five publications it builds on. Because of this, and to keep the description consistent between the comprehensive summary and the publications, some sections are of necessity very similar to the corresponding 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 a more complete story of my research. The first part of the project, that builds on interviews with educators, has also been previously described in my licentiate thesis (Larsson, 2019). To allow for this comprehensive summary to fully describe my thesis research, those parts that describe the first three publications that were included in the licentiate, are similar to the corresponding sections in the licentiate comprehensive summary. The sections correspond to each other in the following ways: Chapter 1 (Introduction) and 2 (Background: Teacher education in Sweden) are fully new. In Chapter 3, Sections 3.1 (An overview of Physics Education Research) and 3.5 (Teacher professional identity) have been revised with mainly editorial changes for clarity and readability. Sections 3.2 (Physics teacher education in PER) and 3.3 (The organization of physics teacher education) consist mostly of newly written material, with some parts included from the licentiate literature review. Section 3.4 (Physics education and social justice) does not correspond to any section in the licentiate kappa. In Chapter 4 (Theoretical framework) the sections that describe the theoretical approach for the first part of the project (Sections 4.1, 4.3 and 4.4) are similar to corresponding sections in the licentiate kappa. Section 4.2 builds on the corresponding section in the licentiate kappa, but this text has been largely restructured and the new theoretical approaches used in the second part of the project have been added. In Chapter 5 (Methods and Methodology), the text that describes the first part of the project is mostly unaltered, but descriptions of project part two have been added to every section. In Chapter 6 (Findings) the descriptions of findings of the first part of the project are mostly unaltered, with an exception for publication three, where the description has been altered to correspond to the revisions to this paper in response to reviews after the licentiate thesis was finished. Finally, Chapter 7 (Discussion and looking forward) is mostly newly written for this comprehensive summary.

2 Background: Teacher education in Sweden

Physics teacher education is carried out in 18 institutions in Sweden, counting institutions that graduated at least one physics teacher 2017/18 and that have done so consistently over the last three years. In the period 2007-2017, on average 79 new physics teachers graduated each year (eligible to teach pupils from age 13). The interwoven physics teacher education programme in Sweden consists of 300 ECTS (ten semesters), alternating between educational science, school placement and subject matter studies. The standard (mandatory) combination of subjects is physics together with mathematics, and the usual study program consists of one year of educational science, one semester of full-time school placement and three and a half years of subject matter studies—normally two years of physics and one and a half years of mathematics.

At the institution where the student interviews for this thesis took place, the majority of the subject matter courses are studied together with the physics bachelor programme (physics majors, usually with an elective in mathematics). These courses are also attended by Master of Science in Engineering students. Thus, neither physics nor mathematics courses are specifically tailored to trainee teachers' needs, but this may vary between universities. At this institution, trainee teachers also take ten ECTS of what in Swedish is called "physics didactics" (fysikdidaktik) as part of their physics coursework. These courses focus on the specifics of teaching physics, utilizing the knowledge base of Physics Education Research. They are open for any physics student who is interested.

Trainee physics teachers can receive a bachelor degree in physics in addition to their teaching degree by choosing an appropriate degree project. After finishing their degree, bachelor students may also choose to become physics teachers by adding a postgraduate teaching degree of 90 ECTS, this is called the Bridging teacher programme. This entails two semesters of educational courses and one semester of school placement. In Sweden, this degree path contributes to 25% of upper secondary school teacher degrees (Universitetskanslersämbetet, 2018).

The students studying physics together thus consist of trainee physics teachers explicitly enrolled on a teacher programme (but who might choose to also earn a bachelor in physics), bachelor students who are planning to take the postgraduate teaching degree, bachelor students who are considering the postgraduate teaching degree, and bachelor students aiming towards research or other physics-related futures. See Figure 1 for a visual representation of the

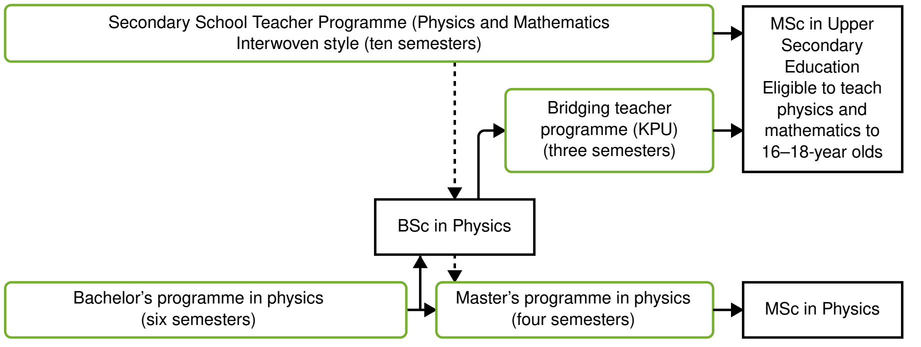

Figure 1. Degree pathway flowchart. Students on the Secondary School Teacher Programme can receive a Bachelor degree in physics by choosing an appropriate degree project. They may then continue on the Master's programme in physics (dotted arrows). Conversely, students who complete the bachelor program may choose to become physics teachers by adding a postgraduate teaching degree of three semesters (the bridging teacher programme). (Reproduced from Publication III under the CC BY 4.0 license.)

significant degree paths. The precise number of students studying each variation of the system is unclear. This is because when students move between the different programmes or leave the programme, this is not immediately documented in the system. When starting their studies, the two cohorts of students in focus in this thesis each consisted of approximately 10 teacher trainees, 40 physics bachelor students and 130 engineering students.

The Swedish teacher education programme was created in its current form in the 2011 Swedish teacher education reform (Regeringskansliet, 2008, 2009). 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 instead organized in separate programs for each age group, ranging from preschool to upper secondary school. This represents a return to an earlier model of teacher education that was implemented between 1988 and 2001 (Sjöberg, 2019). This history 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 where 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.

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 school placement 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 a personal appropriateness test, assessing for example character and mental health. Today, passing the school placement 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 school placement. 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 or rigidity, and the inability to change their behaviour according to their mentor's suggestions. (Nordänger & Lindqvist, 2015)

Historically Swedish teacher education has been organized into separate teacher training colleges as opposed to academic institutions. This 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 and 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) The dynamics of how these two discourses play out in teacher education is sometimes called the theory practice gap (Korthagen, 2007). This will be further discussed in Section 3.3 (The organization on physics teacher education.)

3 Previous research

The purpose of this chapter is to situate the thesis in relation to several fields of research as well as to describe the literature that my work is written in dialogue with. My thesis work is situated in Physics Education Research (PER), a strand of research that investigates the teaching and learning of university level physics with a “deep grounding in the discipline’s priorities, worldview, knowledge, and practices” (National Research Council, 2012). With a focus on physics teacher education, and on the interplay between the discourses of the educational system and individual trainee physics teachers performing gendered identities, my thesis also draws on the fields of science education, science teacher education, teacher professional identity, and gender studies.

The first section of this chapter (3.1) provides a short history and overview of Physics Education Research, describing some of the research about physics teaching and learning that informs the knowledge base of physics teachers. This section thus situates the work of this thesis within the wider field of PER. Section 3.2 (Physics teacher education in PER) describes the research that has been carried out within PER that focuses on physics teacher education. It is here that I identify a need for further research that explores issues of identity in physics teacher education. Section 3.3 (The organization of physics teacher education) further explores three specific issues pertaining to physics teacher education that have proved to be important in understanding and discussing my empirical results. These are: Physics content and the purpose of learning physics (3.3.1), The theory-practice gap in physics teacher education (3.3.2), and Relevance and motivation when learning physics (3.3.3). Section 3.4 (Physics and social justice) describes how issues of social justice have been approached within PER, with a special focus on gender and the use of identity perspectives. Here, I point out that while much is known about the interplay between identity and gender in physics, very little research has focused on how trainee physics teachers navigate these discourses, both as learners of physics and with respect to their future role to create inclusive physics classrooms (3.4.3). Finally, Section 3.5 (Teacher professional identity) provides an overview of how teacher identity has been approached outside of PER within the fields of teacher education and science education. I conclude that while teacher identity is a well-researched subject, studies have tended to focus on teacher professional knowledge. There is thus a lack of studies that have offered a social critical perspective on the construction of physics teacher identities.

3.1 An overview of Physics Education Research

In order to situate my work within the wider field of Physics Education Research (PER), I will now present a brief overview of the development of the field. In many ways modern 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 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 the academic discipline with the closest connection to the "Space Race", reforms were first implemented there. Initially, the main issues of interest within PER were the difficulties students experienced when faced with learning particular areas of physics. Such difficulties were investigated by exploring conceptual understanding (Heron & Meltzer, 2005). Meanwhile, the societal need to increase the number of students entering 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—the overarching interest was in what works rather than why.

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 et al., 1996; McDermott & Shaffer, 2002) by the University of Washington PER group. These Tutorials proved to be effective and became widely implemented in university physics education in the USA. The development of such empirical, research-based materials to improve learning outcomes was the main thrust of PER for many years. Now an increased interest in understanding *why* students learnt physics in a particular way also began to develop. 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 et al., 1992) it became clear that many students still have poor conceptual understanding of Newtonian physics even 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 practically orientated and less concerned with theoretical descriptions. Moreover, since the researchers were practicing physicists, the methodologies 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 has developed a rich and effective range of learning interventions. 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 between 2011 and 2013 in the three key PER journals (American Journal of Physics, European Journal of Physics and Physical Review Physics Education Research), I identified the following themes: Conceptual understanding, Problem solving and expert-like thinking, Attitudes and beliefs about physics learning, Representations in physics, Assessment and concept inventories, and Development of educational initiatives. These themes, to a large extent, correspond to the topical areas reviewed by Docktor and Mestre (2014).[3] Docktor and Mestre, however, discuss "Representations" and "Expert-like thinking" in subsections under "Conceptual 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.

3.1.1 Conceptual understanding

In PER, "conceptual understanding" 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 et al., 2001), quantum mechanics (Sadaghiani & Pollock, 2015), physics equations (Airey et al., 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 realization that students have difficulties understanding basic concepts in physics, even when they have passed regular examinations. The terms "misconceptions", "naive conceptions" and "alternative conceptions" have been suggested to describe student conceptual understanding and are often used to refer to the understandings that students constructed from their everyday life experiences, typically before they entered

[3] Here "curriculum and instruction" correspond to the theme of development of educational initiatives.

physics classrooms (Docktor & Mestre, 2014). This kind of characterization has been criticized 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 3.1.3 (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 et al., 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 understanding of measurement uncertainty could be achieved by explicitly addressing the conceptual aspects directly rather than only through the practice of application which is largely formula driven. In general, the theoretical foundation of the research on conceptual understanding has to a large degree been loosely grounded in cognitive psychology, and this influence began to shift the research focus onto individual students (see McDermott & Redish, 1999). At the same time, 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 teacher-reflected epistemology and conceptual challenges (e.g. Linder, 1992), epistemic games i.e. how students access the knowledge they have in the context of solving a particular problem (e.g. Tuminaro & Redish, 2007), the epistemological reasoning of students and understanding of physics concepts (e.g., Ding, 2014), and the connection between response time and understanding (e.g. Miller et al., 2014). 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 using this perspective see Harlow et al., 2013). This perspective is grounded in the theoretical view that all knowledge is constructed through the collection of a large number of small contextual parts that are referred to as phenomenological primitives shortened to "p-prims" (diSessa, 1988, 1993).

3.1.2 Problem solving and expert-like thinking

In the area of student problem solving, "novice" approaches to problem solving have been compared with those 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 focused more on surface features. A lot of research followed in the footsteps of this paper (Savelsbergh et al., 2011), both in PER and in other fields, even though the original findings have been hard to replicate (Wolf et al., 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 instructional goals were proposed for ways to encourage and support students learning to think and act like physicists.

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 et al., 2017). Typical questions here centre around how the use of different representations affects student learning and student approaches to problem solving.

3.1.3 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) affects how students learn in the classroom (Marton & Säljö, 1976; Mason & Singh, 2016; Prosser & Millar, 1989; Trigwell et al., 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", that is "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". 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)

Student attitudes are often compared to physicists' attitudes to physics, science, and knowledge (Hammer, 1994; Redish et al., 1998). In a study of expert-like epistemology and the impact of student epistemology on learning in physics (Bing & Redish, 2012) it was 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 et al., 2014). In other work, McCaskey (2009) compares and discusses different ways of measuring student epistemology.

3.1.4 Representations in physics

A relatively new direction in PER explores 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). 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 used by 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 et al., 1987; Volkwyn et al., 2020), 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 et al., 2017; Roth, 2001; Scherr, 2008), Diagrams (e.g. Heckler, 2010; Rosengrant et al., 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, that is how teachers can increase the pedagogical affordance of a representation. Airey and Eriksson (2019) suggest that 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 et al., 1997; Rosengrant et al., 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 emphasized 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 et al., 2018, 2019).

The use of Social Semiotics (Jewitt et al., 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, 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 give 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 construct disciplinary 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 (Samuelsson et al., 2019).

3.1.5 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: 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 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 physics teaching community because they revealed how challenging these concepts were for students 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. 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 et al., 2014). For a list of published concept inventories and validation studies see (Docktor & Mestre, 2014, p. 24).

Besides of 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 analyzed 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).

3.1.6 Development of educational initiatives

The realization that many students leave introductory physics courses with the same (or even less!) conceptual understanding of physics than before (Beichner, 2009b), has 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 classes 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. This approach has also been used in 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. See also Section 3.2.1.
- **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 et al., 2010). See also Section 3.2.1.
- **Scale-Up.** An interactive learning environment for introductory college courses in physics, chemistry, and biology. There is no separate lab work, rather labs and lectures are integrated. Interaction between small groups of students is 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 et al., 2010; Chabay & Sherwood, 2015).
- **PhET.** A collection of open-ended game like simulations to be used in the learning of physics, chemistry, mathematics, biology and earth science. (Wieman et al., 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) Students are encouraged to form testable explanations of phenomena based on their observations and using their own language, before the scientific description is introduced. This classroom practice has great empowering potential, since the responsibility to judge the value of ideas is given to the students. Ideas about physics as a passive collection of facts are negated and the burden on students to have "correct ideas straightaway" is reduced (Etkina et al., 2019, pp. 6–3).
- **The use of technology in teaching and learning**. Some elements of this direction have been around for a long time (like open-source tutorials), and some focus on how to make use of new technological development (Martínez et al., 2011). See for example Euler & Gregorcic (2017) who discuss the role of the digital learning environment Algodoo in aiding students to move between the physical context and the formal mathematical context when solving problems, and (Gregorcic et al., 2018) about the use of interactive whiteboards in a high school physics classroom.

3.2 Physics teacher education in PER

Having provided an overview of the development of PER and described some major themes in contemporary PER, I now move on to describe work that has been carried out on physics teacher education within PER. Section 3.2.1 gives an overview of how PER has approached physics teacher education and describes some of the well-functioning teacher education programs that have been developed based on the results of PER, Section 3.2.2 discusses physics teacher professional knowledge and finally, Section 3.2.3 discusses the role of physics departments in preparing physics teachers.

3.2.1 The physics learning of trainee physics teachers

The dissemination of knowledge about teaching and learning physics to the wider field of physicists, was an early and important focus in Physics Education Research. The strategy was to demonstrate to the individual physics teacher the values of using new methods in their own classrooms. For the K12 level, (corresponding to ages 5 to 18 in the Swedish system), it was thought that creating reformed materials and offering summer courses to teachers would be enough to spread new 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 physics teachers have been made in the US context.

From the outset, PER was concerned with the particular needs and differences between different groups of learners. One theme here is trainee physics teachers learning of particular physics content (Aiello-Nicosia & Sperandeo-Mineo, 2000; Mäntylä, 2012; Mäntylä & Koponen, 2007; 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) and Ding and Zhang (2016) investigated pre-service teachers' epistemological approaches to knowledge production. Through interviews and a conceptual test, Kaltakci-Gurel et al. (2016) found several misconceptions in trainee physics teachers reasoning in geometrical optics. They concluded that for trainee teachers, such misconceptions are especially problematic, and called for conceptual concept teaching courses to be included in teacher education.

In the explorations described above, the focus primarily has been on what distinguishes trainee teachers when learning the same physics as other student groups, where the perspective of how this physics content is connected to physics teaching is left out. However, the knowledge base of PER has also been utilized in developing several successful programmes of physics teacher education.

Early on, the need for trainee teachers to learn physics through courses that are designed particularly for them was recognized at the University of Washington (McDermott, 1975, 1990). The physics teacher education program at the University of Washington refutes the belief of many physicists that "the effectiveness of a precollege teacher will be determined by the number and rigor of courses taken in the discipline" (McDermott, 1990, p. 736). Physics courses have been developed with the specific needs of pre-service and in-service teachers in mind, using Physics by Inquiry (McDermott et al., 1996). Physics by Inquiry is a laboratory-based curriculum. It was originally designed on the premise that trainee physics teachers have particular needs, both because they will teach the physics they learn and because they often have different academic backgrounds than other students (McDermott et al., 2000). Before teaching starts, the students' prior knowledge is tested and the results are used to guide instruction. Throughout the course, prospective teachers are taught physics in ways that they themselves will be expected to use in their own classrooms, with a focus on scientific reasoning and discovery. Knowledge about typical student difficulties is also used in teaching, both to facilitate trainees in overcoming these difficulties themselves, and to introduce them to these difficulties to prepare them for teaching (McDermott et al., 2006).

Another initiative focused on the recruitment and education of physics teachers is The Colorado Learning Assistant Program (Otero et al., 2010). It was developed in 2003 to improve the physics learning of all undergraduate students and to increase recruitment into physics teacher education (Otero et al., 2010). The program utilizes undergraduate physics students as Learning Assistants (LAs) to promote teaching based on educational research. In general, the LAs work to facilitate interaction between students, since the Learning Assistant Program is grounded in the importance of collaborative work. LAs do this through leading small group learning teams, and though facilitating groups discussions during large scale lectures where students "articulate, defend, discuss, and modify their ideas" (Otero, 2015, p. 109).

The learning assistant program uses methods such as Peer Instruction (Mazur, 1997), Context-rich problems (*PhysPort Methods and Materials*, 2021), and Tutorials in Introductory Physics (McDermott & Shaffer, 2002). It is based on a commitment that learning to teach science must involve practice as well as theory, and on recognizing that teaching physics is a challenging endeavour (Otero, 2015). LAs are required to take a course in Mathematics and Science Education that provides practical training in guiding collaborative learning, as well as completing theoretical reading assignments in educational research. Where the LA-model is implemented, physics majors are encouraged to see teaching physics as important knowledge, and trainee physics teachers are then recruited among these students.

Physics courses reformed using the Learning Assistant model show learning gains close to double the US average in introductory physics (Goertzen et al., 2011; Otero, 2015). Students who have served as LAs have been shown to outperform students who have not, in an upper-division electricity course (Otero, 2015). The LA program has also increased the number of graduated physics teachers, where around 12% of LAs enrol in a teacher preparation program (Otero, 2015). Teachers who have served as LAs are also more likely to use research-based teaching methods (Gray et al., 2016).

At the University of Texas, Close et al. (2016) investigated the transformation of the physics identity of LAs using a blended identity framework based on the "physics identity" framework (Hazari et al., 2010) as well as on the theory of communities of practice (Lave & Wenger, 1991). Working as an LA was shown to strengthen both "physics student identity" and "instructor identity", resulting in an overall strengthened "physics identity" (Close et al., 2016).

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 seen as the entrance to learning physics. It offers courses in physics pedagogy, interdisciplinary science, and contemporary physics (Hestenes et al., 2011).

3.2.2 Physics teacher professional knowledge

One strand of research concerned with the professional knowledge of teachers, uses the construct of Pedagogical Content Knowledge, PCK, 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 et al., 2015). In an extensive literature review, Park & Oliver (2008) argue that PCK simultaneously represents teachers' understanding and their enactment of this understanding. This means that PCK cannot only be passively received, but needs to be created by teachers through their own experiences. PCK in physics has mainly focused on trainee teachers learning of applications, metaphors, representations, common student difficulties and strategies for dealing with them, and is also used as a tool to measure the learning gains of pedagogical efforts (Hiller, 2013; Milner-Bolotin et al., 2016; Thompson et al., 2011).

In PER, the related concept Content Knowledge for Teaching (CKT) is preferred (Etkina et al., 2018; Loewenberg Ball et al., 2008). In the context of teaching mathematics, Loewenberg Ball et al (2008) suggest that teachers need specialized content knowledge that is not related to student understanding or teaching, but that is still unique to teachers. This Specialized Content Knowledge involves "an uncanny kind of unpacking of mathematics that is not needed—or even desirable—in settings other than teaching." The need for such specialized content knowledge has been demonstrated by for example

Seeley et al. (2019). With a majority of teaching now moving online, the significance of trainees also learning Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2006) is increasing.

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 for how to implement what they have learned in practice. In addition to gaining practical experience of high school physics classrooms, trainees also take an active role in teaching parts of a university physics course using the ISLE method (Etkina, 2010). 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 et al., 2017).

PCK, CKT and other conceptualizations about teacher knowledge put forward different ideas about what physics teachers need to be taught (Etkina et al., 2018; Milner-Bolotin et al., 2016). While this literature contributes greatly to our understanding of the process of learning to teach physics, it does tend to presuppose views about the purpose and meaning of physics and how this connects to the school curriculum. Too little is known about how these views affect trainee teachers, and what the interplay between the culture of physics departments and teacher education might mean for students. A further exploration of the significance of the norms and culture of physics for teacher education is needed.

3.2.3 The role of physics departments in teacher education

International studies identify large variations in how physics teacher education is organized, both across and within countries (Evagorou et al., 2015; T-TEP, 2012; Vollmer, 2003). However, two basic models can be distinguished. In the first, physics content, didactics, pedagogy, and school placement is interwoven into a single teacher degree, given by either a specialized institution or a university. In the other, an initial physics degree (or equivalent) is followed by a postgraduate teaching degree containing pedagogy, didactics, and school placement. For information about the specific ways this is implemented in Sweden, see Figure 1 in Chapter 2. In some cases, the postgraduate teaching degree is studied at a university, in others the training takes place more or less entirely in school (as in the "teach first" initiatives common in England and increasingly in Sweden (Teach for Sweden, 2020)). In Europe, trainee teachers are to a large extent taught physics within physics departments by physicists and physics education professionals (Evagorou et al., 2015; Mäntylä, 2011; Vollmer, 2003). In Sweden, as well as in Germany, trainee physics teachers on the interwoven programme generally study physics courses that have been designed for the bachelor of physics programme together with other physics students (Massolt & Borowski, 2020). This arrangement can also be found in Finnish mathematics teacher education (where 20% of the trainees also take physics) (Koponen et al., 2016). In many cases, trainee physics teachers who study the postgraduate teaching degree have learnt physics as part of a degree unrelated to teaching.

It is common for trainee physics teachers to learn physics from physicists together with potential future researchers and engineers. This model of physics teacher education has been identified as problematic in several ways (Fraser et al., 2014; Mäntylä, 2011; McDermott et al., 2000; Nachtigall, 1990). One concern is that trainees are not taught how to transform undergraduate physics content to a level that is relevant for use in schools (Fraser et al., 2014). Another concern is that physics faculty may not necessarily use teaching methods that have been shown to be effective—typically, the traditional lecturing teaching style of university professors does not provide a good model for teaching physics for schools (Mäntylä, 2011; Nachtigall, 1990).

In addition to the practices of physics teaching that trainees encounter when learning university physics, another important aspect is the physics departments' attitudes towards teacher education. In an extensive review of well-functioning[4] US physics teacher programmes, the commitment of physics departments to physics teacher education was singled out as the most important factor for success (Scherr et al., 2017). It has further been suggested that departments should "present teaching as a valid career choice […] develop a welcoming and encouraging environment that shows respect for the scholarship and practice of teaching […] encourage their best students to consider teaching and […] promote teaching as an intellectually challenging endeavour" (T-TEP, 2012, p. 23). The ways in which physics departments approach physics teacher education, and especially the support and discussion of teaching as a valid career option, have also been identified as important factors in increasing the recruitment of trainee teachers (Marder et al., 2017). This is of concern since physics faculty have been shown to inadvertently undervalue the role and status of school physics teachers, framing teaching at pre-university level as a lesser choice than a career in a physics department or in industry (Scherr et al., 2015).

In summary, it is common for physics departments to play a significant role in physics teacher education, by providing physics courses in some form. This role has to some extent been discussed in terms of the suitability of the teaching practice of physicists as a role model for trainees. This is because it is unusual that newer ways of teaching physics that have been shown to be ef-

[4] The T-TEP report (2012) defines well-functioning teacher preparation programs as having continuous output of at least two physics teachers a year for at least five years. This definition highlights the very difficult situation for the training of physics teachers in the US, where the existence of an ongoing program is enough to be considered successful. See Chapter 2 (Background: Teacher education in Sweden) for the corresponding Swedish numbers.

fective are widely implemented in physics departments. There is also a discussion in the US context that connects physics departmental attitudes to teacher education with issues of status and problems in recruiting trainees. I have been unable to locate similar discussions in the Swedish context, and this is something I wish to address in this thesis. One question is the extent to which physics faculty present teaching as a valid career option in Sweden. This is important since a major channel of recruitment to physics teaching is through students already enrolled in technical education programmes[5]. The way this option is presented in physics departments has the potential to affect who sees teaching as something for them. Moreover, the way physics staff talk about physics teaching has the potential to affect the extent to which pre-service physics teachers on the interwoven program are motivated to learn physics. I discuss this further in Section 3.3.3 (Relevance and motivation when learning physics). I also aim to connect these themes to issues of equal participation in physics, considering how trainee teachers' experiences of learning physics in a physics department prepares them to teach physics in an inclusive way. I discuss this further in Section 3.4 (Physics and social justice).

As argued above, one significant direction in PER that is focussed on teacher education (described in Section 3.2.1) examines how to spread the outcomes of Physics Education Research to teachers, both at the pre-service and in-service stages. Another focus, that has been discussed in the current section, is to evaluate and document the success of such efforts, and of several well-functioning programs for pre-service teacher education. However, there are few qualitative exploratory studies on the process of becoming a physics teacher using perspectives of identity as constructed in social interaction. Such exploratory studies do however exist in PER in other areas of physics learning, as well as in the fields of science education and teacher education. Such work, is further discussed in Sections 3.4 (Physics education and social justice) and 3.5 (Teacher professional identity).

3.3 The organization of physics teacher education

The following sections explore issues pertaining to physics teacher education that have come to be important in understanding and discussing my empirical results.

3.3.1 Physics content and the purpose of learning physics

Teacher education is an inherently political arena, affected by both national political agendas, a number of academic disciplines, and public opinion. In

[5] See Chapter 2 for a further description of the relative importance of the different paths to becoming a physics teacher in Sweden.

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. To some extent, physics teachers can be expected to form their understanding of what physics is, and should be, during their university years (Aikenhead, 2011). Thus, school physics is transformed through different stages in practice.

In Sweden, school physics has been described as a static, simplified version of university physics, that has failed to adapt 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 the societal and equity aspects of physics. This growing emphasis on the role of physics in society in the Swedish curriculum for upper secondary school (Skolverket, 2011a) in many ways mirrors the curriculum trends in other European countries (Sundberg & Wahlström, 2012). The curriculum states that teaching in physics should give students in school the opportunity to develop their knowledge of physics, its history, how it is used to solve problems, its significance for both the individual and society, and the ability to use physics to communicate and evaluate information. (Skolverket, 2011a, p. 1) However, the introduction of new teaching practices in school to match these aims seems to be slow and limited (Engström & Carlhed, 2014). Similarly, it is reasonable to consider whether the process of adapting university physics content to new demands on physics teaching is also slow and difficult.

A range of ways of understanding the purpose of physics teacher education co-exist in the educational system, and each such purpose also casts a different light on the physics content that could potentially be included in the educational program. Recent work has indicated that stakeholders may not be clear in their views on what physics content is needed in good quality education. deWinter and Airey (2019) asked 324 stakeholders across England about the "key attributes of a 'good' secondary school (11–18) physics teacher" (p.4). Whilst physics content knowledge was high on this list of attributes, very few of the stakeholders actually specified the level or nature of the physics knowledge required. Frågåt, Hendriksen and Tellefsen (in press) asked first and final year trainee science teachers and in-service physics teachers in Norway what knowledge and skills are needed to be a good teacher. They found that all respondents emphasized physics content, and especially so the in-service teacher group, where most physics teachers had taken the post-graduate teacher degree. Further, trainee teachers described teaching in terms of the transference of knowledge, mirroring the teaching in many traditional university physics classrooms.

The ways of understanding the role of physics content in teacher education are closely connected to the understanding of the purpose of such educational programs in relation to the purpose of school science. 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 in school, each with a different purpose assigned to the learning of 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 within the scientific discipline. Learning how to apply this knowledge outside the scientific context is not considered, or may be taken for granted as an automatic consequence of learning science. School science teaching within Vision I then, can be said to imply students with futures in science (Ulriksen, 2009), and literacy within Vison I can be read as what is needed to make a future in science possible for all students.

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. Students should be able to apply their knowledge in everyday life or political contexts as citizens, and the skill to do this needs to be taught and practiced in school. 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).

Even though the visions of scientific literacy have been developed in the context of school science teaching, they can provide tools that can be used to discuss what content should be included in university physics teacher education. If trainees are preparing to teach physics within Vision I, the things they need to learn are quite different compared to if they are learning to teach to the wider purposes also included in Vision II. Only a handful of students in school will become physicists and explicitly need Vision I physics, while all students are citizens and can be assumed to need Vision II physics. However, if choosing further study of physics is to be equally open to all students, the distinction between these different needs should not be made too early, or perhaps at all. In any case, the connection between university physics courses included in teacher education and the purpose of school physics specified in Swedish curricula, warrants further discussion.

In contrast to school physics, the aim of university physics is usually not understood to be general literacy towards society or even science in general, but rather specialized knowledge for a particular future. Physics courses are nevertheless studied by students aiming towards many different futures, ranging from research in physics, to physics teaching, and it is therefore relevant to consider how the purpose of physics knowledge is envisioned in this teaching. The importance of upper secondary school teachers' solid foundation in content knowledge is a recurring standpoint in political discourse, but the nature of this content, the form it is provided in and its connection to teaching has not been problematized (deWinter & Airey, 2019). In this thesis I discuss the purpose of physics content in teacher education and how this is talked about by both teacher educators and trainee teachers.

3.3.2 The theory-practice gap in physics teacher education

A perennial issue in the organization of physics teacher education is how the educational theory presented is perceived as relevant by trainee teachers. The claim that the pedagogical part of teacher education is too far removed from the reality of teaching due to its theoretical nature, and therefore not valued by trainees, has now been well-established (Allen, 2009). McGarr et al (2017) explored how educational theory is discursively positioned as intrinsically or extrinsically relevant by trainee teachers. They suggest the perceived relevance of teacher education pedagogical content can be understood through a social power perspective. Student acceptance of educational theory might in this perspective be based on accepting the authority of the teacher educator rather than directly experiencing relevance. There is thus a difference between acceptance of theory (talking positively about it) and internalization (applying it to one's own practice). Another perspective on the theory-practice gap is provided by Björck and Johansson (2019), who argue for a non-dualistic understanding of theory and practice as inseparable in learning. They suggest that a disconnect between theory and practice is created by the design of teacher education as divided between campus-based learning (theory) and work placement (practice). A non-dualistic understanding of theory and practice can be supported by creating "third spaces" in between university and school, where students can experience how theory is part of, and created through, practice.

There is also some indication that difficulties in trainees not perceiving educational theory as relevant are especially pronounced within science teacher education (Guilfoyle et al., 2020; Molander & Hamza, 2018; Sjølie, 2014). Sjølie (2014) found that secondary pre-service teachers with a subject specialization within science were more negative towards educational theory than trainees with a language specialization. Similarly, 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, trainees still experienced educational science as too disconnected from practice. In a recent study in the Irish context, Guilfoyle et al (2020) explored how trainee teachers view knowledge in science compared with knowledge in education. They found that trainees’ epistemic beliefs are significant in how they value educational theory. These results can perhaps be read as suggesting that it is the familiarity with the practice and knowledge system of science, rather than distance to practice, that leads trainee science teachers to reject educational theory.

To facilitate crafting an education that matters to teachers, both pre- and in-service, it is important to understand the reasons for trainees rejecting or valuing the content of physics teacher education. A disconnect between the different contexts of teacher education is suggested by the literature, where the distance between educational theory and school practice as well as the distance between the disciplines of science and education seem to affect student motivation to learn. How can we understand this latter difference and its effect on trainee physics teachers? In Section 4.4 (Developing disciplinary literacy) I suggest that it may be fruitful to adopt a Bernsteinian perspective, using the concept of knowledge structures (Bernstein, 1999, 2000) to discuss the differences between physics and education.

Another interesting issue is why the gap between science content courses and teaching practice seems to be discussed less than the theory-practice gap. This might be read as an indication that trainee science teachers tend to accept the science content of their education as valuable to their future teaching practice. It can however be argued that physics knowledge, especially when learnt as part of physics courses that primarily aim towards providing the prerequisites for more advanced physics courses, is even further removed from teaching reality than educational theory. In this respect, my work explores how trainee physics teachers experience their physics courses as relevant to their teaching future.

3.3.3 Relevance and motivation when learning physics

The experiences of non-physics majors when learning physics have been thoroughly examined in the literature[6]. One key finding in this work is the significance of perceived relevance. Students who experience relevance in their physics courses have been found to have better learning outcomes and motivation (Afjar et al., 2020; Bennett et al., 2016; Descamps et al., 2020; Gaffney, 2013; Geller et al., 2018; Nair & Sawtelle, 2019; Plomer et al., 2010). For

[6] Since trainee physics teachers in Sweden can receive a Bachelor’s degree in physics, they cannot technically be considered non-physics majors. However, the literature on the experience of such students is still relevant for this thesis, as it investigates learning physics as part of a path that is not aiming towards research in physics.

example, Plomer et al. (2010) showed that adapting physics laboratory work specifically to the needs of medical students resulted in higher test scores, both in the adapted content and on "pure physics questions". Furthermore, the students' motivation and their enjoyment of the course increased. For non-science majors, finding physics content relevant to their future career has been shown to be a strong predictor of motivation to learn. "Student aspirations are one of the most significant indicators of academic achievement (Oyserman et al., 2006), and this highlights the importance of encouraging future-oriented thinking and the exploration of future identities or selves." (Bennett et al., 2016, p. 2). Investigating engagement in physics for life-science majors, Geller et al. (2018) found that students reported high engagement when the physics content was connected to personal experiences or could give an alternative perspective on problems studied in other courses in their program. Similarly, programme affiliation and perceived relevance of course content has also been connected to performance differences when several program groups take the same physics course (Andersson & Johansson, 2016).

A quantitative study of 329 Finnish physics students' aspirations and motivations found that self-efficacy and positive intrinsic motivation (that is, studying physics for its own sake rather than as a means to an end) predicted the students' aspirations for continuing with physics (Barthelemy & Knaub, 2020). These factors were also found to have lower values for the female respondents. All this work highlights the importance of perceived relevance of physics studies for student performance.

Some research has been carried out into trainee teachers experience of relevance of their physics courses (Gaffney, 2013; Körhasan, 2015). Körhasan (2015) investigated trainee teachers' motivation in learning quantum theory, using Expectancy-Value theory. While some students identified quantum theory as important for their future in physics teaching, this was not the most significant factor in student motivation. Elements found to affect motivation to learn quantum theory were the instructor, previous performance in the quantum physics course, and the nature of quantum mechanics content. Gaffney (2013) investigated student expectations and affect in an Astronomy for Teachers course given by the University of Kentucky. Not meeting student expectations was found to result in negative assessment of the course. "This study suggests that such negative affect arises within the classroom when students are unsure of the role of the course within their professional development" (p. 13) The author points out the need for science teachers to have positive experiences of learning science, and thus the importance of avoiding negative affect with respect to physics.

In their qualitative case study of life-science majors' experiences of learning physics, Nair and Sawtelle (2019) challenge what they call "deficit interpretations" of students' ability to see physics as relevant. They argue that the use of large-scale surveys such as CLASS or MPEX (Adams et al., 2006; Redish et al., 1998) to measure student beliefs about relevance, risks framing such beliefs as a cognitive property of the students themselves. In such studies, experiencing a lack of relevance is thus interpreted as a failure on the part of the students, rather than a failure of their physics courses to demonstrate such relevance. Nair and Sawtelle suggest using Ecological Systems Theory, to highlight the importance of the interplay between the physics classroom and student disciplinary experiences, as a way to create connections relevant to the students. "This approach enables us to build a construct of relevance that goes beyond treating a student's sense of relevance as contained within the student, it allows us to ask questions about the intersection of the many experiences in a student's life that have contributed to their view of the relevance of physics." (p.3). This line of thinking, if applied to trainee physics teachers, highlights the question of how physics courses are both made relevant to trainee teachers and whether they prepare trainees for making physics relevant to their future students.

3.4 Physics education and social justice

Physics is one of the sciences with the most pronounced challenges regarding underrepresentation (American Physical Society, 2018; OECD Publishing, 2017b, 2017a; Universitetskanslersämbetet, 2016). This has spurred an interest in issues related to social justice and equal participation in physics. For example, the American Physical Society work within a "mission of empowering and supporting physics departments, laboratories, and other organizations to identify and enact strategies for improving equity, diversity, and inclusion" (*APS Inclusion, Diversity, and Equity Alliance*, 2021). By social justice, I refer not only to overcoming the current inequalities in participation in physics, but also to the role of physics in fostering a just society, even though the focus of most research discussed in this section refers to the former. This field is significant to my thesis work in two ways. First because it describes the context of higher education physics that trainee teachers participate in as part of physics teacher education. Second, because it identifies and explores unequal structures of the physics discipline that school physics teachers have to negotiate and hopefully, work to change in their classrooms. In this section, I give a limited overview of research on issues of social justice in physics. For an extensive overview and resources pertaining to these issues, particularly focused on gender, see Blue et al. (2019).

In Physics Education Research, questions concerning equal participation in physics have traditionally been concerned with the "gender gap", i.e., that men typically numerically dominate physics programmes and often perform slightly better than women in standardized measurements. One way of interpreting this research area within PER is that questions of unequal participation in physics in the Western world have generally been approached within a so-called “deficit model” (Traxler et al., 2016) or a “gender as a variable” approach (Harding, 1986, p. 33). In its simplest terms, this means that the problem is formulated in terms of why underrepresented groups fail to be more like the “standard” successful white male physics student. Here gender is seen “as a property of individuals and their behaviours rather than also of social structures and conceptual systems.” (Harding, 1986, p. 34) This type of formulation means that the problem of unequal participation in physics becomes a function of something that women and minorities lack, or something problematic they possess. It is perhaps not surprising then, that solutions to these perceived problems in many cases consist of trying to attract women to physics, without considering the properties of the system these women are expected to participate in (Vidor et al., 2020). This approach risks reinforcing the existing bias against women and minorities in physics as it conditions participation in physics on adapting to existing structures (Gosling & Gonsalves, 2020; Traxler et al., 2016).

To avoid reproducing stereotypical thinking, it has been suggested that Physics Education Research should encourage and legitimize more studies 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, 2018b, 2016; Traxler et al., 2016; see also Hussénius et al., 2013 for a similar argument in science education).

3.4.1 Physics and gender

The issue of physics and gender has been approached both from within Physics Education Research and from other disciplines, corresponding to the need to understand these complex issues both from the inside through research that is close to the physics discipline, and with an outside perspective, utilizing tools developed within other disciplines (Johansson, 2018b).

A large amount of research has documented and problematized the gender gap, for example showing consistent differences between women’s and men’s performances on concept inventories (Madsen et al., 2013; Scherr, 2016). A significant strand of this research has focused on the quantitative construct of “physics identity” (Hazari et al., 2010). This construct is based on the model of “science identity” (Carlone & Johnson, 2007) and measures performance, recognition by others, competence, and interest, in questionnaire data. Physics identity has been shown to significantly affect student career choices (Hazari et al., 2010) as well as to correlate with motivational factors and gender (Kalender et al., 2019, 2020). In a survey of 500 introductory level physics students, Kalender et al. (2019) found significant gender differences in physics identity, meaning that women identified less with physics, and to a lower degree answered that others recognized them as a physics person. The authors conclude that gender differences in calculus-based physics classrooms impact student motivation and hypothesize that this might affect career decisions.

Large scale surveys have also been used to test common hypotheses about what might encourage female students to consider careers in science. Here, 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. They found that only one factor—discussing the underrepresentation of women in physics class—had a significant positive effect.

As discussed above, quantitative research on gender in physics has investigated the "gender-gap" as it relates to "physics identity" and motivation. Another quantitative approach to gender differences in physics is to measure gender bias. One interesting example is the study by Potvin and Hazari (2016) where gender bias was found in how physics college students rate their secondary school physics professors. 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 here is whether physics newcomers adapt to already existing gender biased discourses in the physics environment.

Andersson and Johansson (2016) problematize the traditional way of understanding gendered achievement gaps in the context of 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*. These learning approaches could be connected to how significant students perceived the course to be in relation to their program affiliation. The apparent gender gap that motivated the study, could through further analysis be re-framed as a program gap. Here programs "further from the discipline of 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 social practices have only relatively recently begun in PER (Danielsson, 2009; Johansson, 2016; Traxler et al., 2016), this is not a new research theme in science education and science studies. For example, Latour and Woolgar (1979) adopted an anthropological approach to science and the production of scientific facts in complex social networks. The specific perspective of gender and physics has been studied both from the more theoretical perspectives of philosophy of science (Barad, 2007; Harding, 1991; Rolin, 1999) and from empirical perspectives (Hasse, 2002, 2015; Traweek, 1988). From both of these perspectives, the tension between the epistemological values of the physics discipline as universal and objective (Schiebinger, 1999) and its cultural features, has been pointed out. Harding (1991) discusses how ideas around objectivity and rationality in the discipline of physics make its cultural features difficult to discern for physicists.

The empirical study of physics and gender has been influenced greatly by the seminal anthropological work of Traweek (1988) who studied the high energy physics community. In her book, Traweek described the culture of particle physics as one with a mythology of heroes and geniuses and showed how physics students are expected to attempt to walk the one legitimate path towards becoming a "timeless genius". She showed how traits and norms associated with masculinity are ever present in the culture of physics, while physics is considered removed from the concerns of people and therefore non-variant across cultural contexts. This discussion of physics as a "culture of no culture", a characteristic that works to hide the actual cultural features of physics under a supposed objective neutrality, has been taken up by many later studies (see for example Gonsalves et al., 2016).

One re-appearing dividing line in discussions on gender and physics is if questions of gender only pertain to the people involved in physics, or whether gender can be understood to also affect the production of physics knowledge (Bug, 2003). For example, Rolin (1999), discusses whether gender ideologies can be shown to have influenced physics knowledge. She concludes that "gender ideologies can influence what questions scientists consider significant, what sorts of explanations they seek, or what sorts of problems they consider urgent to solve" (p. 221) but that empirical evidence of this being the case does not have to be indication of "bad science". Empirically, this question was approached by Hasse (2015) who suggests that the examples chosen to motivate certain topics in physics education also promote certain ideas about what future directions physics should be striving for. Hasse observed how physics content in an undergraduate physics program was connected to science fiction stories about colonizing Mars, which functioned as a source of motivation and enthusiasm for predominantly male lecturers and students. In this case, the science fiction fantasies that motivated some students also promoted certain ideas about the purpose of physics. Hasse argues that such science fiction fantasies, if "allowed to permeate science and education in subtle ways, may in practice exclude many women from participating actively in the creation of tomorrow's worlds." (p. 936)

Together, the large amount of quantitative research that documents gendered differences in physics, as well as the perspectives brought from feminist science studies, highlight the importance of further understanding the interaction between the physics discipline, the people it is made up of, and the knowledge that is produced as a result. Empirically these questions have been approached in terms of identity, and in the next Section (3.7.2 Gendered physics identities) I provide an overview of the empirical findings of such research.

3.4.2 Gendered physics identities

One strand of research that is rapidly becoming more significant in PER investigates how “gender interacts with constructs like power, privilege, agency, discourse, positionality and inequity and how these are tied up in identity construction and trajectories into and out of physics.”(Gonsalves & Danielsson, 2020a, p. 3) This emerging work uses sociocultural frameworks and a performative view on gender to challenge taken-for-granted assumptions on who belongs in physics (Gonsalves & Danielsson, 2020b). In this section, some of this work is summarized, with a special interest in how physics students have been found to negotiate notions of femininity in relation to the physics discipline.

One early example of this research theme is the longitudinal study of women of colour in physics where Ong (2005) showed how the embodied intersections of race and gender of women of colour is at odds with the norm of the white male physicist. Some women engaged strategies of “racial or gendered passing”. To pass as “ordinary” and thus be taken seriously, some women deliberately moderated both their dress and their behaviour to appear less feminine than they would otherwise prefer. Ong uses Dyer (1997) to suggest that in the context of science, passing as “ordinary” rather than minority, can be essential to assume a position as an objective knowledge producer: “minorities often are considered to speak and act as representatives of their respective groups, while whites effectively speak as individuals. Consequently, particularly in the context of science, the successful achievement of being white allows the performer—especially a male performer—to speak from positions of neutrality, objectivity, and authority” (Ong, 2005, p. 599)

One woman in Ong’s study managed to employ a strategy of multiplicity, strategically using the stereotype of the “loud black woman” to resist compliance with the white, male physicist norm. This strategy made her highly visible and intelligible, as it allowed her opportunities to successfully talk about physics with professors and other students, without disturbing the existing order. This strategy could be read as harmful, since it perpetuates a negative stereotype about black women. However, by simultaneously assuming the position of loud black woman and successful physicist, this woman can be read as distorting discourses of who the “ordinary” producer of knowledge in physics is.

In the study by Ong, the women of colour negotiated positions in physics through alignment in two ways. First, though aligning with masculine expectations on physicist dress and behaviour, and second though aligning with (and thus not challenging) stereotypical expectations on coloured women. This pattern of dual alignment in women’s identity work is also identified by Danielsson (2009, 2012). This study shows how female physics students in complex ways negotiate masculine norms associated with technical skill as well as stereotypical expectations on female physics students to be well-prepared, organized, and diligent. Several of the female participants negotiated their position as female physics students by rejecting stereotypical femininity, and by "drawing on a discontinuity between traditional femininity and physics they are able to position themselves as non-participating in one and participating in the other" (Danielsson, 2012, p. 36). The strategy of women gaining recognition in physics by passing as "one of the boys" is well documented (Tsai, 2004; Walker, 2001). Further, several of the women managed to negotiate stereotypical and negative expectations on female physics students by combining them with a high-status position of well-prepared, theoretically inclined and "analytical physics student" (p.37). By doing this, they could identify as successful in physics without breaking normative expectations. Female students thus have to negotiate masculine norms in physics where the possible ways of being successfully recognized as both woman and physicist are constrained. (Due, 2012; Gonsalves et al., 2016)

While strategies of dual alignment with gendered expectations make women recognizable in physics, such alignment also limits the ways in which women are recognized as competent. In an ethnographic study of an experimental plasma physics lab in the US, Pettersson (2011) found that competence in experimental work was defined as physical strength, hard labour, and willingness to get your hands dirty. Physicists associated this work strongly with masculinity. The premises for participation in this practice differed for women and men, where a female physicist's success in physics were explained by stressing characteristics such as her communication skills (Gonsalves et al., 2016). Pettersson suggests that the emphasis on physical labour in this context functions as gendered "boundary work" by defining "real physics" as different from other more theoretical strands of physics often associated with higher status.

Another theme in research on identity and gender is how gendered discourses of physics are produced together with notions of the physics discipline as neutral and objective. In the context of a Canadian physics department, Gonsalves (2014a) empirically investigated the tension between discourses of the physics discipline as gender neutral, its association with masculinity, and the various ways that women PhD students found recognition in physics. Recognition was dependent on either re-working, or reproducing, gendered norms, in relation to the image of the stereotypical physicist. This image was found to be associated with masculinity as well as with "geekiness", involving lack of attention to appearance, and awkward social behaviour. While stereotypical femininity, like wearing high heels or a dress, was recognized by the participants as problematic in physics, they also described their working environment as gender neutral or androgynous, telling the story that "gender is not a problem" in physics (p. 17). Gonsalves thus shows how in this context, physics is produced as gender neutral in a way that reproduces its gendered connotations as opposed to femininity.

In a comment to this paper, Danielsson and Lundin (2014) use Halberstam (1998, p. 234) to note how white male masculinity "rests on a stable notion of realness" while femininity "reeks of the artificial". This opens for understanding discourses of physics as simultaneously gender neutral and masculine, because the "non-performativity of male masculinity makes it conflated with the performance of gender-neutrality." (Danielsson & Lundin, 2014, p. 3) Certain masculinities are thus easily combined with gender neutral discourses (see also Ottemo et al., 2021). However, the more traditional femininity that some participants in Gonsalves's work desired to express is "recognized as a performance of gender and as such difficult to combine with the Discourse of gender-neutrality" (Danielsson & Lundin, 2014, p. 3). These discussions reconnect to the notion of the culture of physics as neutral (unmarked) by the people it is made up of (Traweek, 1988).

All three case studies of women negotiating physics identities in Sweden, Canada and the US described above, document how masculine notions of competence are associated with physics. Though an in-depth re-examination of these case studies, Gonsalves, Danielsson and Pettersson (2016) conclude that although largely different, the three examined physics contexts are similar in that they could identify "various constructions of masculinities associated with the technical and analytical skills required to perform and be recognized as a competent physicist." (p.13) Similarly, Ottemo et al. (2021) found that recognition in physics and engineering education was strongly bound to disembodiment, and rejection of concerns for appearance. Such concerns were in turn positioned as feminine. Thus, caring about dress or looks undermined subject positions of competence, while certain forms of masculinity were perceived as aligned with the discipline's orientation towards rationality, and therefore could be performed with ease in these contexts. (Ottemo et al., 2021)

While most research on physics and gender has focused on the undergraduate or graduate level, one study looks into the experiences of women who have reached a successful professional position in physics research. Miller-Friedmann (2020) interviewed six successful women physicists in the UK and found that early experiences of learning to handle experiences of isolation by preferring to work alone, was one factor in their success. This is interesting in the light of the collaborative nature that is often highlighted as an important feature of the physics discipline (Sonnert, 1995). Negotiations around white, middle class masculinity in relation to working class background and femininity were also important components in the women's stories (Miller-Friedmann, 2020).

Finally, the focus of this thesis is on the production of physics teachers. To date, qualitative research on physics and gender have paid little attention to this particular physics-path. There is one study, of two researchers in astrophysics who both decided to leave astrophysics to become physics teachers (Gonsalves, 2018). Both of these women argued that gender was not a significant factor in their experiences of physics. However, Gonsalves shows how notions of gender neutrality, masculinity, and rejection of normative femininity worked as both affordances and constraints to these women's work to identify as physicists. Choosing physics teaching positioned them outside of physics research, yet made it possible to identify as physicists. Gonsalves suggests that identity trajectories such as these open up questions about how the experience of leaving university physics for school might shape physics teaching. Will these physics teachers reproduce the physics norms they encountered in their research, or will they recognize such norms as problematic and work towards breaking them?

The research discussed above shows some of the ways in which women in physics struggle to gain recognition. This is a problem that is especially pronounced for women of colour (Johnson et al., 2017). However, the situation can also be greatly improved through conscious efforts by physics faculty. Johnson (2020) adopted an intersectional perspective in investigating a physics institution where women of colour reported feeling comfortable and at home in physics. A number of properties of the physics learning environment that enabled this were identified. Combined, they promoted ideas about physics as collaborative, success in physics being the result of hard work rather than innate talent, and the idea that physicists can be wrong. This study empirically shows how problems of equality in physics are not a given, and can be changed through the intentional work of physics faculty. I will come back to this study in Section 3.4.3 (School physics and inclusive physics teaching).

The current section has described some of the research that takes an identity perspective on physics and gender and showed how discourses of physics as simultaneously masculine and neutral work to reproduce notions of physics as opposed to femininity. This results in complex negotiations around traditional femininity for women who strive for recognition in physics. Some strategies have been described, that can be summarized in terms of a dual alignment. First, women have been shown to align with ideals of the stereotypical physicist to pass as "one of the boys", displaying typically masculine dress and behaviour. (Danielsson, 2009; Gonsalves, 2014a; Ong, 2005) Second, women have been shown to align with gendered expectations, such as being well-prepared, analytical, and communicative (Danielsson, 2009; Gonsalves et al., 2016). These unequal and contradicting expectations of adaptation on the part of women are problematic, and the discipline would gain from a wider array of gendered expressions being seen as compatible with physics. Here, more research is needed, that does not pre-suppose femininity as problematic, but that takes up the direction suggested by Ong (2005) where women can be understood as, in constructive ways, actively using stereotypes to distort and renegotiate the physics discourse. There is a need to further explore how the doing of femininity intersects with science and physics in ways that open for femininity to both restrict and perhaps enable physics identities.

The studies above further point towards issues around who is considered legitimate as a producer of new knowledge in physics, since gendered lines are drawn between those "successful enough" to do research, and those who choose to use their physics interest in pursuit of other physics-related careers, such as teaching (Gonsalves, 2018). The choice to study physics to become a physics teacher is one that navigates the masculine/natural brilliance connotations of physics in relation to the teaching profession that is generally associated with lower status and femininity (Hjalmarsson & Löfdahl, 2014). Further research is needed to explore how these dynamics play out when trainee teachers engage with the physics discipline as part of becoming physics professionals. Here, the research described in this section functions as an empirical base, documenting the environment trainee physics teachers participate in when learning physics. The now well-established frameworks of identity as constructed in social interaction and gender as performative provide a good toolbox for doing so.

In the following section (School physics and inclusive physics teaching) I connect the gendered discourses of university physics with the school physics classroom, and with the role of physics teachers in reproducing or challenging such discourses. Then, in Section 3.5 (Teacher professional identity) an overview is provided of research that takes an identity perspective on teachers.

3.4.3 School physics and inclusive physics teaching

Research on how students in school see and identify with science and scientists in many ways mirrors what we know from research on university physics. For example, in a study of a Swedish upper secondary school physics classroom, Due (2012) found similar competing discourses of "physics being masculine" and "physics being understood as gender neutral" that have been reported from studies at both undergraduate, graduate and research level (Danielsson, 2012; Gonsalves, 2014a; Traweek, 1988). Berge and Danielsson (2020) identified three storylines constituting the physics community in an upper secondary physics classroom. These were "mastering physics", "appreciating physics" and "feeling physics". While "mastering physics" was a narrative that only some students participated in, the "appreciating physics" storyline was staged by the teachers with no response from the students. The authors suggest that this can be explained in terms of students simply not appreciating physics. Another possible explanation is that students do not feel the authority to, for example, judge an equation as beautiful, if they have not first mastered physics.

In school level science, girls who are "girly"— i.e. who perform "desirable hetero-femininity", have been shown to find a future in science "unthinkable" since science is neither "glamorous" nor "girly", but rather perceived as masculine (Archer et al., 2013). Being girly is thus difficult to combine with identifying with science (Carlone et al., 2015). Interest in science has further been shown to be associated with geekiness and social awkwardness (Mendick, 2005; Mendick & Francis, 2012). School students also connect science with positive characteristics like being really smart or keen, and while this discourse projects positive or desirable images of scientists, it still portrays scientists as different from normal people (DeWitt et al., 2013).

Girls who do identify with science have been found to employ several strategies to make this position intelligible. Some of these are constructing science as objective and gender neutral, and defining science as being about nurture and helping others (Godec, 2018). Archer et al. (2017) found that "most of the girls who aspired to continue with physics engaged in 'non-girly' performances of gender that aligned with a cultural arbitrary, which sees femininity as incompatible with authentic performances of physics identity" (p. 119). Female students showed that they belong in physics by positioning themselves as "exceptional". This meant being highly competitive, achieving high results in physics, preferring theoretical physics, and rejecting stereotypical femininity.

In summary, at school level, science and especially physics is often perceived as special in a way that "preserves its elite status and reputation as being only for certain types of people" (Gosling, 2020, p. 178). In a longitudinal interview study of 15 students aged 10-18, who studied Advanced level physics in England, such ideas were found to develop and grow stronger during secondary education (Archer et al., 2020). Especially the female students over time came to see physics as too difficult and as something only for the "effortlessly clever physicist", a notion that discouraged even highly interested and well-performing girls from continuing with higher level physics. The authors suggest that the change in students' ideas around physics was caused by secondary education in several ways. First, by "attainment-based practices of debarring and gatekeeping" that is, by entry requirements for physics being higher than for other subjects in the UK-system. Second, by a differentiation between school physics and "real" physics, created by physics classroom practice and syllabus, that keep even successful students from feeling they master the "real" subject. And finally, by both other students and teachers reinforcing the elite image of physics, making students "accept that physics is too hard for all but the natural, effortlessly clever, genius physicist" (Archer et al., 2020, p. 373).

It is of central importance that physics teachers in school build a classroom environment that both "values and includes non-dominant students" (Gosling & Gonsalves, 2020, p. 343) and that breaks the norm of a particular masculine cleverness needed in physics (Gosling, 2020). Here, it is important to make "alternative modes of participation" (Hyater-Adams et al., 2019) in physics visible. Inspiration can be taken from the inclusive environment in college level physics described by Johnson (2020, p. 77). Here, physics faculty emphasized physics as collaborative by teaching through group work, and following up on the group's social dynamics. They promoted many different careers in physics, and did not promote academic research as the most "real" physics job. Hard work was advocated before innate talent, and seeking consensus through discussions with peers emphasized. Finally, physics faculty protected students from racist or sexist microaggressions and male faculty were found to take responsibility for gender issues.

Physics teachers have been found to greatly influence female students' physics identities (Hazari et al., 2017). For science teachers to teach in a way that works to overcome the current inequalities in participation in physics, it is important that trainee science teachers are given the possibility to address their own bias and assumptions about science, science teaching and diversity, already during their education (Mensah, 2009; Moore, 2008). Here, further research on how the identity of trainee physics teachers is negotiated in relation to, and in interplay with, the physics discipline is needed. In the next section (3.5 Teacher professional identity) an overview of research that treats teacher learning and practice from an identity perspective is provided.

3.5 Teacher professional identity

In the previous sections I have presented the fields of Physics Education Research and Teacher Education, that this thesis is situated within. I have identified a need for further research that takes an identity perspective on the creation of physics teachers through the system of physics teacher education. While very little research that combines issues of gender, identity and physics exists, the concept of professional identity has been applied in a wider sense to teacher learning and professional knowledge. In the current section I give an overview of such research.

In the intersections between Physics Education Research, Science Education Research, Teacher Education Research and Gender Research that are addressed in this thesis, 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 seen as able to answer. In presenting an overview of teacher professional identity research, I have chosen to focus on what problems the identity concept is used to solve in the literature. As a start, I have drawn on four review papers about teacher identity. The particular theoretical perspective on professional identity taken in this thesis is presented in Section 4.2 (Theorizing identity).

In a recent review paper on trainee teachers' professional identity, Rodrigues and Mogarro (2019) point out how identity in the literature is used as both a theoretical lens to examine aspects of learning to teach, and as an empirical focus on something teachers have or use in their practice. This distinction is also present in the review by Avraamidou (2014), that both lists empirical properties of teacher identity and also asks "In what ways have researchers used the construct of teacher identity to examine science teacher learning and development?”. This latter question implies understanding identity as a theoretical tool that can be used to investigate teacher learning and development rather than being the object of investigation per se.

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, together with the review by Beauchamp and Thomas (2009) 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 all taken to point to different important features or facets 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.

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 et al., 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.

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 trainee teachers with a focus on their stories as statements about identity. They conclude that trainees’ professional identity is affected by their social relations with university teachers, fellow students, and supervisors, and by the quality of communication in the education. The importance of teacher educators for trainees' professional identity is also brought up as central in the review by Rodrigues and Mogarro (2019). 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.

In many cases, it is not possible to separate identity as an empirical phenomenon from identity as theoretical tool. 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 categorized as "teacher as subject specialist", "teacher as didactical expert" and "teacher as pedagogical expert". The 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. This implies 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.

In another study that connects teacher identity with subject matter, teachers in physics and chemistry were found to experience greater confidence as subject teachers when participating in a Science Additional Specialism Programme (Woolhouse & Cochrane, 2010). Interestingly, this new confidence was connected to identifying with a learner position and experiencing learning subject matter in a "safe space" that makes it possible to take risks and ask questions. This way of connecting teacher professional identity with subject matter learning seems to be rare, and Rodrigues and Mogarro (2019) identify this as an important area for further research.

Mensah (2008) investigated the positional identity of three secondary science teachers in terms of race, ethnicity, economic status, gender, religion, and age. The teachers all reported experiencing gender and racial oppression, both when learning and teaching science. Further, the teachers' positional identity was found to be significant in their teaching science. Yet, despite similar backgrounds the teachers' knowledge of science and teaching differed significantly. This study suggests that positional identity needs to be considered when considering increasing professional development opportunities.

The study by Stears mentioned earlier 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; Smith & Jang, 2011) and on how to help students teach with a Nature of Science approach (Akerson et al., 2014). Saka et al. (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. They found that the reformed-minded teacher identity developed in the trainee teachers' educational programme, interfered with the teacher's ability to take advantage of support systems and resources in school. While exploring teacher identity in school, this study among others (cf. Danielsson & Warwick, 2014a, 2014b; Olsen, 2008; Varelas et al., 2005) points out that to be prepared to handle identity conflicts when entering school, trainee teachers need to explicitly negotiate their teacher identity during their education. One way of encouraging such work is to use video analysis together with reflection (Schieble et al., 2015).

In the work on social justice, gender and culture in physics discussed in Section 3.7 (Physics and social justice), the construct of identity is used as a way of exploring questions of power and equal participation in science. One example that takes this approach in the context of teacher education is the study by Alderton (2020). Through class observations, reflective emails and one interview, Alderton followed one trainee mathematics teacher, Kelly, taking a postgraduate certificate in education. She found that Kelly struggled to be recognized as mathematical, both during the on-campus mathematics sessions, and in the classroom at her school placement. Kelly's former negative experiences as a learner of mathematics, as well as her performances of passive femininity, made it difficult to gain recognition as a competent mathematics teacher. The teacher education course content emphasized active ways of learning and teaching mathematics. However, Alderton suggests that although the course questioned traditional transmission-based mathematics teaching, it failed to challenge discourses that align mathematical ability with masculinity. In this study, as well as in the body of research on physics and gender, the identity construct is 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 physics (Rosa & Mensah, 2016). As argued above, this line of research has not yet been used to problematize physics teacher education, or physics teacher identity. There is a lack of studies that take a social critical perspective on the construction of physics teacher identities.

4 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, Physics Education Research 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. The current methodological diversity found in PER has also reinforced the need for agreement about which methods can be considered valid and what standards of evaluation are appropriate (Robertson et al., 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 issues of power into account.

Traditionally, cognitive 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, like 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. In this thesis I have argued for a need to simultaneously see both the context of physics teacher education and the experiences of individual students, keeping focus on the interplay between them. I do this using discourse analysis, which can be seen as theory and method in one. I will not clearly separate these two functions that I believe are inseparable, and because of this, a traditional division between theory, methodology and method is difficult to make. In this chapter, I describe the theoretical tools I use in a way that touches on methodology. In Chapter 5 (Methods and methodology) I pick up the thread where I leave it in this chapter, and expand on the practical implications of the theory described here.

In the following sections I describe the discourse analytical framework put forward by Gee (2005, 2011, 2014) and in particular Gee's notion of Discourse models. I connect a discourse theoretical framework to my way of approaching identity by using three concepts: Celebrated Identity Performances adapted from Archer et al. (2017), subjectification through simultaneous mastery of and submission to discourse (Butler, 1990) and the performance of femininities based on Shippers (2007). Finally, I describe the supporting theoretical constructs, the Culture Model of Schein (2010), the concept of disciplinary literacy (Airey, 2011a), and the categorization of Disciplinary Knowledge Structures according to Bernstein (1999, 2000).

4.1 Discourse and discourse analysis

4.1.1 Discourse

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 thesis I 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 4.2 (Theorizing identity).

Gee (2014, p. 8) argues for two ways of defining discourse. First, discourse can be thought of 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 at a particular point in time. In my work, the emphasis is on this latter understanding. 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 language works.

Gee draws on ideas from a range of influences and characterizes his approach as critical discourse analysis. By this Gee is suggesting that discourse analysis should always be critical since it is always political (Gee, 2014). By political Gee means that 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." In that same spirit I aim to use discourse analysis to provide understanding about physics teacher education and the trainee teachers who take these courses, that can be used to change the physics teacher education for the better.

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 work with a transcribed record of that conversation. This way of working tends to make the researcher focus on spoken language. During an interview however, more things than simply what is said carry meaning, and this wider Discourse should not be ignored by the researcher. The interviewer thus brings with them a layer of interpretation depending on things that are not captured in an audio recording. This is the case for the analysis for the first, fourth and fifth publications of this thesis, where I carried out all the interviews. Here, the analysis in part includes Discourse aspects, rather than just the words (and tone of voice) recorded. For Publication III some of the interviews were conducted by my supervisor John Airey, and 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 work I have taken a practical approach to discourse analysis. For Publication I the tools of Gee are used because they 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 tools that may be used to carry out discourse analysis. For Publication I, I chose 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 5.5 (Coding and analysis) I will go deeper into the way in which I employed discourse models as a tool when doing discourse analysis.

4.1.2 Discourse models

For Publication I, Gee's (2005) concept of discourse models works as a way of describing and analyzing the discourses at play in interviews with teacher educators. Discourse models function both as a tool of inquiry, guiding me through the analysis, and as a specific way to characterize and describe the discourses at play in the interviews.

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 formalized, well-defined, and shared between people. One 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 there is a formalized understanding of when one discourse model applies and when another is appropriate. In most other situations, however, we do not have such an understanding—often several competing discourse models can be identified, and it is not uncommon for discourse models to be vague and inconsistent.

Gee proposes several 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)

Identifying discourse models involves trying to understand what the speakers need 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. Note that in this quote Gee uses the term "figured worlds" (Holland et al., 1998) as a synonym for the term discourse models, something I will come back to later.

Are discourse models 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) and later "To give another example, consider the figured world (or typical story) that might arise in someone's mind if they think about an elementary school classroom" (p. 89). This would imply that discourse models are properties of people, 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. The discourse models present in Publication I do not exist in the minds of educators. They do however *represent* real analytical objects, as they are an interpretation and characterization of patterns existing in how the interviewees talk. The results of my analysis are *analytical constructions*, and they represent 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, and cannot be said to be individual properties of the interviewees. Consequently, since the discourse models are generalizations of educator talk, they cannot be used to explain the very talk or behaviour they are representing (Lundegård & Hamza, 2014). Similarly, the five assumptions presented in Publication III should be understood as properties of, or patterns in, the way the interviewed physicists talk. They should not be understood as assumptions the physicists *have*, and cannot explain *why* they talk in this way. The analytical constructions thus have value in that they describe the patterns I identify in my analysis, and work as a way of communicating them to the reader. However, greater value might be ascribed to these constructions if they also have some bearing on the wider reality of the interviewees outside the interview situation. I believe this is the case, since my interviews were not performed in a vacuum and the talk of the interviewees needs to have some consistency across the environments we are working in.

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 uses the term figured worlds for the same theoretical construct. Gee comments on his 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, to me it 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. Thus, 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 issue, mentioned earlier, 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 thus believe it is better to point to this understanding rather than using the concept of "figured worlds".

4.2 Theorizing identity

In this thesis I approach the context of physics teacher education from two directions. First by asking how teacher educator discourses can be understood as a part of the context that limits and enables trainee physics teachers in their becoming physics teachers. Here I focus on the educators as a major influence in the context within which pre-service physics teachers perform their own professional identities. Second, I approach the context of physics teacher education by asking trainee teachers how they negotiate and position themselves through and in relation to, the discourses of their educational program. In both these perspectives I use a variety of discourse analysis-inspired theories regarding identity. These perspectives are explicitly used in Publications III and V, but have informed and guided my interpretations throughout the thesis work. In this section I will discuss and contextualize my use of identity theories.

4.2.1 What is identity?

Although the concept of identity is regularly invoked in educational research, in the past it has rarely been explicitly defined. In this respect, a 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 something that is constructed in social interaction.

As argued in Section 3.5 (Teacher professional identity), research on teacher professional identity often approaches this as an empirical phenomenon. Here, teacher professional identity is regarded as something a teacher has, that can be explored for example by asking teachers what their own professional identity consists of (Beijaard et al., 2000). In my work I utilize identity as a theoretical tool and wish to shift the focus from individual identities to the structures within which these identities are performed, by choosing to view identity through the lens of discourses (Søreide, 2007, p. 538). I take *professional* identity to imply a professional *context* rather than a special, professional kind of identity. Thus, the theoretical construct of identity does not change for personal and professional use. Rather, it is the professional discourses that distinguish 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 making yourself intelligible as a professional within specific professional discourses. 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. 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).

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 there has been an overemphasis on the individual student or teacher in empirical research, 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)

4.2.2 Celebrated identity performances

For Publication I, identity was viewed in terms of identity performances (Archer, Dawson, et al., 2017; Butler, 1990; Davies, 2006) and in this section I discuss this specific identity construct. Before this however, a discussion of the choice of this specific construct is in order. In Publication I, I use discourse analysis following Gee (2005), but I do not use the identity concepts developed by Gee. The reason for this is that my interest in the analysis for Publication I was the discursive structure of physics teacher education as it limits and enables the professional identity of trainee teachers, and I did not find Gee’s identity concepts to be the most productive for this. Here the way Butler uses the concept of subjectification provided tools for conceptualizing how the individual subject is produced in discourse.

Butler (1997) uses subjectification as a way of discussing the relationship between individual subjects and discourse. Becoming *someone*, a subject with agency, requires using the positions available in an acceptable way and thus involves submitting to the discourse. This submission requires using, and thus accepting, the language available. To successfully do so, the subject must master the discourse, that is, use it in the right way to be recognized by others. There is always a risk of being recognized as "inappropriate" or "incompetent". Submission and mastery are not separate acts but occur together and rely on each other:

> The individual subject is not possible without this simultaneous submission and mastery. The formation of the subject thus depends on powers external to itself. The subject might resist and agonize over those very powers that dominate and subject it, and at the same time, it also depends on them for its existence. (Davies, 2006, p. 426)

As such, power does not just force us into particular ways of being, such ways of being are also made desirable to us, in that they make us intelligible, both to ourselves and to others around us (Foucault, 1982). 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 ongoing 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).

What is intelligible in the discourse thus limits possible ways of being a subject with agency, and agency is thus severely limited, but not extinguished, by structure: "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) Agency is possible as the subject is created together with the discourse, simultaneously 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 et al., 2017, p. 168).

In order to be "intelligible" or achieve recognition (Carlone & Johnson, 2007; Gonsalves, 2014a) an identity performance has to align with the dominant discourse. In Publication I, the term celebrated identity performances (Archer, Dawson, et al., 2017) is used to ask what are "intelligible" and "valued" ways of performing a trainee physics teacher identity in the discourses of the physics teacher education. These performances, the ways that trainee teachers can make themselves intelligible as competent teachers-to-be through the discourses of the education, cannot in a direct way be assumed to transfer to future ways of performing identities as competent physics teachers in school. However, performed identities are not simply fluid and ever-changing. In some ways they "stick" to the body (Ahmed, 2014). Their stability lies in patterns of repeated acts and expectations, and taken-for-granted ways of interpreting reality. Butler speaks of gender as a "copy of a copy" (1990, p. 41), that is a pattern that is repeated, but that never can be identically perfect. In this imperfection lies the possibility of dislocation or change, but even though these patterns and expectations can be distorted, they do not just change, or change completely, from one moment or context to another. Thus, the identity performances as competent teachers-to-be that are intelligible in the context of teacher education can be expected to overlap with the identity performances of professional teachers in a school context.

4.2.3 Femininity

For Publication V, I continue to use Butler's (1990) conceptualization of subjectification through simultaneous submission and mastery, now with a focus on the performance of different femininities. Finding a way of theoretically defining femininity that does not presuppose its empirical content is difficult, since what is feminine is highly context dependent, but at the same time part of a larger pattern of meaning making that is repeated as part of what can be called the heterosexual matrix (Butler, 1990). If femininity is defined as what has been empirically found to be considered feminine before, or as coinciding with the researchers' own notions of femininity, there is a risk of reproducing our own assumptions in our research (Ottemo, 2015; Ottemo et al., 2021).

One issue is how femininity and masculinity should be defined in relation to people's bodies and gender identity, that is, should masculinity and femininity be tied to male and female bodies? (Halberstam, 1998; Paechter, 2006). Schippers (2007) develops this discussion of how femininities should be understood in relation to the well-established but widely debated concept of hegemonic masculinities (Connell, 1995). Connell suggested that masculinity, at least in part, should be defined as what men do, and that hegemonic masculinity is "the configuration of gender practice which embodies the currently accepted answer to the problem of the legitimacy of patriarchy, which guarantees (or is taken to guarantee) the dominant position of men and the subordination of women" (Connell, 1995, p. 77). Schippers argues that hegemonic masculinity cannot be understood on its own, as the purpose is not to identify the behaviour or characteristics that claims power for the person doing them. Rather, masculinity and femininity need to be understood together as a relation that works to legitimize the current, local, system of power. The specifics of how this relation looks, and thus what is understood as masculine and feminine is an empirical question. In paper V, I follow Shippers (2007, p. 90) who takes femininity and masculinity to denote the patterns of meanings associated with each gender:

> Embedded within the system of symbolic meanings that articulate and define gender positions and their relationship to each other are qualities members of each gender category should and are assumed to possess. I argue, in contrast to Connell and Messerschmidt (2005), it is in the idealized quality content of the categories "man" and "woman" that we find the hegemonic significance of masculinity and femininity.

Femininity is thus not exclusively bound to bodies recognized as female. I take "normative femininity" to mean the pattern of symbolic meanings that is embodied in ways of doing woman that goes unnoticed, that is, passes as normal, in a particular context (Schippers, 2007, p. 92). In physics education, normative femininity has empirically been shown to involve rejection of stereotypical or hyperfeminine expressions of femininity, which are seen as incompatible with the purported neutrality of physics (Archer, Dawson, et al., 2017; Gonsalves, 2014b). This rejection can be understood as "a claiming of power" since "to oppose stereotypical or normalized feminine positioning is to reject the disempowerment that comes with it" (Paechter, 2006, p. 257).

This argument is in line with how feminine femininities from a feminist point of view traditionally have been understood as defined by male desire and subordination. However, in the last decade, "hyperfemininity" has been increasingly understood in queer contexts as a possibility for resistance, where exaggerated or pronounced feminine dress or behaviour, together with reclaiming historically derogatory expressions such as "bimbo" or "slut", can be interpreted as challenging and breaking expectations on women to accept their positioning in the heterosexual matrix (Dahl, 2011). In the analysis of the identity performances of the participants in study V, these multiple aspects of femininity come into play in the students' negotiations of positions as trainee teachers, women, and physics learners.

According to Butler, gender is created through repeated acts that create the illusion of a stable gender identity. Not just gender, but all more or less stable identities, such as race, class, or age are produced in this way. These different identities cannot be considered alone, but are produced together and uniquely influence each other, as the social axes intersect in each point in social space (Phoenix, 2006). Doing white middle class woman in the context of physics education is different from doing black middle class, or working-class woman. The image of intersecting social axes however, risks creating an impression that each identity interacts in a linear way with the others as we move through the coordinate system of social space. The geometry of identity production is not "Euclidean", as the social space is bent and curves around social identities, variously socially heavy, distorting distances, changing the properties of each unique point (Barad, 2007). As such, not only established categories of identity are intersecting, but also being a science person, a physics student or aspiring teacher changes the dynamics of the space within which the subject is struggling to be recognized and valued. Ottemo (2015) for example suggests that masculinity, technology, and heterosexuality are social axes, intersecting in the production of subjects of technology students. However, it is important not to theoretically assume that such identities are equally "heavy". In my thesis work, I have explored how the positions of trainee physics teacher and successful physics student are produced together with positions of feminine woman, and feminist in a predominantly normatively white context.

4.3 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 III uses discourse analysis as an analytical tool in a similar way to Publication I. 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).

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)

While the culture of a group is changeable, fluid, and complex, the definition also implies a degree of stability. Culture is something transferred to new members of a group and 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. These assumptions 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 4.1.2 (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.

4.4 Developing disciplinary literacy

Publication II 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 II is quite different from the one used in the other publications 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, 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.

4.4.1 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 that students meet, and as such connects to the broader discourse theoretical framework used in my work.

Following Airey (2011c, p. 3) 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), but is more specifically aimed towards mastering the specific tools of significance in the discipline.

One way of making this differentiation is to separate disciplinary communication aimed towards the academy, the workplace (outside of academia), and society. Figure 2 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.

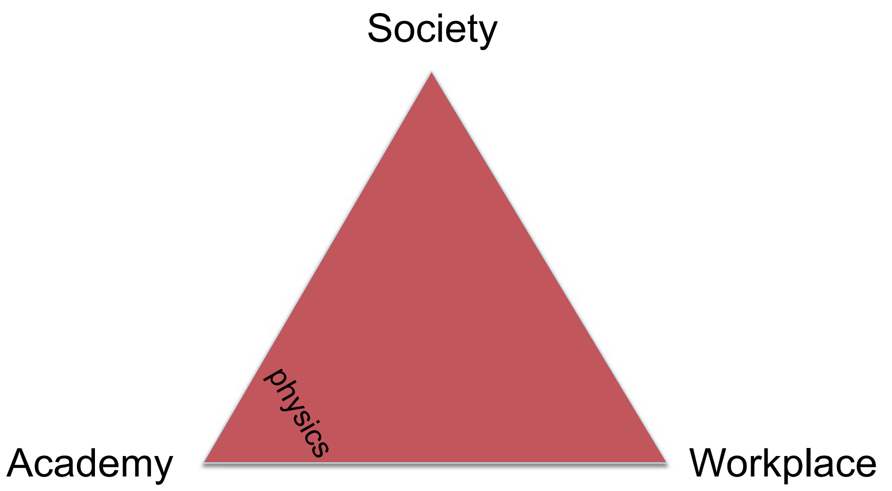

Figure 2. The disciplinary literacy triangle. Here, the discipline of physics is placed in the left corner. This represents the focus on teaching for the academy that was reported by the physics lecturers that were interviewed for Publication II. Reproduced from Publication II with the permission of Springer.

The disciplinary literacy triangle can be used as a way of representing the relative degree to which an individual, 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 lecturers. For example, in Publication II, the interviewed physics lecturers 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 2).

4.4.2 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 more 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 more horizontal knowledge structures organize knowledge in a series of independent specialized "languages", these are in Figure 3 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 importantly 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 of description and through the introduction of new such languages. In Figure 3, the differences between hierarchical and horizontal knowledge structures are illustrated though the use of triangles, inspired by Martin (2011).

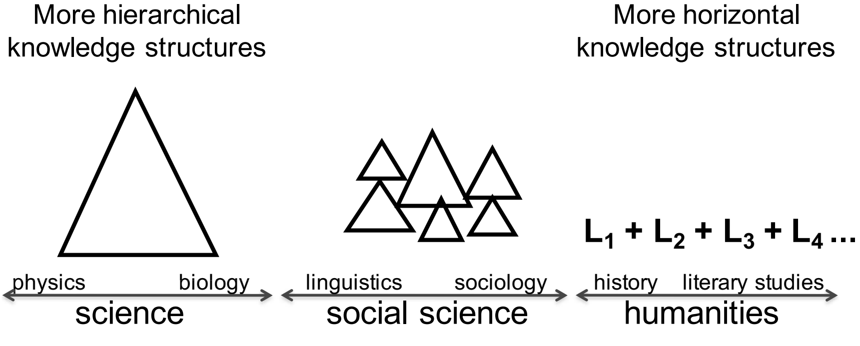

Figure 3. The difference between horizontal and hierarchical knowledge structures. Picture adapted from (Martin, 2011). Reproduced from Publication II with the permission of Springer.

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 II it is argued that this difference creates unique challenges for trainee physics teachers when moving between the education department, and physics department. This will be further discussed in Section 6.2 (Findings Publication II).

5 Methods and methodology

This chapter connects the general purposes of the two parts of the project, to the more specific research questions of each publication and the methods chosen to answer them. The intention is to explain to the reader what methodological choices were made and how they are an appropriate match to the questions asked. In the following section (5.1), I give an overview of the two project parts and how their research questions guided method choices. In the succeeding sections discuss interviews (5.2), observations (5.3), transcription (5.4), and coding and analysis (5.5) respectively. Finally, in sections 5.6 and 5.7 I discuss aspects of trustworthiness and ethical considerations in my work.

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.

5.1 Methods chosen in each publication

In this section I motivate my methodological choices as they relate to my aim of investigating the discourses of physics teacher education among trainees and educators, and how these are negotiated by trainees in the process of becoming physics teachers.

5.1.1 Publication I

In Publication I the focus is on the talk of teacher educators. The following research 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 recognized and valued within these discourse models?

To gain access to how physics teacher educators talk about the education and the creation of physics teachers, I chose to carry out 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 in this thesis as interview round a. The decision to carry out just nine interviews could be considered in quantitative paradigms to be a very small sample. However, in this study, the aim was not to provide a generalizable description of the state of physics teacher education in Sweden, but rather to investigate the discourses of one specific physics teacher education programme as an illustration of wider issues that would be easy to overlook when taking a less focussed, broad-brush, quantitative approach.

Publication I can be thought of as a case study chosen on the basis of *information* (Flyvbjerg, 2006). Such case studies are chosen because of the 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 placement into one coherent programme, suggesting fragmentation and competing discourses are often inherent in teacher education (Danielsson & Warwick, 2014a, 2014b; Hökkä & Eteläpelto, 2014; Sandifer & Brewe, 2015; Scherr et al., 2015; Sjølie, 2014). In the particular educational programme studied in Publication I, these parts of the programme are physically separated, located on different campuses. Thus, the geographical context of Publication I presents an extreme rather than typical case providing 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 first part 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' perspectives on the goals of teacher education in relation to their practice. As such, the data I required involved educators talking extensively about physics teacher education, and such talk was not expected to arise spontaneously in the classroom setting.

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 trainee physics 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 more direct way than they would do in the classroom, I was able to better elicit tacit assumptions and norms about the educational program. These more elaborated descriptions could then be used to create discourse models that I would expect to either be hidden from view or expressed in much more implicit ways in the classroom. Time constraints made it impossible to carry out 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.

5.1.2 Publication II

Publication II is a book chapter that takes a theoretical perspective on the different parts of physics teacher education. The chapter has three main parts. The first part presents and explains the theoretical framework of disciplinary literacy (Airey, 2011c, 2013) combined with the concept of disciplinary knowledge structures by Bernstein (1999, 2000). In the second part of the chapter the disciplinary literacy goals (Airey, 2011c, 2011a, 2013) of undergraduate physics lecturers in Sweden are discussed. The third part presents an argument that using Bernstein's constructs of hierarchical and horizontal knowledge structures (1999, 2000) can give valuable insight into the specific difficulties of physics teacher education.

The ideas in Publication II were developed in parallel with work on Publication I. Initially the chapter was planned to be entirely theoretical. However, the interview data collected for Publication I took on new and interesting meaning when viewed through the theoretical lens of the chapter, and thus a preliminary analysis of this material was included.

5.1.3 Publication III

Publication III aims to deepen and extend the findings of Publication I by exploring if the *physics expert model* that was presented in Publication I can be viewed as an expression of local physics culture as it pertains to teacher education. The following research question is asked:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

The data set from Paper II was complemented with a re-analysis of a previously collected data set referred to as interview round b. Here, the intent was to broaden the original findings by exploring whether a group of physicists teaching in different settings use the physics expert model as identified in Publication I, and if so, in what way.

The eight round b interviews were originally conducted by my supervisor John Airey for another project concerned with scientific literacy (Airey, 2012). Here, one question posed in the interviews was the nature of physics lecturers' goals for trainee physics teachers and how they perceived their role in helping trainee teachers reach these goals. Both interview rounds a and b thus deal with overlapping themes of physics lecturers aims for, and role in helping, educate future physics teachers, and can in this respect be treated as parallel datasets.

In the original analysis for publication III, the combined 17 interviews from rounds a and b were used including both physicists and other teacher educators. This was the case even though the research question concerns physics departments and physicists. In the analysis, the interviews with non-physicists were used as a contrast and background to how the physicists talked about teacher education. However, in the review process of Publication III it became apparent that this approach was too complex and difficult to communicate and in the revised version of Publication III only the 11 interviews with physicists were used.

5.1.4 Publications IV and V

The general intention when starting part two of the thesis project was to explore the same questions that were asked from an educator perspective in part one, but this time from a student perspective. Here three themes and some tentative research questions, inspired by the results of part one, guided the planning of data collection:

Fragmentation – How do trainee physics teachers experience the different parts of their education? How do they describe differences and similarities between the environments? How do they describe being affected by them? Can the discourse models described in Publications I and III be recognized as significant in students' professional identity performances?

The particulars of being a trainee physics teacher – How do trainee physics teachers describe their experiences of being a trainee teacher at the physics department? How do they talk about their choice of subject among the other trainee teachers at the education department? How are differences in status between the students and subjects expressed and dealt with?

The gendered experiences of trainee physics teachers – In what ways do the trainee physics teachers describe gender as being (in)significant in their experiences of studying to become physics teachers? How do they talk about gender and physics, both in their experience of learning physics and for the subject in general? How do they describe their own role as future physics teachers in working with or changing gender imbalances?

A first pilot study was designed to provide insight into the student experience of the physics teacher program, and aid in the planning of data collection. Two courses for trainee teachers taught by the education department were observed. The courses were chosen because they contained content dealing with equity in school, hoping this would provide insight into trainees' earlier experiences of talking about these subjects during their education. One question was whether classroom observations combined with student interviews would be a viable method.

The pilot study consisted of 16 hours of observations in two courses. Based on the pilot study I decided to use classroom observations as a way to meet the students and to gain familiarity with the programme environments, but that my previous experience of observations and the time available were both insufficient to be able to use observations as main source of data collection.

For the main data collection for project part two, I observed a further 26 hours of classroom sessions in three courses and carried out 17 semi-structured, qualitative interviews with trainee physics teachers. The interview guide was designed using the three themes mentioned above. The research questions used in Publications IV and V were created after the initial round of open coding, for more details pertaining to this, see Section 5.5 (Coding and analysis).

5.1.4.1 Publication IV

One theme that became apparent in the first open coding was that the students were describing experiences that in different ways connected to being unmotivated, detached or disengaged in relation to the physics courses. This was further explored in Publication IV using the following research question:

> How do upper secondary trainee physics teachers experience the purpose and goals of their undergraduate physics learning, when studying physics together with other programme students?

Publication IV was written with an audience of physics educators in mind and intended for a journal closely connected to undergraduate physics studies. To increase accessibility for this audience, a thematic approach (Braun & Clarke, 2006) was adopted.

5.1.4.2 Publication V

When reading through the transcripts, I was struck by the common story told by the three trainees that are called the Trio in Publication V. The Trio all described experiences of not being taken seriously as women in physics. Despite this, it seemed like they used the position of being women in physics in a positive way to create a constructive approach to studying physics. Wanting to explore this further, the research question for Publication V became:

> Which ways of learning science are enabled by femininity performances when trainee physics teachers negotiate their combined positions as physics students and trainee physics teachers?

The theoretical framework utilized in Publication I to discuss trainees' identity performances was further utilized and deepened for the analysis of Publication V.

Having given an overview of the methods used in data collection and analysis for each publication, in the following sections I will now discuss these methods.

5.2 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 interviewee room to show the interviewer what is significant and important from their point of view. This allows for flexibility to let interesting topics arise during the interview and for interviewer and interviewee to explore these 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 situations 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 one way of questioning and starting with the same interview guide, each interview is expected to develop in a unique direction. (Kvale et al., 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 is of course drawing on and therefore a source of knowledge on active outside discourses (Kvale et al., 2009).

5.2.1 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 mostly 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 is 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 situation, we position ourselves in relation to each other and the context. The interviewee's answers to a question are 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 interviewed teacher educators, the dynamic was affected by the educators being older than me, being in a more senior position than me (in all but one case, where the interviewee was a physics PhD student), and doing the interview as part of their professional role of teacher educator. The formal framing was the practice of a research interview and I generally aimed to position myself as a researcher and the interviewee among other things as a willing participant. However, such positions constantly change during the interview, which also changes the situated meaning that the interviewee and I create together (Gee, 2005). During the interviews with educators, I sometimes tried to bring forward my position of a novice PhD-student with less knowledge than the interviewee, framing the educator as a more experienced and benevolent colleague who will be of help by telling me how things work. This was a way to frame my questions as innocent and information seeking in a situation that could potentially be read as threatening, since the educators are answering my questions as professionals in part responsible for the quality of the educational program that is the focus of my research. I thus tried to avoid the interviewees feeling they had to defend the system of teacher education, and encouraged sharing of their own understanding of it as sometimes flawed.

My positioning was somewhat different during the interviews with students. In contrast to the educator interviews, in the interviews with students the asymmetric power dynamic of researcher and interviewee was reinforced by me being older (in all but one case, where the interviewee was the same age as me), having completed a version of the educational program they are currently participating in, and that I am also acting as a professional in the interview situation while they are not. In these interviews, I intentionally (and genuinely) sided with the students, trying to balance this dynamic. I explained my purpose as being about capturing their experiences, wanting to write about what is significant to them, being interested in issues of equal participation in physics, and wanting to improve physics teacher education for the students. In my one-on-one interactions with the students, both during observations and interviews, I not only listened, but also to some extent shared my own experiences of studying physics to become a teacher, creating a sense of shared experiences. In general, the atmosphere of these interviews was relaxed and friendly. This was especially true of the interviews with "the Trio" that are the focus of paper V, where one telling example is the interview with Julia:

> Julia: I've always thought like this I'm not one of those physicists, I'm the kind of girl who just ended up here. But I do believe there is a group of physicists that I'm part of, you know a group of gender-aware women, er that are a bit, you know, vegetarians, buy second hand, that I'm part of. I think it is a new group of physicists actually. Maybe you're part of it too?
> Johanna: Yes (smiling and nodding)
> Julia: Yes (laughs)

Here Julia positions me as part of her group, and us as similar, which I confirm. During this interview, I perceived Julia as very open and relaxed, and my position as primarily being a fellow feminist and physics student, rather than researcher. This was convenient and nice, but also uncomfortable since in the end I have the power to interpret and write about this situation, that Julia does not have. Because of this, and because paper V is particularly focused on the Trio students, I chose to meet with the Trio to present and discuss my analysis. Each finding theme was presented in Swedish and discussed. Overall, the Trio recognized their stories in the text, and expressed feeling empowered by their experiences being analyzed.

I have myself completed a four-year master in physics as well as the bridging teacher programme, 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 and students familiar. This provided the possibility to interpret the interviews drawing on a common frame of reference and 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. However, on balance, I believe this is a strength rather than a weakness of the study.

5.2.2 Interview round a

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 school placement 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 prioritize 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 valuable for creating professional physics teachers. The interview guide can be found in Appendix A.

The interview guide consisted of a general introduction and three themes. The first theme was "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 about what motivates trainees to become physics teachers contrasted against other choices such as a teacher of another subject or a physicist.

5.2.3 Interview round b

Interview round b consists of eight interviews 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 students (see Airey, 2011c).

Physics lecturers in round b 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 11 interviewees for Publication III consisted of physics lecturers working at four different 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 teacher only groups. For an overview of the 11 interviewees, their context and teaching situation, see Table 1.

Table 1. A summary of all 17 round a and b interviews with teacher educators along with information about the context. An upper-case L or S stands for larger or smaller university and a lower-case a or b indicates the interview round.

Round	Interviewee code	Position	University
a	Physicist 1La	Senior lecturer	Large, research-centered university.
a	Physicist 2La	Senior lecturer	Large, research-centered university.
a	Physicist 3La	PhD student	Large, research-centered university.
a	Mentor 1La	Physics teacher	Upper secondary school
a	Mentor 2La	Physics teacher	Upper secondary school.
a	Mentor 3La	Physics teacher	Upper secondary school
a	Education lecturer 1La	Lecturer	Large, research-centered university.
a	Education lecturer 2La	Senior lecturer	Large, research-centered university.
a	Education lecturer 3La	Lecturer	Large, research-centered university.
b	Physicist 4Sb	PhD student	Smaller, teaching oriented university
b	Physicist 5Sb	Professor	Smaller, teaching oriented university
b	Physicist 6Sb	Senior lecturer	Smaller, teaching oriented university
b	Physicist 7Sb	Senior lecturer	Smaller, teaching oriented university
b	Physicist 8Sb	Senior lecturer	Smaller, teaching oriented university
b	Physicist 9Lb	Senior lecturer	Large, research-centered university.
b	Physicist 10Sb	Post-doc	Smaller, teaching oriented university
b	Physicist 11Lb	Senior lecturer	Large, research-centered university.

5.2.4 Interview round c

For the second part of the project, I interviewed 17 students who are either studying the interwoven physics teacher program or planning to take the postgraduate teacher degree. I chose to interview trainee teachers on years two and three of the interwoven program, for several reasons: First, I aimed to talk to students with experiences of both physics courses and pedagogical courses, which excluded year one. Second, classroom observations were used to recruit interviewees. Here, student groups who at the time were taking part in regular classroom teaching were chosen. This excluded year four who were doing school placement at the time and year five who were doing individual projects. In the two chosen student groups, year two had just started their first semester of on-campus pedagogical courses at the education department after taking three semesters of physics. Year three had come back to studying physics after finishing their first period of pedagogical courses and school placement.

In year two, nine students were asked to participate and six agreed. In year three, seven students were asked and five agreed. Four additional students were interviewed who were studying at an individual pace due to health or personal reasons. Finally, two of the interviewed students were not registered on the teacher programme, but were planning to take the postgraduate teaching certificate. For an overview of all interviewees, se Table 2.

Table 2. *Overview of the 17 round c interviews with trainee physics teachers.*

Pseudonym	Study year	Interview duration
Elin	3	01:16:19
David	Individual study pace	01:22:01
Marcus	Individual study pace	00:53:15
Tom	2	01:30:42
Hampus	3	01:26:28
Finn	2	01:13:06
Julia	3	01:16:37
Niklas	Individual study pace	01:35:03
Amanda	Bachelor student	02:00:00
Magnus	2	01:40:50
Alex	2	01:33:50
Isak	3	01:26:31
Daniel	2	01:14:51
Katja	2	00:44:38
Andrej	Individual study pace	01:44:14
Ellen	3	02:14:32
Dennis	Bachelor student	01:30:17

The 17 semi-structured interviews (Kvale, 1996) were carried out in Swedish and lasted between 45 and 120 min. In compliance with Swedish Ethical Research Standards (Swedish Research Council, 2017), the students were informed of the purpose of the study, their right to withdraw at any time, informed about confidentiality and consented to be recorded during the interview.

The interviews took place in a study room on campus. It clearly affected the interview situation that I had met and talked with each student before the interview and was familiar with their current courses, teachers, and classmates. This familiarity made the interviews feel comfortable and relaxed for the most part.

The interviews were guided by six themes: (1) introduction and background, (2) the choice to become a physics teacher, (3) what a physics teacher should know, (4) trainee teachers compared to other students, (5) the physics subject, and (6) experiences of the physics teacher program. The interview guide can be found in Appendix B. These themes were chosen to enable quite open exploration of student experiences of studying on the program. Apart from the obvious interest in student motivations for becoming physics teachers, theme (2) was also designed to explore how the trainees talked about differences in status between different physics program paths. Theme (3) consisted of questions mirroring the ones used in the round a interview guide. The intention was to analyze student answers in terms of identity performances and in relation to the discourse models described in Publication I. Theme (4) included questions about what a typical trainee teacher is, and potential differences between trainee physics teachers and other physics students. Theme (5) focused on trainee experiences of learning physics. And finally, theme (6) focused on differences and similarities between the different environments of physics teacher education, asking how trainees experienced moving between the programme parts. One question included here was: "What is it like for you to learn physics in a male dominated environment?" aiming to inspire open discussions about experiences connected to gender.

These six themes, including quite different and open purposes and questions, made for a quite extensive interview guide, and a potential for there being a lack of time to explore all of them during the interviews. This proved to be the case. Each theme was covered in each interview, but not all were given equal weight. This was in large part steered by the interviewees willingness to talk about different subjects, as care was taken to let the interviews be guided by what the students gravitated towards as significant in their experiences of studying physics. For example, for the Trio that is in focus in Publication V, questions about gender were spontaneously brought up early in the interview and given weight throughout the interviews. In some of the other interviews, I experienced these questions as difficult to bring up, the answers were short and the atmosphere a bit awkward.

5.3 Observations

Classroom observations were used in the pilot study to give insight into the student experience of the physics teacher program, and aid in the planning of data collection. In the main data collection for the second part of the project, observations were used as a way of recruiting trainee teachers to the interviews, and as a source of background information to guide interpretation of the interviews.

At the first course sessions of the year, I introduced myself and my project. I had previously informed the trainee physics teachers and the responsible teacher about the project by email (see Appendix C). Since trainee physics teachers study together with other program groups, the students attending these sessions mostly consisted of physics students who were not considering teaching (year three) or trainee teachers who had not chosen the physics subject (year two). All students that were present received written information about the project and the possibility to opt out of participation (see Appendix D). I explained that I was interested in what happened in the classroom and especially interested in trainee physics teachers who I was also hoping to interview. Here I specified that I wanted to talk to anyone who was on the path to become a physics teacher, even if they were not registered on the interwoven program

During the classroom sessions I took notes of what the teachers were doing and saying, but did not attempt to capture the lecture content in full. Rather, I focused primarily on the trainee physics teachers and what they were doing and saying in relation to the teaching that was going on. I alternated between writing by hand and on my computer, and transcribed my notes directly after each session, adding any details that I could remember. I took care to sit with the trainee physics teachers that were present, and during the breaks I alternated between listening to, and participating in, the conversations taking place. During the observation period, I personally asked each present trainee physics teacher if they wanted to participate in an interview.

5.4 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 hesitations, but focused on the *content* of the interviews.

In interview round c, the first interview was transcribed directly in connection with the interview, as a way to test and reflect on the interview design before continuing with the rest of the interviews. One interviewee asked not to be recorded and extensive notes were instead taken during the interview and transcribed directly after. The remaining interviews were transcribed verbatim by a professional transcriber, with three exceptions. One because the interviewee asked that the recording be handled only by me, and two interviews because they were scheduled after the audio files had been sent for transcription.

For the professionally transcribed interviews, the transcriptions were gone through and closely checked against the audio file. Since the experience of transcribing also brings a familiarity with the text that is missing when not transcribing yourself, I needed to read through these transcriptions in their entirety again before beginning the analysis.

The transcribing of interviews from rounds a, b, and c were all 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 meant recording in text, my interpretation of what was 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 conducted the interviews. This step of course in a different way also served as a way of starting the analysis process. Finally, for interview round c, most of the interviews were transcribed by someone else. This added an additional step of reading the transcripts while listening to the audio recordings.

All quotes that appear in this comprehensive summary and in the publications have been edited to enhance understanding. Repetitions and false starts have been removed and the quotes from interview rounds a and c that were held in Swedish have been translated into English. The translations were done after analysis and only the quotes used when writing up the publications have been translated. In the translation process, care was taken to keep the original meaning of the quote rather than literal word-for-word translations.

5.5 Coding and analysis

Here I will present and reflect upon the analytical processes employed in Publications I, III, IV, and V. Since Publication II is more theoretical in nature this is discussed in Section 4.4 (Developing disciplinary literacy).

In this thesis, the general analytical approach is discourse analysis. As stated in the theory section, I understand discourse analysis 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 (4.1). A qualitative analysis software package, QRS NVivo, was used for coding and analysis throughout the thesis work.

5.5.1 Publication I

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. In the first part of my project, 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 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.

To begin the 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 material in each tentative category from round one was collected in a separate document and printed. Examples of categories at this stage were "the subject physics", "said about knowledge", and "the choice to become a teacher". 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 open and resulted in a comprehensive revision of the categories, where some categories were recognized as more significant, whilst others were decided to represent side-tracks that would not be the focus of further analysis for now. The selected 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 4.

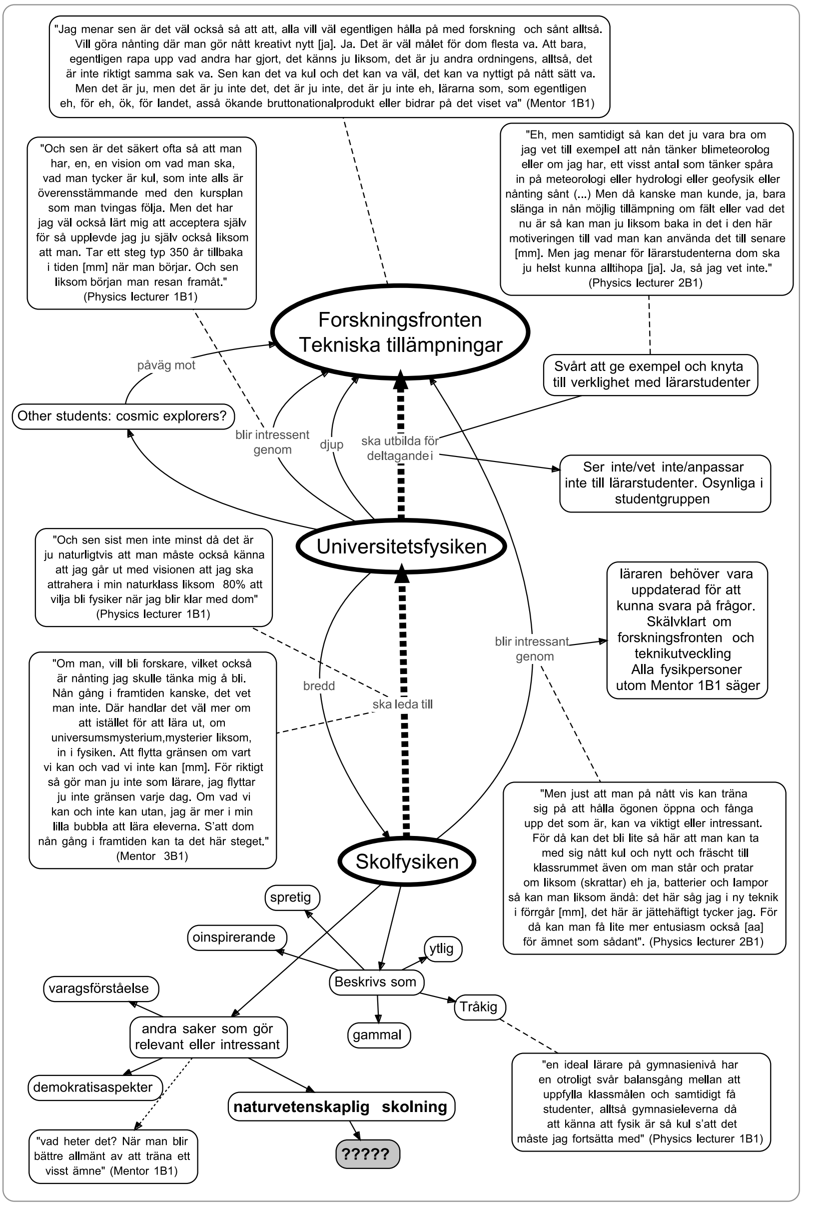

Figure 4. An early version of the visual representation used in analysis to make visible structures in meaning around physics teaching. In later iterations the particular representation depicted here became the physics expert model.

Using the visual representations as a support, the material was then read 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.

5.5.2 Publication III

In Publication III, the earlier finding of the physics expert model was 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 my two of my supervisors and co-authors.

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. An explicit purpose of the first analytical iteration was to explore whether the *physics expert discourse model*, was viable as a lens to understand physicist talk. The *physics expert discourse model* is organized according to a particular goal of the education, the implied professional future of the student group as physics experts. 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 11 transcripts were gone through with an open focus on what assumptions about student professional future were visible in the material.

It is, of course, a disadvantage that part of the interviews used in the analysis was originally carried out with another purpose. Care was taken in the analysis process to account for the different interview contexts, for example by paying particular attention to the way questions were asked, the relationship between interviewer and interviewee, and the differing teaching contexts.

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 E. 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 were 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. This resulted in the three themes and five assumptions presented in the findings section.

The analysis builds on close reading and re-reading of the transcripts while trying to make visible what is not apparent at a 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.

5.5.3 Publication IV

To start the analysis process of the interview material collected in the second part of the project, the whole interview material of round c was read through and coded openly. At this stage, the particular research questions of Publications IV and V were not yet decided on, and this first coding focused on what was given weight and appeared important in the students' stories. The goal was to create a first map of the material in relation to the three themes described in Section 5.1.4: *Fragmentation*, *The particulars of being a trainee physics teacher,* and *The gendered experiences of trainee physics teachers.* A large number of categories were created, read through and further reflected on, and from this, several ideas for papers and more precise research questions resulted. I will now describe the further analysis for Publications IV.

For Publication IV thematic analysis was used. I did this within the same discourse analytical framework used for the other publications, which means understanding the generated themes as patterns in the discourse of the educators. (Braun & Clarke, 2006). The analysis took its beginning in the openly coded material from the first general coding and the whole material was re-read and coded with a focus on student experiences of learning physics. This resulted in 102 separate codings. Each individual coding was then read through and its relevance for the research question "How do trainee physics teachers experience the purpose and goals of their undergraduate learning physics?" was considered. Codings were merged and those that were deemed less relevant for the focus of Publication IV were set aside. This resulted in four major themes: Teacher programme invisibility, Passive classroom culture, Perceived relevance of physics courses, and No incentive to do well in physics. The Invisibility theme consisted of student answers that dealt with experiences of being noticed or not noticed, as a group. The Passivity theme consisted of comments on classroom norms, The Relevance theme consisted of students' reasoning around the question "How do students find meaning or value in physics beyond its purpose in the classroom?" (Nair & Sawtelle, 2019) The Incentive theme consisted of discussions of grades or efforts made to learn physics. The quotes for each theme were read through and sorted into sub-themes, seeking to explore the different experiences described in the material.

In Publication IV, frequency counts were reported for the main themes of the analysis, see Table 3. The reasoning behind this was to be as transparent as possible about the analysis process. Note that the number of coding instances in each theme is not used as quantitative support for the trustworthiness of the results. Publication IV reports on student experiences that exist and are significant in the study, and there is no claim made that these experiences are directly generalizable to other student groups. Rather, it is suggested that the results will have resonance (Tracy, 2010) with physicists and physics teacher educators who can use them to reflect on their own experiences of trainee physics teachers in their context (Guilfoyle et al., 2020).

Table 3. Frequency counts for the main themes of the analysis for Publication IV

Themes	**Sub-themes**	Number of mentions	Number of coding instances
Teacher Programme invisibility		**8**	**29**
Passive classroom culture		**13**	**11**
Perceived relevance of physics courses	↴	**17**	**155**
	Need to know school level physics	14	32
	Providing inspiration	15	22
	Questioning relevance	13	47
	Personal gain	9	34
	Provides high status	6	7
	Instrumental motivation	5	10
	A real physics experience	2	3
No incentive to do well in physics		**9**	**11**

5.5.4 Publication V

The analysis for Publication V was carried out differently compared to the other publications. Rather than seeking general discursive patterns across the whole material, it focused on three (individual) student interviews and sought to closely interpret how they negotiate gendered discourses around physics and learning to teach. In the first general coding of interview round c, I noted that the three students that are called the Trio in Publication V all seem to tell a common story in relation to the theme of how gender is (in)significant in their experiences of studying to become a physics teacher. Here, the themes around "femininity", "passing as competent in physics", "feminist awareness" and "constructive study practice" stood out in the Trio's interviews. The Trio are friends and they described themselves as a distinct group that both study together and socialize privately. I decided to explore the common story of this group of students further. The Trio's interview transcripts were then closely re-read and case files created where each student's story was summarized. Each theme was coded and connected to quotes, taking care to keep the students' entire narrative in mind. In the "femininity" theme some of the codes used were "not being one of the guys", "performing femininity" and "social competence". In the "competent in physics theme" the codes "questioning competence" and "physics competence of trainee teachers" were used. At this stage, the research question "How do female trainee physics teachers negotiate their positioning as women and physics experts to create spaces for themselves as learners of physics?" was formulated and used as a lens for further interpretative rounds of reading and coding the transcripts. The themes created in each iteration were allowed to guide the focus in the next reading. For example, Julia in her interview talks about a "new feminist awareness". This prompted focused re-reading of the other two interviews, finding themes of feminism and of choosing female companionship. All quotes connected to these themes were collected and re-analyzed, asking how the Trio are negotiating spaces for themselves as learners of physics.

5.6 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, and on what grounds the findings presented can be trusted. This section is 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 the first part of the thesis project, I investigated the discursive practices of teacher educators. It is thus not the realities residing inside the minds of educators that are of interest, but rather the structure of 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 the analysis all can be trusted to make sense in relation to the research questions and findings. Tracy suggests that credible research makes readers comprehend findings as "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 whether 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.

In project part two, Publication V focuses on three students, the Trio, and their identity negotiations around being women, feminists, trainee teachers and physics students. Unlike the results of Publications I, III, and IV that are based on discursive patterns in the whole interview material, the findings of Publication V are based on a close analysis of the individual stories of only three students. Because of this I decided to do a kind of member checking (Guba & Lincoln, 1982) with the Trio, to give them the opportunity to give their opinion about, and affect, how I interpret their stories. I met with the three students and presented the findings. We read the quotes together and discussed each part. During our discussion, the Trio confirmed that they are comfortable with how they are represented and, perhaps more importantly, that my analysis of their stories gave them valuable perspective on their own experiences.

Transferability, according to Guba and Lincoln, is about offering the reader enough information to make a 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 whether the described case context is similar enough to their own, to warrant the findings as applicable in some way to their personal context (Mills et al., 2010). Tracy (2010) discusses transferability in terms of usefulness, a study being valuable "across a variety of contexts or situations." (p. 845) Throughout this 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? The intention is for the findings to work as tools for professionals to more clearly see the meaning-patterns surrounding their own practice. The discourse models of publication I, the five assumptions identified in Publication III, and the student experiences described in Publications IV and V are not claimed to be universal properties present in all physics teacher programmes. Rather, if physicists can recognize even part of these assumptions and experiences in their own environment, this has the potential to work as a tool to guide further reflection around department culture and physics teacher education. 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 never be recreated. Even so, it is important to provide a detailed description of the 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 of 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 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 5.2 (Interviews).

5.7 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 et al., 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 recorded material is not used. Signing a piece of paper with formal formulations, nevertheless risks 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" 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. To ensure that no sensitive information was processed, sections of the recordings that could hint at such information were not transcribed. In one case, the recording was paused when the interviewee wanted to discuss religious affiliation.

In interview round a, participants were initially contacted by me by 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 beforehand. The consent form originally used (see Appendix F) 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 G). The information given to the participants remained the same irrespective of which consent form was used.

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 H. One interviewee requested that the material only be available to the interviewer, and that interview was not included in interview round b.

In interview round c, participants were first informed about the study through an email, and then later asked in person if they wanted to participate. If they agreed, a time and place were decided, and they were sent a confirmation email also containing information about the interview. The consent form and information letter used in interview round c can be found in Appendix I.

In all interview rounds, participants were informed that the interview would be recorded and that they could choose to terminate the recording at any time during the interview. If the participant chose to not be recorded or wanted to end the interview, they would be asked what (if any) of the already recorded material could be used. One student chose to not be recorded, and one student asked that part of the interview, concerning personal matters, should not be recorded. This student also asked for the transcription to be done by me.

The recorded material would be used to do research and would be discussed with my supervisors. This includes using the transcribed material in future publications and presentations. All participants are adults. As such they can be expected to be able to understand the information about their participation in the study.

When informing about the observations, I gave all students the opportunity to opt out of being observed, either by telling me directly or by sending me an email. The practical meaning of opting out was that I would not note or record anything that student said or did. One student, who was not a trainee physics teacher, asked for this.

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 of benefit to the field of teacher education in general, but also to the specific contexts of the educators and students participating in the study. The risks for participants can be considered minimal. In the case of Publication V that focuses on only three students, the risk of someone identifying the students through recognizing their stories was judged as possible. Because of this, the three students were informed of this risk and asked to read through and approve of the analysis and the quoted used.

Regarding the confidentiality and storing of data. Since the data for interview round c was collected after 2018 it falls under the General Data Protection Regulation (GDPR), and the storing of this data complies with this regulation. The consent forms used in interview rounds a and c stated that personal information will not be recorded in any transcripts (see Appendix F, G, and I). 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 was stored in a safe way, encrypted or in a locked space. When not actively used in my work, audio files and transcripts were stored on two hard drives in a locked drawer in a locked room.

6 Findings

Here I present a summarized version of the findings for each individual publication. For further discussion of these findings and how they together correspond to the aim of the thesis, see Chapter 7 (Discussion and looking forward).

6.1 Findings Publication I

The research questions for Publication I 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 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 5.

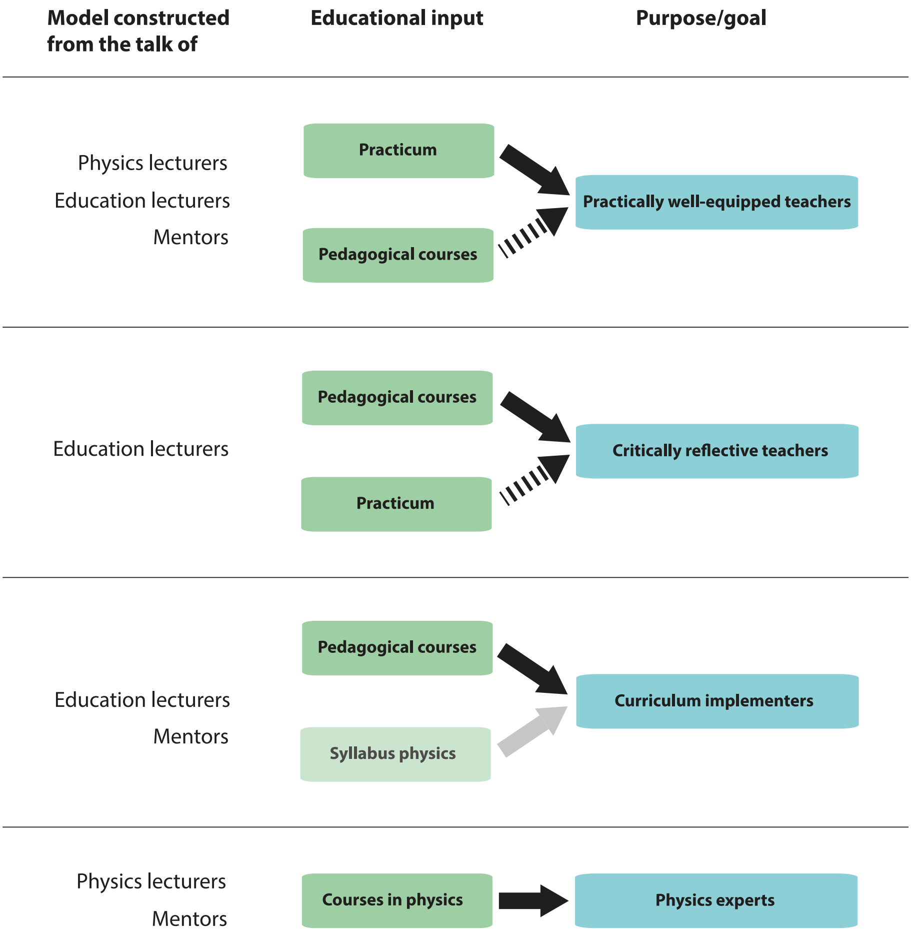

Figure 5. The four discourse models. In each model, the educational programme is understood in relation to the goals represented by blue rectangles on the right. The different educational inputs represented by green rectangles in the middle column are understood in varying ways as contributing to the 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. Reproduced from Publication I under the CC BY 4.0 licence.

Each discourse 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 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 Figure 1, 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.

6.1.1 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, this model frames the educational programme as not providing the tools needed to reach this goal. It is therefore probably difficult to "pull off" (Gee, 2005) this practically well-equipped teacher identity performance (at least on the basis of 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.

6.1.2 The critically reflective teacher model

In the *critically reflective teacher* model, the goal of physics teacher education is to give trainees the theoretical tools they need to critically reflect upon their own practice. To be recognized 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.

6.1.3 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.

6.1.4 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 particular kind of professional teacher stereotype, the *physics expert* model focuses on the creation of physics experts. In this context, a physics expert is someone doing research or working with technical applications of physics. At first glance a discourse model that does not aim to create a kind of teacher, but rather has the production of physics experts as its goal, appears totally unrelated to physics teacher education. However, despite this, in the 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 those who are talented enough. Here, at least two rationalizations of this decision are possible: either trainees do not have what it takes to become physicists, or perhaps they are driven by a cause—to encourage new students to take physics and become future physics experts. 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 either unsuccessful or deviant. It appears that there are no highly-valued ways of performing a physics teacher identity within the physics expert model.

6.2 Findings Publication II

In Publication II the concept of disciplinary literacy is combined with a way of categorizing disciplines in terms of disciplinary knowledge structures. This 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 4.4 (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 I 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 is the experience of learning university physics through the medium of English when the goal is to teach school physics in Swedish. Viewed through the lens of the findings of Publications I and III, the physics 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 II, 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 recontextualized for educational purposes, see Figure 3 in Section 4.4.

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.

6.3 Findings Publication III

The results of Publication III are partly a corroboration of the findings of Publication I. Here, the analysis of the new compiled material of interview rounds a and b together provided a deepened and more nuanced understanding of how the *physics expert* model is an applicable tool to understand physics culture in relation to physics teacher education. The research question for Publication III was:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

For the purpose of Publication III, culture was defined as a pattern of shared basic assumptions that were recurring in the analysis (Schein, 2010). The analysis of the 11 interviews of rounds a and b together resulted in the identification of five assumptions about physics, physics teaching and trainee teachers. In what follows, I present the five assumptions together with their logical implications.

6.3.1 The Physics Expert Assumption

The Physics Expert Assumption holds that *the purpose of all undergraduate physics teaching is to create physics experts*. Regardless of whether they taught mixed groups of students that included trainee teachers, or groups consisting entirely of trainee teachers—physics lecturers talked about their teaching as though their students were expected to move from school physics, via undergraduate physics, to end up working in research. 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 student group he teaches, this physics lecturer 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 later will 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 I their physics learning. However, 11Lb re-constructs this question as being about physics itself, saying 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" and away from 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, where some of the students can be assumed to aim for a future in physics research. However, the same cannot be said of the interviews with physics lecturers who teach trainee teacher-only groups. Here it would be strange to explicitly state that trainee physics teachers should aim towards becoming physics experts. However, even though this idea was not explicitly stated in these interviews, the *physics expert* 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 physics lecturer is careful to not take on an identity of physics teacher. To be recognized as a physics teacher is made 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 this 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 physics lecturer 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.

6.3.2 The Content Assumption

The Content Assumption holds that *the appropriate physics content for future school physics teachers is the same as that for future physicists.* When the physicists discussed the undergraduate physics they teach, the content appropriate for future physicists and engineers was allowed to set the agenda also for trainee teachers.

> Interviewer: Do you have different goals for physicists and engineers?
> Physics lecturer: Yes, I suppose... but only slightly different.
> Interviewer: And for the teachers is it the same?
> Physics lecturer: Yes, I don’t really distinguish between them. You need to understand physics to be able to teach it.
>
> Physics lecturer *7Sb*

Taking part in the same training as future physicists is here assumed to be sufficient to become a physics teacher. The needs of trainee physics teachers were either discussed as identical to those of physics experts, or left unaddressed. This was a recurring theme throughout the interviews with all eleven physics lecturers.

6.3.3 The Goal Assumption

The Goal Assumption, *the role of a school physics teacher is to create new physicists*, was discerned in physicist talk about the goals of school physics teaching. 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

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. This is an example of how, in the interviews, the overarching goal of a school physics teacher was not expressed as contributing to a more scientifically literate society, as set out in the school physics curriculum, but rather the role of a school physics teacher is to create more physicists.

6.3.4 The Student Assumption

The Student Assumption holds that *students who become physics teachers do not have the ability to make it as successful physicists*. A common response throughout the interviews with lecturers teaching at larger universities with mixed groups of students, to any question regarding trainee teachers was "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 students. In this way, a student version of the Physics Expert Assumption, that all students can be assumed to be striving towards research, was seen in the analysis. This means that trainee physics teachers are striving towards something that is assumed not to be desirable, and this is either overlooked or marginalized in physicist talk.

In this structure of meaning, trainee physics teachers are rendered different from the "ordinary", "normal" or "real" physics students, where the "normal" physics student is one who wants to become a physics expert. This assumption about who "normal" physics students are fits well with the goal and content assumptions discussed in the previous sections.

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.

6.3.5 The Teaching Assumption

The Teaching Assumption holds that *if you know physics then it's not difficult to teach it.* In the interviews with physics lecturers, learning to teach physics was above all connected to gaining *enough* physics knowledge.

> I think that you can't really become a physics teacher if you're not really interested, then it's a bit difficult to… And if you are interested, then you should be able to, then I don't think it's that difficult to get good at it. Or at least to get to a level that is good enough.
>
> Physics lecturer 3La

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. Thus, one aspect of physics culture here seems to be the assumption that a genuine interest in physics and in teaching is enough to become a good physics teacher.

6.4 Findings Publication IV

The research question for Publication IV was:

> How do upper secondary trainee physics teachers experience the purpose and goals of their undergraduate physics learning, when studying physics together with other programme students?

The main findings are four central themes describing trainee physics teachers' experiences of studying physics together with other program groups as part of physics teacher education. These themes are: *Teacher programme invisibility*, *Passive classroom culture*, *Perceived relevance of physics courses*, and *No incentive to do well in physics*. Frequency counts for these themes can be found in Table 3 in Section 5.5.3. In what follows, I briefly describe each theme.

6.4.1 Teacher programme invisibility

Learning physics together with physics programme students and engineering students, the trainee teachers experience their visibility as limited on a programme level, and describe feeling they are not treated in the same way as the other program groups. Andrej says:

> If you study with the physics programme students, then the focus is not so much on the trainee teachers, but rather it's a physics programme course. It's the same when we have courses together with the engineering students, then it's an engineering course. [...] There have been courses where they don't – where [the physics lecturer] doesn't know that there are trainee teachers in their – like in the course. And sometimes we feel a bit bitter, because we're also taking this course, shouldn't we also receive the focus we need? But this is something we adapt to, we make it work.

In this theme, the agenda when several groups learn physics together seems to be defined by the other participating programmes, and physics lecturers do not acknowledge that trainee teachers are present. In this way, the trainee physics teachers experience invisibility on a programme level, feeling that they are learning physics in a way that is based on the needs of other student groups.

6.4.2 Passive classroom culture

The theme *Passive classroom culture* captures how trainee physics teachers experience the physics classroom. The trainees describe how they hesitate to carve out visible spaces for themselves in class, due to the risk of giving the wrong answer and thus being perceived as not good enough. They describe a culture within the physics classes, where a majority of the students neither ask, nor answer, questions. One example is given by Tom:

> Interviewer: would you say that there are some norms—that you need to act in a particular way to fit in?
> Tom: [...] Physics students are not good at answering questions [erm] that are put to the whole group and, that has been clear for a long time [...] it's almost an unwritten rule, that no [physics student], and not just the trainee teachers but also the physics programme students, no one answers the question […] I guess it has something to do with not wanting to give the wrong answer and always being sure of the answer before speaking up.
> Interviewer: That shyness, or that unwillingness to be wrong, can you see that anywhere else?
> Tom: [...] It's not really about being shy, but for some reason you don't want to be the one who answers, it's a bit like not wanting to be the one who answered wrong.
> Interviewer: How is it with asking questions, then?
> Tom: We're not good at that either. It feels like most physics students want to lower their heads, take notes, and then go through those notes later to teach themselves.

Here, Tom attributes the unwillingness to ask and answer questions that he has experienced during his physics courses, to a fear of giving the wrong answer. Tom's final comment in this quote was interpreted as pertaining to the general study culture among the trainee teachers, where students prefer to place their active learning outside of the classroom. In this way, the trainee teachers describe a classroom culture of passivity, where asking and answering questions is limited by the fear of not being right.

6.4.3 The perceived relevance of physics courses

The trainee teachers spoke about the relevance of their physics courses in three main ways that correspond to the three largest sub-themes under relevance in Table 3 in Section 5.5.3. These are: *Need to know school level physics*, *Providing space when teaching physics*, and *Questioning relevance*. In summary, the trainee physics teachers expressed confidence in the relevance of introductory physics courses, but ambivalence to the relevance of their higher-level physics courses. The trainees either questioned the relevance of advanced courses or just assumed they were needed in some way. Combined, the three sub-themes of relevance convey a picture of physics courses with limited or uncertain relevance when they exceed content taught at upper-secondary school level.

In the first sub-theme, the relevance of physics courses was judged in terms of their direct correspondence to school level physics. When asked whether he experiences the physics courses as adapted to his future Daniel says:

> Yes, it's on a higher level, but still things that you have, like, that you have seen and worked with at some point in secondary school. So, that, yeah it feels like these are things that will end up in my teaching. Perhaps not on this level. [...] I mean I had in the beginning mechanics courses. Of course, we will have mechanics [in school]. And waves and optics. These are things you learn at some point, uh, even at secondary school and perhaps already at elementary school, on an even lower-level sort of. So yeah, in that way the physics courses feel relevant. {mm} Yes.

In the second sub-theme, *Providing space when teaching physics*, higher-level courses that do not correspond to school physics were described as vaguely relevant in that they provide some extra space to make your physics teaching better. Daniel for example, from the quote above, reflects on higher level physics courses:

> I often think rather that this was interesting, but this, this is not something we talked about in secondary school. This is not something I will ever teach. {mm} But…But I understand that you should…A higher…I mean more knowledge than what you will perhaps teach {mm} but… Yeah.

Here Daniel asserts the relevance of higher-level physics courses, but he does not sound convinced by his own reasoning, signalled by the "but", the tone of his voice and seeking way of speaking. This kind of vague reasoning about relevance is representative of this theme, where a common response was to assume that higher level courses are relevant, but without identifying why.

The third sub-theme, *Questioning relevance*, was the largest theme, mirroring that the most common student response regarding the relevance of the physics courses was to question it. In this theme, learning advanced physics was discussed as irrelevant to the goal of becoming a physics teacher. For example, Ellen fails to connect her physics courses to her future job as a teacher:

> Interviewer: Is there anything you have experienced as difficult about studying to become a teacher?
> Ellen: I guess it's the physics. I think that when I started in the physics teacher programme, I was thinking a little like this: Ok, I want to become a teacher. And sure, I need to know a certain level of physics, but I thought that, maybe that's not super difficult physics. Of course, you need to go deeper in all parts, but I maybe don't need to become like an expert in everything. That was totally wrong (laughing) [...] Because in the beginning it was like, I felt like I was becoming just a physicist, because I saw no connection to anything, anything related to teaching at all.

For Ellen, it did not feel like she was studying to become a physics teacher at all, rather she felt as if she was part of the physics bachelor programme. In the continuation of this quote, Ellen went on to explain that she finds physics content that corresponds to school level physics clearly relevant, while it is unclear why she needs the more advanced courses.

6.4.4 No incentive to do well in physics

The fourth theme captures patterns in how the trainees discussed how being successful in physics courses is irrelevant for their future as teachers. Being successful in physics was throughout the interviews connected to high grades ("getting fives") and the significance of good grades came up in just over half of the interviews, mostly in the context of discussing the differences between trainee teachers and the other student groups:

> Hampus: Yes, in general we have, us teachers—there are seven of us—in general our grades are worse than the physics programme students'. That's true.
> Interviewer: Why is that?
> Hampus: I think we don't care as much about getting fives [the highest grade]. Because it doesn't matter for our jobs anyway. But I think, I don't know that much about doing a PhD, and going on with research and so on but, I guess it's an advantage to have fives if you are going in that direction.

> So that's why the physics programme students work their asses off (laughing) doing as well as possible. We can be a bit more relaxed, since we don't have this, these high expectations when entering the work-force, I believe we are not taking things as seriously {mm}, it's fine to just pass, it doesn't matter if I only get a 3 [pass grade]

Here, Hampus assesses the importance of high grades in physics on the basis of getting a job and the conclusion is that high grades are irrelevant if you are becoming a teacher. At the same time, Hampus does not appear to consider high grades in physics as a sign of having gained deeper knowledge that could be of use in a teaching career.

While some of the trainees did say they do aim for higher grades in physics, none of them frame their success in physics as having any implications for their future career teaching physics. Throughout the interviews, the students talked specifically about grades, rather than about understanding or learning physics on a deep level. Grades were also discussed in terms of getting a job, or getting ahead of the competition, rather than being related to physics knowledge needed for teaching. In the whole interview material, being successful in physics is equated with good grades and seen as an "optional extra" for trainee physics teachers. Physics courses are thus experienced as something that simply need to be passed and there does not appear to be any real incentive for the trainee physics teachers to excel.

6.5 Findings Publication V

In the analysis for Publication V, I chose to focus on the interviews with three female students (the Trio), using the rest of the interview material as a backdrop to aid interpretation. The research question was:

> How do female trainee physics teachers negotiate their positioning as women and physics experts to create spaces for themselves as learners of physics?

The women in the Trio described learning physics in a discourse that connects physics with nerdiness, masculinity and intelligence. They simultaneously submit to and master this "physics nerd discourse" by constituting feminine positions that imply being socially competent, happy, bouncy, and lively. This enables them to resist expectations to perform the right kind of "smart" physics student, and successfully create subject positions of physics student, trainee physics teacher, and positive femininity. However, this resistance is possible first when they submit to the physics nerd elite discourse by accepting and using their position as women and trainee teachers in the "stupid gang".

6.5.1 Female community and feminist awareness

All three of the Trio described preferring to hang out with other women rather than socializing with the mostly male physics students. In doing so, they position themselves as different than the male physics student group, rather than aiming to fit in. To Ellen, being part of a female friendship group that shares a feminist understanding of society, has opened her eyes to new ways of understanding her experiences of studying physics. All three of the Trio described experiences of being interrupted, not heard, or not recognized as competent, due to being women in physics. Ellen previously has taken these experiences as a reflection of herself as a person being inadequate. However, now she can reformulate these experiences in terms of sexist structures in physics and society. The feminist awareness and female community thus make it possible to understand experiences of not being taken seriously or recognized in physics, as a sign of prejudice rather than of a personal lack of competence.

6.5.2 Female overachievers and laid-back teachers

For Julia, finding a feminist female community in physics has made it possible to identify more strongly with being a physicist herself. However, Julia ambivalently positions herself as outside the group of female physics students that aim to do research, even though she says she also has this dream. She says she is too mediocre, or not ambitious or smart enough, to be a bachelor student. At the same time, she rejects the study culture among the female bachelor students where authenticity is signalled by working very hard and appearing stressed and burned out. Julia actively resists this norm by demonstratively talking about taking it easy, feeling good and not studying. However, rather than showing the way towards a more relaxed way of being a woman in physics, this talk positions Julia firmly in the group "laid-back teachers" that do not have to fulfil the same standards as the bachelor students.

Julia's way of talking about herself and other students positions her as different from the female bachelor physics students who struggle to be recognized as competent in physics. This struggle takes place on the premises of a physics student community characterized by elitism and nerdiness, that creates sub-optimal conditions for learning physics (as illustrated by high stress and burnout). The bachelor students take themselves and their education very seriously, and, ironically, the feminist awareness of an unequal playing ground adds to the pressure. Julia expresses disappointment with the female bachelor physics students for trying to master positions of successful physics students and thereby submitting to the physics student culture's premises for legitimacy. They all fight for recognition in physics, but the successful position is not available for Julia as a trainee physics teacher. This means that Julia can take on a more relaxed position, that is paradoxically more likely to enable learning, while the female bachelor physics students have to accept the premises of the physics elite discourse.

6.5.3 Positions of learning physics

In the discourse of learning physics, the Trio describe how legitimacy is created by performances of intelligence and never being wrong. They establish themselves as different from the other students through being critical of their education and speaking up when the demands are unreasonable. They all discuss the workload needed for someone of "average intelligence" to pass the physics courses, rejecting the notion that someone who has what it takes to become a physicist will not be affected by low-quality education. They thus create room to interpret untenable study conditions as being a consequence of the organization of the program rather than they themselves not "having what it takes" to succeed.

Many of the 17 interviewed trainee physics teachers said they react to the study environment by becoming passive and careful not to give the wrong answer or be too visible in the classroom. The Trio also described how not understanding during physics problem solving has a pacifying effect on the students, rather than triggering them to search for knowledge. If understanding does not occur immediately, it becomes difficult to remain in an active learning position, and both lectures and problem-solving sessions become useless as instances of learning. However, the Trio actively and consciously resist this assumption, when they accept visible positions of not understanding and thus renegotiate both physics study practices and the premises of lectures. For the Trio, being able to accept and endure a position of not understanding becomes a prerequisite for the process of learning. They associate success in physics with passion and working hard to arrive at understanding, rather than with the anxiety and stress associated with the demand to instantly understand.

7 Discussion and looking forward

Physics teacher education is one of the main ways to impact school-level physics teaching and learning, a practice that has the potential to affect both who wants to pursue physics and how physics is perceived by non-physicists. Furthermore, a physics teacher education of high quality is an important tool for inspiring ambitious students to choose physics teaching, in a time when both the teaching profession and teacher education is often discussed in negative terms in public discourse (Edling & Liljestrand, 2020; Hjertström, 2019). Students on the physics teacher programme participate in both educational science and physics, two academic disciplines with very different cultural connotations and knowledge structures. This provides them with a potential outsider-within perspective on the discipline of physics, giving them access to an epistemic position that allows them to recognize and verbalize the disciplinary culture. This contrasts with how such characteristics can go unnoticed by students who fulfil the normative expectations of a context (Danielsson et al., 2019). Exploring trainee physics teachers' experiences of learning physics is thus not just important for understanding their particular circumstances, but also holds the potential to shed new light on the discipline of physics and the culture of learning physics.

In this thesis, I have aimed to investigate what is involved in being recognized as a successful physics teacher-to-be in a Swedish physics teacher programme. My goal is not to provide a generalizable description of this environment. The thesis project can be characterized as a case study, which implies a certain set of limitations to the knowledge claims that can be made. In general, all results reported in this thesis build on a limited number of interviews with educators and trainee physics teachers. This data says a great deal about the local context of physics teacher education, but the results should not be assumed to be generalizable to other institutions, within or outside Sweden. Rather, I present one example of the interplay between physics teacher education and trainee physics teachers, and suggest that the results will have resonance (Tracy, 2010) with physicists and physics teacher educators who can use them to reflect on their own practice and their particular context.

In the first part of the project, I investigate what is involved in being recognized as a legitimate physics teacher-to-be, from the perspective of the education that is offered to trainees. I thus focus on the discourses that trainees need to negotiate to be recognized as legitimate physics teachers. Here, I analyse how educators talk about teacher education. In summary, the findings of the first part of the project describe physics teacher educator discourses from three perspectives: First, from the perspective of the different parts of the educational system, analyzing the talk of educators from the physics department, the education department, and school. Here four discourse models are identified, presenting a fragmented picture of physics teacher education. The second perspective on physics teacher educator discourses is theoretical. Here I discuss the differences in knowledge structure between the disciplines of physics and education and how this may present some potential challenges to trainees as they move between these educational environments. Finally, I focus on how physicists talk about physics teacher education. Here, I identify five default assumptions in physicists' talk, that together paint a picture of the goal of learning physics as being about becoming a researcher. Choosing to become a teacher in this system means diverting from the expected path, and moving backwards towards teaching school physics. In such a system, trainee physics teachers can be understood to be incomprehensibly "swimming against the tide", or as in the title of this thesis, to be "going against the flow", by wanting to return to school physics.

The findings of the first part of the project suggest that the educator discourses are fragmented and seem to present some challenges involved in being recognized as a legitimate physics teacher. These challenges are further discussed in Sections 7.2 (Educator discourses and trainee identity performances) and 7.3 (Connecting the five assumptions to trainee experiences).

In the second part of the project, I take the perspective of trainee physics teachers, with a special focus on how they navigate their experiences of learning physics, to be recognized as legitimate physics teachers-to-be. I do this in two ways. First, through analysis of the whole student material, identifying four central aspects of how trainees describe their experiences of learning physics. Second, through deep analysis of three of the student interviews, to explore how they negotiate these experiences in unique and constructive ways. In summary, the second part of the project shows how the programme organization is experienced by the students as foremost meeting the needs of other programme groups, making trainee teachers invisible in physics courses. The relevance of the physics courses for a future in teaching is unclear for the trainees, as they seem to be designed for the progression of the bachelor programme in physics. Further, the trainees describe a study culture that puts emphasis on appearing smart and not being wrong, resulting in a passive classroom culture and high stress. The Trio's identity negotiations show one way in which students are resourceful in navigating this study culture to be recognized as legitimate physics teachers-to-be. By using the very identity markers that make being recognized as successful difficult, they manage to craft constructive positions of learning physics. In Section 7.4 (Negotiating passive and elitist discourses of learning physics) I further discuss how the trainee physics teachers negotiate positions as legitimate physics teachers and learners of physics.

In the following section (7.1), I briefly summarize the findings of the two parts of the project. For the reader who has not read the previous chapters, this section contains enough information on the findings for the rest of the discussion to make sense. In Sections 7.2 to 7.7 I discuss several issues raised by considering the findings of the individual publications together. Section 7.8 discusses the implications of my work. Section 7.9 summarizes my contributions to Physics Education Research. And finally, Section 7.10 points out several interesting directions for future work.

7.1 Research questions and findings

7.1.1 Project part one

In the first part of the project, I focus on how physics teacher educators talk about teacher education. To investigate the discourses of physics teacher education, for Publication I, I interviewed nine teacher educators in the three different environments that trainee physics teachers move between during their education. The research questions for Publication I 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?

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 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. A physics expert is here defined as someone who does research or works with technical applications of physics. This goal means that the choice to become a teacher is difficult to understand and it appears that there are no valued ways of performing a teacher identity within the physics expert model.

The four discourse models represent logical systems of meaning where practice is understood with reference to what the educational programme is striving to achieve. Each such system is also associated with a celebrated way of performing a physics teacher identity. Together these celebrated identity 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. The findings of Publication I thus show that in this system of physics teacher education, there does not seem to be one coherent way of being recognized as a legitimate physics-teacher-to-be.

In Publication II, I use the theoretical constructs of disciplinary literacy together with a Bernsteinian disciplinary knowledge structure perspective to theoretically approach the discourses of physics teacher education. The research question was:

> 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. This means that meaning is taken to be unchanged across contexts and knowledge is constructed through integration into the larger existing hierarchical structure. The discipline is also seen as an end in itself. In contrast, education would be categorized as horizontal region. Here knowledge is created in a number of specialized "languages", each suited to a particular context. In educational science, knowledge from a number of disciplines is recontextualized for educational purposes. In Publication II, it is suggested that these differences in knowledge structures and especially the different ideas about what counts as valid knowledge in the two environments, risks 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 II points towards how the learning of trainee physics teachers could be negatively affected by the discourses of what counts as knowledge in the environments they encounter.

Noticeable in the results of Publication I was the *physics expert model*, where the goal of teaching physics is understood to be to create someone who does research or works with technical applications of physics. In this 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. Eight interviews with physicists from three more Swedish universities were added to the data set for Publication I. The research question for Publication III was:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

The analysis suggested that the culture of Swedish physics departments sustain five underlying assumptions around physics, physics teaching, and teacher education:

1. The *physics expert assumption*: the purpose of all undergraduate physics teaching is to create physics experts.
2. The *content assumption*: the appropriate physics content for future school physics teachers is the same as that for future physicists.
3. The *goal assumption:* the role of a school physics teacher is to create new physicists.
4. The *student assumption:* students who become physics teachers do not have the ability to make it as successful physicists.
5. The *teaching assumption:* If you know physics then it's not difficult to teach it.

The first of these assumptions, the *physics expert assumption*, is a reformulation of, and therefore in substance very similar to, the *physics expert model*.

The talk of the physics lecturers in Publication III could be seen to align in patterns indicating that a "normal" expected progression is for students to go from school physics, through undergraduate physics and on into expert physics. The goal of learning physics was implicitly assumed to be research in physics, and choosing to become a teacher in this discourse means diverting from the expected path, and moving backwards towards school physics. Physics teachers are thus moving away from the expected goal of becoming physics experts, possibly because they do not have what it takes to continue with physics. In such a system, trainee physics teachers can be understood to be incomprehensibly "going against the flow" by wanting to return to school physics.

7.1.2 Project part two

To investigate trainee teachers' experiences of learning physics in the educational system described in project part one, I interviewed 17 trainee physics teachers in project part two. The research question for Publication IV was:

> How do upper-secondary trainee physics teachers experience the purpose and goals of their undergraduate physics learning, when studying physics together with other programme students?

Four central aspects of the trainees' experiences were identified in the analysis:

1. Feeling invisible on a programme level in the physics courses.
2. Experiencing a classroom culture of passivity focused on giving the right answers.
3. Physics content that exceeds the upper secondary school level is experienced by trainees as having limited or uncertain relevance.
4. There is a lack of incentive to be successful in physics.

One way of interpreting these four themes is that they represent aspects of what it is like for this group of students to be part of a physics programme that is not designed primarily for them.

In the analysis for Publication IV, the stories of three of the interviewees stood out due to the unique and constructive ways in which they negotiated these experiences. Publication V focuses on these three of the 17 interviewed trainee teachers and closely explores their identity negotiations. The research question for this publication was:

> How do female trainee physics teachers negotiate their positioning as women and physics experts to create spaces for themselves as learners of physics?

The women in the Trio describe learning physics in a discourse that connects physics with nerdiness, masculinity and intelligence. Many students are passive in the classroom, careful not to be too visible, or give the wrong answer. Not understanding during physics problem solving has a pacifying effect, rather than triggering the students to search for knowledge. The women in the Trio simultaneously submit to and master this "physics nerd discourse", by performing feminine positions that imply being socially competent, happy, bouncy, and lively. This enables them to resist expectations to perform the right kind of "smart" physics student, and to instead inhabit constructive positions of active and relaxed physics learning. However, this resistance is only possible once they submit to the physics nerd discourse by accepting and using their position as women and trainee teachers in the "stupid gang".

Female community and feminist awareness are important resources for the Trio, in the struggle to master positions as competent physics students. This enables the Trio to reinterpret the reasons for their experiences of not being recognized as competent in physics, from individual failure to a fault of the physics learning environment itself.

7.2 Educator discourses and trainee 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 be recognized as a professional teacher (Danielsson & Warwick, 2014b; Olsen, 2008; Saka et al., 2013; Varelas et al., 2005). By suggesting that such a discussion cannot be carried out in a vacuum, this thesis takes up this call, and aims to problematize the training programme as a context that steers and limits professional identity performances.

One implication of the discourses described in Publication I, is that there seems to be no single way of performing a professional physics teacher identity that would be simultaneously recognized and valued within all four discourse models. What can we learn about how these professional discourses of educators can be expected to affect trainee physics teachers? In Publication I, 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 partial incoherence in the discourses of the educators. It is not clear which, if any, physics teacher professional identities trainees are expected to perform.

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 several 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 may lead to a situation where trainees view 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 the interviews I conducted with both educators and trainees. Elsewhere, efforts for programme-cohesion have been made, one example can be found in the literature on reform-minded teaching (Luehmann, 2007). In this work, science teacher education has been designed with a particular identity performance, the reform-minded teacher, in mind. However, even 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 recognized as a professional teacher in school means being able to perform teacher identities that are intelligible within this context. 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 must also be valued in school.

In the particular educational programme studied in Publication I, school placement forms part of the education. Here, the two discourse models that were primarily constructed from the talk of school mentors (the practically well-equipped teacher model, and the physics expert model) would be expected to be most relevant to school reality. Thus, it is perhaps these two ways of viewing the educational programme, that are most likely to render students recognizable as professional physics teachers in school. This might entail an emphasis on the teacher knowing a lot of university physics, combined with a traditional Vision I understanding of the purpose of school physics as aiming towards academia. It would also emphasize being practically able to deal with school teaching, while deemphasizing more theoretical pedagogical understandings, such as critical reflection.

7.3 Connecting the five assumptions to trainee experiences

In this section, I connect the student discourses described in the second part of the project with the educator discourses of physics teacher education described in project part one. In the results of Publication III, the physicists' talk expressed ideas indicating that a "normal" expected progression in physics is to go from school physics, through undergraduate physics and on into doing research in physics. In the analysis I came to see the culture of physics as it pertains to teacher education as being built around this assumption and four others. In a system where the goal of all physics learning is implicitly assumed to be expert physics, choosing to become a teacher means diverting from the expected path in order to go back to school physics. In such a system, trainee physics teachers are moving in an unexpected direction. As mentioned above, trainee teachers can be understood to be incomprehensibly "going against the flow" of university physics by aiming towards returning to school physics. This relationship is illustrated below in Figure 6.

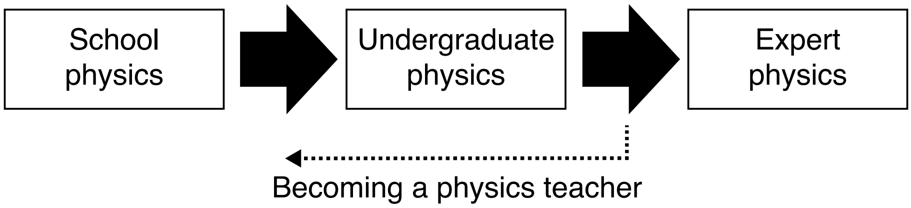

Figure 6. Trainee teachers "going against the flow" of the physics expert assumption. Reproduced from Publication III under the CC BY 4.0 licence.

The student assumption addresses the question why anyone, in the light of the negative discourse associated with the teaching profession in Sweden, would choose to become a physics teacher: *Students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists.* This makes sense in the light of the physics expert assumption, since 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. The teaching assumption further downplays the expert knowledge a physics teacher might need, because understanding physics is assumed to automatically lead to good physics teaching.

In these discourses around physics teaching, advanced physics knowledge is seen as 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. These discourses around being and becoming a physics teacher, seem to enable only limited ways of performing a celebrated professional physics teacher identity.

In Publication IV, the physics learning environment is described from the perspective of trainee teachers, presenting four themes of student experiences. These themes convey an image of trainees as marginalized and learning physics on the periphery of university physics education, with the bachelor and engineering programmes at the centre. The trainee teachers do not experience that physics faculty are committed to physics teacher education, an aspect that has been identified in the literature as an important factor for high quality physics teacher education (Marder et al., 2017; Scherr et al., 2017; T-TEP, 2012)

In the theme of programme invisibility, trainee experiences seem to directly agree with the pattern in educator discourse signalling the emphasis on the creating of physics experts and a lack of focus on the education of physics teachers. Trainees are uncertain of the relevance of their physics courses and experience that they have been designed for someone else. In addition, trainees find no incentive to try hard for good results in physics. This can be connected to the *content assumption*, where physics courses primarily designed for the bachelor programme are assumed to also fulfil the needs of trainee teachers. The teaching assumption—that knowing physics is enough to teach it well—further diminishes any special need trainee teachers might have, and devalues the teaching expert knowledge they might gain in other parts of their educational programme.

The trainee teachers interviewed for Publication IV expressed that they expected the physics content included in teacher education to be clearly connected to the specifics of becoming a teacher, and that this was not the case when they started learning physics. This might be read as a focus close to that of the *curriculum implementer* discourse model, where an important part of teacher education would be "syllabus physics" that directly mirrors and expands on the physics specified in the school syllabus. However, in contrast to the *curriculum implementer* model's understanding of school physics, the trainees did not have a broad awareness of the syllabus and mostly talked about learning to teach the content to prepare students to continue with physics. In this case, student talk mirrored the *goal assumption,* that takes on a straight Vision I (Roberts, 2007) "physics for physics sake" understanding of school physics, that does not correspond to what is in the actual school physics curriculum (Skolverket, 2011a), where both Vision I and Vision II "physics for society" aspects of physics teaching are represented.

Trainee teachers' lack of motivation to excel can be understood as another aspect of the theme of invisibility, since the assessment in physics is designed with the needs and goals of Bachelor students in physics in mind. In order to stand out as successful, a trainee physics teacher would need to strive for good grades without the incentive of these grades having more than a peripheral bearing on their future career opportunities as a physics teacher. Considering this together with the *student assumption*—that students who become physics teachers do not have the ability to make it as successful physicists—make way for a very interesting dynamic. Educator talk about trainee teachers as less competent and ambitious is mirrored by trainees who see no incentive to try hard for good results. I believe this case might be useful when considering the calls for recruiting the most successful physics students to teacher education as a way to increase the quality of physics teachers (Teach for Sweden, 2020; T-TEP, 2012). If confidence and fluency in physics are the primarily prioritized qualities for new physics teachers, it is important to ask whether the educational system is flexible enough to allow trainee teachers to be seen as successful physics students.

These aligning patterns of educator and trainee discourses that I have described could be interpreted as being a consequence of trainees reacting to and experiencing the consequences of physicists' negative views of teacher education. However, the five assumptions do not represent physicists' actual or espoused views of a majority of physicists, but rather patterns in how the interviewed physicists talk about teacher education. Moreover, there is no way in which this kind of causal connection can be made from my interview data. I believe it is interesting enough to understand the combined results of Publications III and IV as representing the shared discourses of physicists, physics bachelor students and trainees who work and study partly in the same environments.

7.4 Negotiating passive and elitist discourses of learning physics

Within the discourses of learning physics, the trainees interviewed for Publications IV and V describe how legitimacy is contingent on appearing intelligent, never being wrong, and instantly understanding physics. The trainees hesitate to carve out visible spaces for themselves, due to the risk of giving the wrong answer and thus being perceived as not good enough. The majority of students do not ask questions in class, and Tom described how physics students prefer to "lower their heads, take notes, and then go through those notes later to teach themselves". This discourse is similar to what Berge et al. (2020, p. 78) call a "storyline of mastering physics" where the risk associated with giving the wrong answer makes the physics classroom a less secure place. It also stands in stark contrast to the collaborative, open, and active physics environment described by Johnson (2020), that was found to be particularly inclusive for racialized women. One initiative that is engaged in breaking such patterns is the ISLE method, that encourages students to contribute with their own "crazy ideas" and thus take an active, legitimate part in the process of constructing knowledge in physics (Etkina et al., 2019, pp. 6–2).

The kind of passive learning environment I identify is not optimal for learning, not least because the activation of students when learning physics has been shown to be of great importance (Fraser et al., 2014). Moreover, students who feel able to openly discuss the fact that they do not understand physics content have been shown to have better learning gains (Dowd et al., 2015). For non-majority students, breaking the stereotype where physics is connected to intellectual superiority is seen as particularly important (Leslie et al., 2015). It is important to ask what the particular meaning of such a classroom culture is for trainee physics teachers who are preparing to create their own classrooms. I will discuss this further in Section 7.7 (Learning to teach physics in an inclusive way).

The discourses of learning physics are however not something just offered to students that they are expected to passively submit to. To successfully be recognized as competent in physics, trainee teachers must master these discourses, and doing so opens up the possibility to subvert and distort them. The

Trio's negotiations are one example of this, where positions of feminine woman, trainee teacher, and physics student are combined to create positions of relaxed and constructive physics learning that challenge the elitist physics discourse. The women in the Trio actively chose to stay in a position of not understanding physics, to give room for joint information seeking and being able to study in a relaxed and constructive way. This doing of physics learning is entangled with the doing of femininity, something that the Trio consciously use to avoid expectations to always instantly understand, or appearing very stressed out.

In contrast to the exceptionality that previous research has shown that female physics students may need to perform (Archer, et al., 2017), the Trio is thus able to reconcile a position of "unexceptionality", where their participation in physics is not conditioned on top performances and nerdiness. Combined with being a trainee teacher, this is associated with a risk of not being recognized as authentic physics students and read "in the dumbest possible way" (Elin). However, the impossibility of gaining status on the premises of a physics student community characterized by elitism and nerdiness also makes it possible for the Trio to be critical of their education and speak up when the demands are unreasonable.

7.5 Different perspectives on the theory practice gap

Student experiences of relevance in physics have been connected to better learning outcomes, higher motivation, and enjoyment of physics (Afjar et al., 2020; Bennett et al., 2016; Descamps et al., 2020; Gaffney, 2013; Geller et al., 2018; Nair & Sawtelle, 2019; Plomer et al., 2010). The question of trainees' experiences of relevance in physics teacher education is thus an important one, that has the potential to affect what they prioritize to learn. Here, the discourses of teacher education may affect the learning of trainee physics teachers, when the intelligible ways of performing professional teacher identities described in Publication I would bring some course content to the foreground, whilst other content is framed as less important (or even a waste of time). One example is the *teaching assumption*, that suggests that knowing university physics is enough to become a good teacher. This ignores the particular challenges of teaching school physics, including the transformation of physics content from university to school level, and from English to Swedish. The content of school physics is experienced as problematic by a large number of students (Angell et al., 2004) and trainee physics teachers need to learn to understand these problems and how they differ from those faced by future physicists. If learning to teach physics is talked about as solely being about learning enough specialist physics as in the teaching myth, then it is unlikely that trainee physics teachers will put much effort into learning the particular complexities of teaching school physics.

One common finding in this area is that trainee teachers find the pedagogical part of teacher education too theoretical and removed from reality, and thus do not see its value for learning to teach. This issue has been extensively discussed in the literature under the heading of the theory-practice-gap (Allen, 2009; Korthagen, 2007). The trainee experiences described in Publications IV and V mirror these findings, in that they in several cases talk about educational theory as too easy, removed from reality, and a waste of time. There is also a pattern of more positive attitudes towards both the physics courses and the school placement in trainee talk. However, the student ambivalence towards the relevance of physics courses described in Publication IV points towards a more complex picture of student perceived relevance than a straight rejection of educational theory and valuing of physics content. Trainees express having difficulties connecting the university physics content to their future in teaching school physics, something that is mirrored by the *expert*, *teaching* and *content* assumptions from Publication III, where physicists' discourses paint a picture of physics content as clearly designed for a future in research. These results point towards a need to further nuance the theory-practice-gap discussion, since in this case it does not seem to be the distance between content and teaching reality that is at the root of trainees' lack of perceived relevance. Here, specialized courses focusing on teaching physics ("fysikdidaktik") can potentially play the role of connecting and motivating both physics content courses and pedagogical courses.

One perspective is to view the theory practice-gap through the lens of epistemology (Guilfoyle et al., 2020). This is discussed in Publication II in terms of the differences between the disciplines of physics and education, using Bernstein's disciplinary classifications. 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 recontextualized for educational purposes. These differences between physics and education can potentially give rise to difficulties when trainees repeatedly move between environments deeply rooted in the different disciplines. Here, collaboration between the education department and physics department would be desirable to help trainees navigate such difficulties.

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 the educational science content of teacher education, something that has been documented to be the case in the literature (Guilfoyle et al., 2017, 2020; Molander & Hamza, 2018;

Sjølie, 2014). The theory-practice-gap can thus in this perspective be explained by differences in the knowledge structures of education and physics.

Another perspective is to understand trainee science teachers' reluctance to value educational theory through a social power perspective, where trainees accept the relevance of theory based on the perceived authority of the teacher educator (McGarr et al., 2017). If teacher education is understood through discourses similar to the *physics expert model* and the five Assumptions, the expert knowledge and authority of education lecturers might be hard to appreciate. If knowledge in expert physics is enough to become a good physics teacher, what is the point of educational theory? The relative status of a subject such as physics, associated with competitive and well-funded research, Nobel prizes, and brilliant intellect, also certainly plays a role in this (Becher & Trowler, 2001). I believe this perspective needs to be explored further, with a focus on differences in status and the relationship between subject knowledge and educational science in teacher education. Here, the perceived status and knowledge structure of specialized courses focusing on teaching physics (fysikdidaktik) are of particular interest, since they might be understood as positioned in between physics and pedagogy.

7.6 The role of physics content in teacher education

In Sweden, the relationship between school physics and university physics has been discussed in terms of how school physics in some aspects has functioned as a static and simplified version of university physics, while at the same time, the Swedish upper secondary school syllabus has brought a larger focus on equity and physics for society (Engström & Carlhed, 2014; Löfdahl, 1987; Skolverket, 2011b; Sundberg & Wahlström, 2012). In this way, the purpose of school physics in the syllabus can be said to have moved from being contained within a narrower Vision I, "physics for physics sake" understanding to opening for a broader Vision II "physics for society" understanding (Roberts, 2007, 2011).

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 school physics. The Vision II aspect of physics teaching (i.e. science for society) goes unnoticed. Only a handful of all students in compulsory school will become physicists. Trainee physics teachers risk learning physics in a way that does not prepare them for their main role of teaching physics for all, if they have only ever met the narrow "physics for physics sake" perspective in their educational programme. Even when questioning the relevance of their physics courses, the trainees that I interviewed did not discuss them in a nuanced way in relation to the school physics syllabus. They judged university physics in terms of corresponding or not corresponding to the subjects listed in the syllabus (as they remember them from school).

In general, discussions about the specific role of physics content courses in physics teacher education still seem to be rare. For example, deWinter and Airey (2019) asked 324 stakeholders across England about the "key attributes of a "good" secondary school (11–18) physics teacher". Whilst physics content knowledge was high on this list of attributes, very few of the stakeholders actually specified the level, nature, or role of the physics knowledge required. I believe there is a distinct need for a more nuanced discussion of physics content and its role in teacher education, one that moves beyond trainees needing more or less physics, and deals with *what* content trainee physics teacher should learn and *how* this physics content prepares trainees to teach physics in a way that aligns with the purposes of school physics. Physics teachers cannot be expected to teach the intimate connections between physics and society if they have not had a chance to learn about these connections during their education. The educational science part of teacher education can indeed put emphasis on the importance of this aspect, but I would argue that the specific and concrete ways such connections manifest themselves in physics need to be learned in close connection to learning physics.

7.7 Learning to teach physics in an inclusive way

As physics-teachers-to-be, trainees have the possibility to affect how future generations of physics students perceive the discipline, by defining what is considered a successful physics student (e.g. hard work versus innate ability) and who is recognized as belonging in physics. This means that trainees can invite both minority and majority students to feel that physics is for them, whether this means choosing to go on with further physics studies in an academic context, or being empowered to learn physics on their own terms and use it in their own lives and contexts (Barton & Tan, 2010). Trainee teachers thus need to be equipped with tools to challenge and break unequal patterns in physics, by creating their own open and inclusive learning environments (Gosling, 2020; Gosling & Gonsalves, 2020; Hazari et al., 2017). One such tool involves being introduced to a range 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. If trainees are presented with a very 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).

Further, trainee teachers cannot be expected to challenge notions of physics as connected to exclusivity, smartness, and nerdiness (Johansson, 2018a), if their own relationship to physics closely reflects this image. If physics teacher education involves struggling against notions of physics teaching as a less desirable choice, or less challenging path, than choosing to become a physicist, and if trainees identify with a subordinate position in relation to other physics students, we might expect this to severely limit their possibility to challenge unproductive learning practices and values around physics. Engström et al. (2014) found that physics teachers from non-academic backgrounds took positions of reverence and regard towards physics, which correlated with less inclination to challenge traditional teaching practices. Consequently, if trainee teachers are presented with and accept images of physics as an elite discipline that is only accessible for the most high-achieving students, there is a risk that they will perceive their role as taking a position at the bottom of the hierarchy in order to reproduce and serve the discipline rather than challenging it. Here, the particular case of the constructive study practice the Trio creates can be of wider importance for discussing how to open up for trainees to learn how to teach physics in an inclusive way.

7.8 Implications

7.8.1 Implications for teacher educators

For teacher educators, the results of this case study indicate the need for a discussion aiming towards creating a common understanding of what the physics teacher programme is trying to achieve. Here, I suggest that the discourse models and five assumptions and how they align with trainee experiences, could be used to facilitate such a discussion. Further, the results can enable educators to make conscious, informed decisions about their own teaching practice. This might also be true for educators working in other subject areas than physics.

The broad perspective on physics teacher education provided by the findings can further afford 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). In particular, for physicists teaching physics to trainee teachers, the findings point towards the need to examine implicit assumptions about what the goal of physics teaching is, and if needed, widen their definition of a physics expert to include expert physics teachers.

The insight into the experiences of a group of trainee physics teachers the findings of Publications IV and V provides, further points towards a need for physicists to examine what is considered a successful physics student in their classrooms. In particular, to what extent is the possibility to be recognized as successful available to different student groups, such as bachelor students, and trainee teachers?

I believe that the description of the Trio's successful and resourceful negotiations around being competent in physics, can work to facilitate a move away from understanding the underrepresentation of women in physics as a consequence of women lacking something. This would mean adopting a nuanced understanding of participation in physics that recognizes the actual difficulties people experience and how it is connected to the culture of physics, without losing sight of the resourcefulness and competence of students.

7.8.2 Implications for the design of physics teacher education

Publications IV and V are case studies describing the experiences of trainee physics teachers who study undergraduate physics together with physics and engineering programme students. The aim was to provide illustrative examples that might be used by physicists and physics education professionals to reflect on the design of physics teacher education programmes and on their own practice. Based on the findings, I make four suggestions for the design of physics courses as part of teacher education:

Creating visibility
Care should be taken to acknowledge the presence and needs of trainee physics teachers in physics courses. This can be achieved on a programme level, by designing physics courses that cater specifically to the needs of trainee teachers—perhaps modelled on some of the successful physics teacher programmes described in the literature (Etkina, 2010; McDermott et al., 2000; Otero et al., 2010). However, for pragmatic reasons, many trainee physics teachers will continue to be taught together with other programme students to some extent. Handled well, such teaching may offer benefits to trainees in terms of providing an authentic experience of university physics. However, my research suggests that such teaching needs to explicitly acknowledge the presence of trainee physics teachers in mixed groups of students.

Offering a sense of relevance
The processes of experiencing relevance and motivation are complex and need to start with the individual student—students cannot be forced to experience their course content as relevant. However, explicit discussion about how the physics content being taught is connected to trainees' future in teaching should give trainees a starting point for finding their own relevance and motivation. Specific teaching-related examples and the inclusion of guest lectures by school physics teachers are other suggestions (Andersson & Johansson, 2016). Specialized courses focusing on teaching physics can also work to provide a sense of relevance to trainee teachers, as they typically connect directly to practical physics teaching. However, it is important that the responsibility for creating relevance is not reserved for individual courses, while such considerations are not applied to physics courses in general.

Creating an incentive to do well in physics
The assessment of physics courses, whether for trainees specifically or those given to several student groups, need to be designed to give trainee teachers an incentive to excel. The highest grades for trainee teachers should correspond to knowledge connected to teaching physics. This does not mean that trainee teachers should only learn the exact physics they are going to teach. What it does mean, however, is that efforts should be made to discuss with trainees how higher grades in more advanced courses are relevant to their professional knowledge. This might involve changing the course examination criteria, or just being explicit about how the existing criteria connect to a future in teaching. It might also involve changing the form of the examination by putting more emphasis on oral/visual/practical demonstrations of knowledge in physics.

Creating an interactive classroom culture
An overwhelming body of research has shown that activating students is key to improving their physics learning. This is of particular importance to trainee teachers, for whom a passive physics classroom environment is a bad model for their future physics teaching. There are a number of tools that have been developed to guide students and teachers towards this goal, such as the ISLE method (Etkina et al., 2019; Fraser et al., 2014). However, the experiences described in Publications IV and V—a passive classroom culture focused on giving the right answer—highlight the importance of also addressing aspects of classroom culture that may work against student interactive engagement. This includes working against stereotypes of the smart physicist (Lewis et al., 2016).

7.8.3 Implications for trainee physics teachers

Knowledge of the educator discourses presented in Publications I and III can help trainee physics teachers entering the system to understand the motivations and goals of the different parts of their programme and allow them to question which aspects are relevant for their desired future in teaching physics. This could facilitate trainee physics teachers in navigating the different goals of their educational programme and in making informed choices about their own particular approach to becoming a professional physics teacher.

In Publication V, awareness of women's underrepresentation in physics was found to be a resource that helped the Trio to renegotiate experiences of feeling inadequate. For the Trio, being able to accept and endure a position of not understanding was a prerequisite for the process of learning physics. This strategy was however made possible by being positioned outside the struggle of other physics students to appear smart enough. I believe that these results could be of use to trainee teachers as tools to empower them to question norms of brilliance and elitness in physics.

7.9 Contributions

The findings presented in this thesis are based on analysis of two sets of interviews. First, 17 interviews with teacher educators who in different functions meet trainee physics teachers during their education. Second, 17 interviews with students aspiring to become physics teachers. 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 (Bernstein, 1999) combined with the concept of disciplinary literacy can be seen to give insights into the potential problems for trainee physics teachers as they move between the different environments of the educational programme.

- I introduce a way of using Gee's (2005) discourse analytical tool discourse models, to give an overview of the different ways of understanding the education that exist in an educational environment. By analyzing the talk of informants, a number of discourse models can be identified that together describe what is tacitly valued in the educational environments. Each discourse model is structured with a single overarching goal, and while multiple discourse models may be invoked in a certain context, they often represent incompatible sets of goals, values, and structure in the education. This approach differs from Gee's interpretation in that I do not take discourse models to necessarily reside inside educators' minds. Rather, they are analytical models identified in patterns in educator talk.

- I use the developed approach as a way to operationalize how the discourses of the teacher education programme can be understood to enable the performance of different physics teacher identities.

- In the local system of teacher education, I identify four discourse models in the talk of teacher educators. 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 enable 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 takes 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 Butlers' (1990) theoretical way of approaching gender, and especially the concepts of intelligibility, submission, and mastery, is useful for describing the interplay of structure and agency in the identity negotiations of trainee teachers.

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

- I demonstrate how five implicit assumptions in the talk of the interviewed physicists appear to unintentionally undermine and devalue physics teacher education. These assumptions are:
    - The *physics expert assumption*: the purpose of all undergraduate physics teaching is to create physics experts.
    - The *content assumption*: the appropriate physics content for future school physics teachers is the same as that for future physicists.
    - The *goal assumption*: the role of a school physics teacher is to create new physicists.
    - The *student assumption*: students who become physics teachers do not have the ability to make it as successful physicists.
    - The *teaching assumption*: If you know physics then it's not difficult to teach it.
    - 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 five assumptions.

- I describe the experiences of trainee physics teachers learning physics in four major themes that together can be understood to represent aspects of what it is like for this group of students to be part of a physics programme that is not designed primarily for them. The themes are:
    - Teacher programme invisibility
    - Passive classroom culture
    - Perceived relevance of physics courses

– No incentive to do well in physics.

- I take a novel approach to the identity negotiations of women in physics by considering how the doing of femininity is entangled with the doing of physics, and how this makes constructive learning strategies possible. I show how the women in the Trio simultaneously submit to and master a "physics nerd discourse", by performing feminine positions that imply being socially competent, happy, bouncy, and lively. This enables them to resist expectations to perform the right kind of "smart" physics student, and to instead inhabit constructive positions of active and relaxed physics learning.

7.10 Future work

Moving forward, it would be worthwhile to further investigate the interaction between discourses in the training environment and trainee physics teachers' identity work. The alignment of discourses of the physics teacher educators and the trainee physics teachers that emerges when viewing the publications together suggests a number of challenges that trainees in the environment studied in this thesis have to negotiate when learning to become physics teachers. These challenges, and the ways in which trainees negotiate them, warrant further exploration.

One direction is to further analyze student talk though the lens of the educator discourses. Here, the analytical question of how student talk is patterned to indicate different goals of teacher education could be used. Some of these patterns are preliminarily visible in the trainee interviews, one example is the *practically well-equipped teacher model*. This model seems to appear together with the physics expert model in students talk, in a way very similar to how educators talk about physics teaching. I would also like to investigate the extent to which the ability to deal with the discourses of teacher education are equally distributed. The example of the Trio's constructive study practice, and how it stands out from the other students' physics learning, indicates that further exploration of the varying strategies of different student groups would be fruitful.

One particular context that is especially interesting moving forward is courses for trainee physics teachers, that focus on the specifics of teaching physics, using physics education research. In the Swedish context, such course work would be called "physics didactics" (fysikdidaktik). The results presented in Publication IV suggest that trainees struggle to see their physics coursework as relevant to teaching. It is not far-fetched to imagine that such relevance is more clearly established during physics didactics coursework, this is also preliminary supported by the student interviews. If this is the case, do such notions of relevance also influence how trainees experience the relevance of other courses? Didactics courses are also of particular interest as a context for trainees' identity performances. Preliminary analysis of the trainee interviews suggests that the course content that includes knowledge that is very particular for physics teaching, such as CKT and PCK for physics, supports trainees in performing more expert-like identities. Further research should investigate physics didactics courses as an arena for trainee identity performances, with a focus on how this context makes performances of successful future physics teacher available to students.

The role of physics content in physics teacher education is another direction that needs to be explored. I argued above that discussions of physics content in teacher education should move beyond considering whether trainees need more or less physics. We need a discussion about how the physics content prepares trainees to teach physics in a way that aligns with the purposes of school physics, and how university physics courses can be utilized to prepare trainee teachers to teach physics in an inclusive way. A first step in this direction would be an overview of how physics content courses are utilized in physics teacher education programmes in Sweden and internationally. How are the physics courses designed and how does this correlate with the school syllabus and general teacher education documents? The connection between school and university physics could further be approached through interviews with physicists. I believe it would be especially fruitful to work together with physicists interested in social justice, to explore how to prepare trainee teachers for creating their own inclusive physics classrooms.

I have argued that the creation of inclusive physics classrooms is a crucial task for physics teachers. Going forward, I want to further investigate the disciplinary culture of physics and how it positions trainee teachers to deal with this complex issue. How do trainee teachers negotiate 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 examining this issue 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 potential masculine notions of physics in relation to the goals of physics teaching.

I have found Butlers' (1990) theoretical way of approaching gender very useful for describing the identity negotiations of trainee teachers. Especially the concepts of intelligibility, submission, and mastery, have worked to capture the interplay of structure and agency in student negotiations of positions of learning physics. I believe there is great potential in the further use of these and other theoretical constructs from gender theory, to investigate how trainee teachers negotiate the gendered dynamics of learning to teach physics. In particular, there is a need for further investigation of femininities and their potential for subversion in the physics context, something that could be explored together with physics students. There is also a lack of research on the intersection of gender, race, and class with identity positions of trainee teacher and successful physics student. In the Swedish context in particular, there is an urgent need to understand how social class comes into play, as new groups of students enter teacher education. For physics teacher education, these issues might be amplified by the high status of the physics subject, and the differences in the qualifying merit points for entering the bachelor program, and the physics teacher program.

Another worthwhile path to explore is the extent to which discourses similar to the ones described in this thesis, can be identified in other physics teacher-training programmes within and 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 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 clear how further evidence of these discourses existing in other institutions would make them more useful tools. However, the case for using these tools could be made more convincing. 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 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 explore physicists' assumptions about physics teacher education in a number of countries.

It would also be interesting to investigate the relationship between different ways of organizing teacher education and educator discourses. However, I believe that further exploration of educator discourses should be done in close collaboration with physics teacher educators. Working together with educators, the usefulness of the discourse models could be explored and expanded, and a project where educators from the different parts of teacher education are brought together could be one way of trying to bridge the fragmentation identified in Publication I.

Finally, one additional direction for future work is to further explore the theory-practice gap from the perspective of differences in both knowledge structure and status between the disciplines of physics and education. Here, courses in physics education, that combine knowledge from both domains, might be an especially well-suited context for beginning such explorations. How do the ways in which trainee physics teachers appreciate and identify with the physics subject, affect how they value the subject matter of teacher education?

Sammanfattning på svenska

Den här avhandlingen utforskar vad det innebär att bli erkänd som kompetent fysiklärarstudent på en svensk lärarutbildning. Den handlar om den grupp studenter som läser fysiklärarprogrammet för att få behörighet att undervisa fysik på gymnasiet och högstadiet och om de fysiklärarutbildare som de möter under utbildningen. Fysiklärarprogrammet består av tre delar förlagda till tre miljöer, en fysikinstitution, en utbildningsvetenskaplig institution och skolor där studenterna gör sin verksamhetsförlagda utbildning. De lärarutbildare som studenterna möter i dessa miljöer är fysiker, utbildningsvetare och fysiklärare. Jag har intervjuat fysiklärarstudenter och de lärarutbildare de möter under sin utbildning för att utforska fysiklärarprogrammet som en miljö där fysiklärarstudenter formar sin professionella identitet, både som fysikstudenter och som framtida fysiklärare.

När fysiklärarstudenterna deltar i utbildningens olika praktiker och miljöer måste de samtidigt förhålla sig till den bild som deras lärare på utbildningen skapar av vad en fysiklärare är och bör lära sig. Lärarstudenternas identiteter formas på så sätt i samspel med lärarutbildarnas diskurser, alltså deras sätt att tala om utbildningen samt hur de tolkar dess praktiker, syften och mål. Dessa lärarutbildardiskurser är i fokus för den första delen av avhandlingen. Avhandlingens andra del fokuserar på hur fysiklärarstudenter förhandlar dessa och andra diskurser i utbildningen.

På fysikinstitutionen läser lärarstudenterna fysik tillsammans med kandidatstudenter och ingenjörsstudenter. Här deltar de i undervisningen tillsammans med andra fysikstudenter utan att det görs någon större skillnad mellan de olika studentgrupperna. Samtidigt som lärarstudenterna lär sig mekanik, elektromagnetism och vågrörelselära skapar de sig också en bild av fysikämnet. De lär sig vad som är syftet med fysik och vad det innebär att plugga fysik, bilder som påverkas både av andra studenter och de fysiker som är deras lärare. De skapar sig också en bild av vem som hör hemma i fysikgemenskapen, vem som förväntas vara bra på fysik, och hur de själva passar in i den bilden. I sin roll som framtida fysiklärare förbereder sig lärarstudenterna dessutom för en position där de kommer ha stor möjlighet att påverka hur andra uppfattar fysikämnet. Den här dubbla positionen, att som studenter påverkas av fysikdisciplinen men också ha framtida makt att påverka, betyder att lärarstudenternas upplevelser av att lära sig fysik är särskilt viktiga att förstå.

Både i Sverige och internationellt är fysik ett ämne som har stora problem med underrepresentation av kvinnor och minoriteter. I västvärlden är ca 20% av fysikstudenterna på grundnivå kvinnor och andelen är ännu mindre på högre nivåer i utbildningssystemet. I Sverige ligger andelen fysikstudenter som är kvinnor på grundnivå runt 30%, bland forskare är det 20% och bara 12% av professorerna i fysik är kvinnor[7]. Fysikämnet domineras alltså av män på alla nivåer och det har historiskt också ofta associerats med maskulinitet och ”manligt” intellekt. Utbildningsvetenskap domineras istället av kvinnor, och associeras vanligtvis med låg konkurrens, låga antagningspoäng, och låg status. Det betyder att fysiklärarstudenter samtidigt som de lär sig undervisa fysik också behöver förhålla sig till att fysik och utbildningsvetenskap är kodade på olika sätt. I mitt intervjumaterial har jag bland annat kunnat se de här spänningarna i hur att ställa frågor och be om hjälp kopplas samman med en risk att inte verka smart nog för att framstå som en framgångsrik fysikstudent.

Obalansen mellan män och kvinnor i fysik är relevant i relation till fysiklärarutbildningen eftersom att den pekar på hur viktigt det är att synliggöra hur fysikämnet framställs i skolan. Bilden av fysik i skolan kan påverka vem som väljer att fortsätta med fysik på universitetet. Tidigare forskning har visat att när fysikämnet i skolan framställs som särskilt svårt, och kopplas ihop med nördighet och smarthet, så avskräcker det framförallt kvinnliga studenter från att se fysik som något för dem. Det här är bilder av fysik som fysiklärare har möjlighet att påverka, och på så sätt kan de också påverka vem som vill fortsätta med fysik. Fysiklärare är också ansvariga för att göra fysikkunskaper relevanta för de elever som inte fortsätter med fysik på universitetsnivå, men som behöver förståelse för fysik för att delta i samhällets demokratiska processer. Det här betyder att fysiklärares förståelse av fysikämnet, dess syfte och plats i samhället och skolan, är en viktig faktor i huruvida ojämlika mönster av deltagande i fysiken återskapas eller utmanas i skolan.

Fysiklärarutbildningen har stora problem med att rekrytera studenter, och många av de studenter som påbörjar utbildningen hoppar av innan de tagit examen. Det här är ett stort problem både i Sverige och internationellt då tillgången på utbildade fysiklärare är och förutspås fortsätta vara låg. Dessutom är samtalet kring lärarutbildning i Sverige ofta negativ, läraryrket ses inte som ett attraktivt val, och antagningskraven till lärarutbildningen kritiseras för att vara alldeles för låga. Dessa diskussioner får konsekvenser för hur de som väljer läraryrket uppfattas, där lärarstudenters kompetens och lämplighet ofta ifrågasätts. För en person som är intresserad av och är bra på fysik komplicerar det här potentiellt valet att bli fysiklärare, framförallt i relation till fysikämnets relativt höga status. Lärarstudenterna i mitt intervjumaterial är tydligt medvetna om skillnaden i status mellan att läsa fysik med sikte på en forskarkarriär och att läsa till fysiklärare. För att bättre förstå valet att bli fysiklärare, och vad

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som får vissa studenter att stanna på utbildningen, är det viktigt att skapa kunskap om hur fysiklärarstudenter förhåller sig till dessa diskurser. På vilket sätt kan fysiklärarstudenter förstå sig själva som framgångsrika, och hur påverkas fysiklärarstudenters identitet av det? Om den dominerande bilden av lärarstudenter är att de är inkompetenta eller misslyckade, och om en sådan bild också i någon mån påverkar hur fysiklärarstudenter förstår sig själva och valet att bli fysiklärare, då kommer det potentiellt också att påverka skolans fysikundervisning och vem som väljer att bli fysiklärare.

I Sverige har diskussioner kring hur lärarutbildningens kvalitet kan förbättras ofta handlat om den utbildningsvetenskapliga delen av lärarutbildningen, medan ämneskurserna inte ifrågasätts på samma sätt. När ämnesinnehållet i lärarutbildningen diskuteras, handlar det ofta om att lärarstudenter behöver mer ämneskunskaper. Vilka dessa kunskaper egentligen är, och på vilket sätt de bidrar till en bättre utbildning är oklart. Det behövs en vidare forskningsbaserad diskussion av syftet med fysikkunskaper inom fysiklärarutbildningen, och av hur sådana kunskaper interagerar med de andra delarna av lärarutbildningen. Den här avhandlingen bidrar till den diskussionen genom att undersöka hur lärarutbildare talkar om ämneskurserna som relevanta, samt hur fysiklärarstudenter förstår fysikinnehållet som en relevant del av lärarutbildningen och som viktig för deras framtida fysikundervisning.

Mer generella frågor kring vad det innebär att bli lärare är relativt väl utforskat i tidigare forskning, men vi vet mindre om samspelet mellan fysiklärarutbildningen som system och fysiklärarstudenters identitet. Detta gäller speciellt för fysikkunskapers roll i lärarstudenters förhandlingar kring sin läraridentitet.

Som jag nämnde inledningsvis är avhandlingens övergripande syfte att utforska vad det innebär att bli erkänd som en kompetent lärarstudent på en svensk lärarutbildning. Jag förstår processen att lära sig att bli fysiklärare som att lära sig behärska ett antal professionella diskurser. Det innebär att en fysiklärarstudent behöver lära sig att tala och bete sig på rätt sätt för att bli bedömd som kompetent och professionell i de olika utbildningskontexter hen deltar i. Jag undersöker den här processen från två olika perspektiv, som motsvarar avhandlingsprojektets två delar. I projektets första del utforskar jag fysiklärarutbildningen från lärarutbildarnas perspektiv. Här ligger fokus på lärarutbildarnas diskurser som något som fysiklärarstudenter behöver förhålla sig till när de skapar sin fysikläraridentitet. Jag analyserar hur lärarutbildare talar om fysiklärarutbildningen och hur detta tal möjliggör vissa sätt att erkännas som kompetent samtidigt som det omöjliggör andra. I projektets andra del undersöker jag lärarutbildningen från fysiklärarstudenternas perspektiv. Jag analyserar hur fysiklärarstudenterna förhandlar sina erfarenheter av att läsa fysik som en del av lärarprogrammet, och hur de förhåller sig till lärarutbildarnas diskurser. Här fokuserar jag särskilt på fysikkurserna och den roll som genus spelar i studenternas identitetsförhandlingar.

Resultat del ett

Projektets första del består av tre publikationer som på olika sätt behandlar hur fysiklärarutbildare talar om lärarutbildningen. För att undersöka lärarutbildarnas diskurser intervjuade jag nio fysiklärarutbildare, tre utbildningsvetare, tre mentorer (fysiklärare på gymnasieskolor) och tre fysiker. För avhandlingens första publikation ställde jag följande forskningsfrågor:

1. Vilka diskursmodeller (olika sätt att förstå utbildningen på) kan identifieras i hur lärarutbildare talar om lärarutbildningen?
2. Vilka sätt att "göra" en fysikläraridentitet möjliggör dessa diskursmodeller?

Analysen resulterade i fyra diskursmodeller. En diskursmodell är ett specifikt mönster som lärarutbildarnas sätt att prata om utbildningen på följer. Varje diskursmodell är strukturerad enligt ett mål som utbildningen antas syfta till. De fyra diskursmodellerna är: *Den praktiskt kunniga lärarmodellen*, *den kritiskt reflektiva lärarmodellen*, *tjänstemanna-lärarmodellen* och *fysikexpert-modellen*.

I den *praktiskt kunniga lärarmodellen* antas målet med utbildningen vara att utbilda lärare som klarar det vardagliga lärararbetet. När lärarutbildarnas tal stämde med den praktiskt kunniga lärarmodellens logik så var det framförallt den kunskap lärarstudenter får under den verksamhetsförlagda utbildningen som framställdes som viktig medan fysiken och utbildningsvetenskapen var mindre viktiga. På samma sätt så betonar de andra diskursmodellerna olika delar av utbildningen.

I den *kritiskt reflekterande lärarmodellen* är målet att skapa en lärare som har de teoretiska verktyg som krävs för att kunna reflektera kring och kritiskt ifrågasätta, både den egna praktiken såväl som skolan och samhället. Här är det framförallt utbildningsvetenskapen som ses som viktig för att kunna skapa kunniga fysiklärare. Både fysiken och praktiken är i den här modellen potentiellt problematiska, eftersom de riskerar att reproducera traditionella undervisningsmönster. Här uppmuntras läraridentiteter som handlar om att förändra skolan och fysikundervisningen.

I *tjänstemanna-lärarmodellen* ligger fokus på att lärare måste lära sig att både tolka och undervisa enligt läroplanen. Läraren ses som en tjänsteman med ett tydligt uppdrag att utföra. Här är det framförallt den utbildningsvetenskapliga delen av lärarutbildningen som är viktig, men de övriga delarna antas också bidra till tjänstemannalärarens kunskaper.

Den fjärde och sista diskursmodellen är *fysikexpertmodellen*. Till skillnad från de andra diskursmodellerna har fysikexpertmodellen inte en fysiklärare som sitt mål. I detta mönster som var det särskilt tydligt hur fysikerna och mentorerna talade om fysikutbildning genom att utgå ifrån att utbildningens främsta syfte var att skapa forskare i fysik. Trots att intervjuerna uttalat handlade om lärarutbildning blev alltså lärarutbildarnas tal i analysen meningsfullt främst utifrån antagandet att målet med deras verksamhet var att skapa fysikexperter.

De fyra diskursmodellerna som identifierats i lärarutbildarna tal om utbildningen representerar fyra skilda logiker, alltså system för att förstå och värdera fysiklärarutbildningens delar. I vissa fall ger en diskursmodell ingen möjlighet att tolka en viss del av lärarutbildningen som värdefull. Ett exempel är den *praktiskt kunniga lärarmodellen*, där enbart praktiken krävs för att utbilda praktiskt kunniga fysiklärare. Det betyder att beroende på vilken diskursmodell som är aktiv så framstår olika delar av utbildningen som värdefulla eller nödvändiga. Ingen av modellerna framställer hela utbildningen som samtidigt värdefull. På samma sätt erbjuder de fyra diskusmodellerna inget sätt att skapa en fysikläraridentitet som bygger på hela utbildningen som viktig professionell kunskap. Utifrån intervjuerna med lärarutbildare går det inte att veta vad de här diskursmodellerna betyder för lärarstudenter. Vad som är möjligt att uttala sig om är att studenterna sannolikt behöver anpassa sig till lärarutbildarnas skiftande diskurser när de rör sig mellan utbildningens olika delar.

Avhandlingens andra publikation är ett bokkapitel som teoretiskt diskuterar fysiklärarutbildningen ur ett kunskapsperspektiv. Här används det teoretiska begreppet disciplinär litteracitet (”disciplinary literacy”) tillsammans med ett sätt att förstå hur vetenskapliga discipliner förhåller sig till och organiserar kunskap utvecklat av Basil Bernstein. Litteracitet är ett begrepp som ursprungligen använts i betydelsen förmåga att läsa och skriva. I forskning kring litteracitet har begreppet kommit att användas i utvidgad betydelse och innefattar då alla sätt att kommunicera på som används i en specifik kontext. Disciplinär litteracitet betyder förmåga att behärska de sätt att handla och kommunicera på som används inom en disciplin. Frågan som ställs i den andra publikationen är om en kombination av Bernsteins sätt att klassificera discipliner utifrån kunskapsstruktur och disciplinär litteracitet kan användas för att beskriva de specifika utmaningar som det innebär att kombinera fysik och utbildningsvetenskap i lärarutbildningen.

Enligt Bernsteins klassifikation av disciplinerna är fysikdisciplinen en hierarkisk singular (”hierarchical singular”). Det betyder att kunskap i fysik antas vara oförändrad oberoende av kontext och att disciplinen kräver att ny kunskap inordnas i ett existerande system. Utbildningsvetenskap är i den här klassifikationen en horisontell region (”horisontal region”). Det betyder att kunskap i utbildningsvetenskap skapas i en mängd specialiserade språk som är anpassade för olika kontexter, och inte behöver vara koherenta med varandra. Ny kunskap behöver därför inte inordnas strikt i samma system som tidigare kunskap, utan värderas utifrån om den tillför meningsfulla perspektiv. I den andra publikationen föreslår jag och min medförfattare att de här skillnaderna i kunskapsstruktur, och framförallt skillnader i vad som räknas som riktig, värdefull och funktionell kunskap i de olika kontexterna, kan skapa problem för fysiklärarstudenter. När de rör sig mellan utbildningens olika delar lär sig studenterna vad kunskap är inom de olika disciplinerna. Om fysiklärarstudenterna då tar till sig ett sätt att förstå kunskap på som hierarkisk och oberoende av kontexten, vilket är vanligt i fysikundervisning, så finns det risk att de uppfattar utbildningsvetenskapen som osammanhängande och ovetenskaplig. I den andra publikationen backas det här teoretiska resonemanget upp av en analys av intervjuer med fysikföreläsare.

I den tredje publikationen smalnar avhandlingens fokus av. Till skillnad från de två första publikationerna som berör fysiklärarutbildningens tre olika delar fokuserar publikation tre specifikt på fysikkurserna och hur fysiker pratar om dem som en del i fysiklärarutbildningen. Analysen utgår från fysikexpertmodellen, som är ett av resultaten från den första artikeln. Fysikexpertmodellen innefattar ett mönster i lärarutbildarnas tal där fysiklärarutbildningen förstås och värderas utifrån målet att skapa forskare i fysik. För att vidare utforska hur svenska fysiker talar om lärarutbildningen kompletterades det ursprungliga intervjumaterialet med ytterligaste åtta intervjuer med fysiker. Frågan som ställdes till det nya utökade materialet var:

> Vilka aspekter av fysikkultur kan identifieras i fysikers tal om lärarutbildningen hos fysiker på fyra svenska fysikinstitutioner?

I analysen av fysikernas tal om lärarutbildningen identifierades fem antaganden om fysiklärarutbildningen och fysiklärarstudenter. Dessa fem antaganden är, precis som diskursmodellerna, mönster i hur fysikerna talade. Det betyder att de här resultaten inte beskriver vad de intervjuade fysikerna faktiskt tror eller tycker om lärarutbildningen. Antagandena är ett sätt att förstå och beskriva sättet som talar pratar på, och syftet med en sådan beskrivning är att vidare kunna analysera vilka konsekvenser dessa talade mönster kan få för fysiklärarstudenter. De fem antagandena är:

1. *Fysikexpertantagandet*: Syftet med fysikundervisning på universitetsnivå är att utbilda fysikexperter (forskare i fysik).
2. *Innehållsantagandet*: Samma fysikinnehåll är lämpligt för både fysiklärarstudenter och de som siktar mot en framtid som forskare i fysik.
3. *Målantagandet:* En fysiklärares roll är att skapa nya fysiker.
4. *Studentantagandet:* Studenter som väljer fysiklärarutbildningen har inte förmåga nog att kunna bli framgångsrika fysiker.
5. *Undervisningsantagandet:* Att lära ut fysik är inte svårt så länge du har tillräckliga ämneskunskaper.

Fysikexpertantagandet är en omformulering av fysikexpertmodellen. Det innebär att ett resultat av analysen från den tredje publikationen var att bekräfta att fysikexpertmodell fungerar som ett sätt att förstå fysikers sätt att tala om fysiklärarutbildningen. De intervjuade fysikerna talade om lärarutbildningen och sina studenter på ett sätt som antydde att det normala och förväntade är att studenter rör sig från skolfysik, via universitetsfysik, för att slutligen bli fysiker. Studenter som avviker från den här vägen gör det troligtvis för att de inte har vad som krävs för att bli fysiker. Fysiklärarstudenter, som läser fysik med syftet att återvända till skolfysiken för att undervisa den, kan förstås som att de avviker från den förväntade riktningen. Det är denna motrörelse som avhandlingens undertitel ”going against the flow of physics” syftar på.

Resultat del två

Avhandlingsprojektets andra del består av två publikationer som bygger på analyser av intervjuer med 17 fysiklärarstudenter. De flesta av dessa studenter läser sitt andra eller tredje år av fysiklärarutbildningen. Några läser individuell studietakt och två har läst eller läser mot en kandidatexamen i fysik och planerar att läsa den kompletterande lärarutbildningen.

Publikation fyra beskriver hur de intervjuade lärarstudenterna talade om sina erfarenheter av att läsa fysik på lärarprogrammet. Forskningsfrågan för denna publikation var:

> Hur upplever fysiklärarstudenter som läser fysik tillsammans med andra programgrupper fysikundervisningens syfte och mål?

Här identifierade jag fyra teman i hur lärarstudenterna beskrev sina erfarenheter. Dessa var:

1. Lärarstudenterna är osynliga bland de andra studentgrupperna på fysikkurserna.
2. Klassrumskulturen på fysikkurserna upplevs som passiv och fokuserad på att framstå som smart och att alltid svara rätt.
3. Studenterna ifrågasätter relevansen hos det fysikinnehåll som inte kan kopplas direkt till skolfysiken.
4. Studenterna upplever att det inte finns någon anledning att anstränga sig för att få höga betyg i fysikkurserna.

Ett sätt att förstå dessa teman är att de representerar olika aspekter av hur det är för fysiklärarstudenter att läsa fysikkurser som är utformade för att fylla andra studentgruppers behov.

I analysen för den fjärde publikationen var det tre studentintervjuer som väckte särskilt intresse. Dessa tre kvinnliga fysiklärarstudenter, som är vänner och pluggar ihop, beskrev hur de på ett unikt och konstruktivt sätt förhöll sig till sina erfarenheter av att plugga fysik. Dessa tre studenter, som jag kallar för Trion, är i fokus i publikation fem. Forskningsfrågan för denna publikation är:

> Hur förhandlar kvinnliga fysiklärarstudenter sina positioner som kvinnor och fysikexperter för att skapa utrymme för konstruktivt fysiklärande?

De tre studenterna i Trion beskrev alla hur de på grund av att de var kvinnor och läste till fysiklärare inte blev tagna på allvar och inte uppfattades som bra på fysik. Det handlar t.ex. om erfarenheter av att bli avbruten eller inte lyssnad på i grupparbeten. Elin berättade om hur en tjejs klädstil påverkar hur hon uppfattas bland fysikstudenterna:

> För om man har lite mer så här, funktionskläder eller typ en ironisk t-shirt-stil som tjej. Då kanske man får mer, då tänker nog folk mer att man är väldigt intresserad av ämnet av någon anledning. Jämfört med om man kanske har en kort kjol, och lite så, piffar, sminkar sig, så känns det som att folk får mer nån typ av, jag skulle inte säga bimbo men om det finns en skala mellan typ nörd och bimbo så känns det som att man blir liksom kategoriserad mer på den sidan av skalan typ. Och kanske inte förväntas, eller folk kanske inte tror att man får så bra på tentor och så där.

Att ha en feminin stil, som associeras till bimbos, gör det svårare att bli uppfattad som framgångsrik bland fysikstudenterna. Trion beskriver hur nördighet, maskulinitet och intelligens är starka normer i den här miljön. För att undvika att göra sig synliga och därmed riskera att uppfattas som osmarta eller dåliga på fysik är det få studenter som ställer eller svarar på frågor under föreläsningar och lektioner.

I analysen av trions berättelser framträdde positionen ”att inte förstå” som särskilt viktig. För att bli erkänd som kompetent är det viktigt att snabbt förstå fysiken, eller att framstå som att man gör det, vilket hindrar fysikstudenterna från att aktivt utforska vad de inte förstår och göra något åt det. Trion gör motstånd mot den här diskursen genom att aktivt välja att visa att de inte förstår och väljer att stanna i den positionen medan de studerar fysik. Detta blir möjligt då Trion som feminina tjejer och lärarstudenter redan antas vara sämre på fysik och inte lika ambitiösa som andra fysikstudenter. De har redan misslyckats med att framstå som kompetenta fysiker och behöver därför inte uppfylla kraven som andra studenter kämpar med. Genom att vara glada, livliga och tjejiga gör trion vidare motstånd mot vad som förväntas av en typisk fysikstudent. Detta gör att de kan motstå förväntningar om att framstå som tillräckligt smarta, och plugga fysik på ett avslappnat och aktivt sätt. Trions motstånd innebär dock att de förlorar möjligheten att framstå som lyckade eller särskilt begåvade på fysik, både i andra studenters, lärares och sina egna ögon.

Analysen av trions intervjuer visar också att umgänget med andra tjejer och feministisk medvetenhet är viktiga resurser när de studerar fysik. Den feministiska medvetenheten gör att de kan förstå sina erfarenheter av att inte bli tagna på allvar som en konsekvens av ojämställda strukturer i fysiken, snarare än som beroende på egen inkompetens.

Diskussion

Tidigare forskning har identifierat ett behov av ytterligare kunskap kring hur studenter skapar professionella identiteter som fysiklärare. Med den här avhandlingen argumenterar jag för att fysiklärarstudenters identitet måste förstås som att den både skapas genom och begränsas av de diskurser som är närvarande i deras utbildning. De fyra diskursmodellerna som beskrivs i den första publikationer ger inget utrymme för en fysiklöraridentitet som samtidigt integrerar alla delar av fysiklärarutbildningen som värdefulla. Den tredje publikationen kompletterar den här bilden av utbildningens diskurser genom att visa hur fysikerna pratar om lärarstudenterna fysikkurser som framförallt syftande till att skapa forskare i fysik. Här förstås lärarstudenter som avvikande eftersom de rör sig åt fel håll, bort från forskningsfronten och mot skolfysiken. Antagandet att studenter som väljer fysiklärarutbildning inte har samma förmåga som andra fysikstudenter kan förstås som en förklaring till varför lärarstudenter väljer denna avvikande riktning. De väljer den lättare vägen att bli lärare eftersom att de inte har vad som krävs för att bli fysiker. Undervisningsantagandet, att goda kunskaper i fysik räcker för att kunna undervisa, nedvärderar vidare fysiklärares professionella kunskap. I dessa diskurser kring fysikundervisning och lärarutbildning är avancerade fysikkunskaper vad som framförallt premieras, medan lärarutbildningens övriga delar blir oviktiga. Dessa diskurser verkar möjliggöra endast begränsade sätt att framstå som framgångsrik och kompetent som fysiklärarstudent och fysiklärare.

I de fjärde och femte publikationerna beskrivs fysikkurserna från lärarstudenternas perspektiv. Här förmedlas en bild som speglar lärarutbildarnas diskurser. Fysiklärarstudenterna beskriver upplevelser av att lära sig fysik på marginalen, medan kandidatfysikstudenter och ingenjörsstudenter står i centrum. Lärarstudenterna upplever inte att deras fysikföreläsare är engagerade i lärarutbildningen, något som i tidigare forskning har identifierats som en viktig faktor i högkvalitativ lärarutbildning. Att lärarstudenterna inte ser anledning att anstränga sig för höga betyg i fysikkurserna kan förstås som en annan aspekt av detta tema, då de uppfattar att betygssystemet är designat för att bedöma kunskaper som krävs för en forskarkarriär. Även här speglar lärarstudenternas upplevelser fysikernas diskurser, då fysikernas negativa förväntningar på lärarstudenternas kompetens motsvaras av att studenterna inte ser någon anledning att anstränga sig för höga betyg. Med utgångspunkt i avhandlingens resultat så tror jag att en förståelse av den här dynamiken kan vara viktig för att belysa problematiken med att rekrytera duktiga och intresserade studenter till fysiklärarutbildningen. För att fysiklärarutbildningen ska framstå som ett utmanande och givande alternativ för nya studenter så är det också viktigt att ta hänsyn till vilka möjligheter utbildningen erbjuder att uppfattas som framgångsrik och kompetent.

De intervjuade fysiklärarstudenterna beskriver hur legitimitet i fysik uppnås genom att framstå som intelligent, aldrig ha fel och att snabbt förstå fysik.

I den här miljön tvekar fysikstudenterna innan de ställer eller besvarar frågor, och en passiv studiemiljö skapas baserad på risken att inte framstå som smart nog. Den här sortens studiemiljö är inte optimal för lärande. Vad som främjar förståelse av fysik är ett aktivt lärande, att studenter vågar ställa frågor och visa när de inte förstår. För de studenter som är i minoritet i fysikklassrummet är det särskilt viktigt att bryta normer där fysik kopplas ihop med intellektuell överlägsenhet. Därför behöver frågan ställas hur fysiklärarstudenters erfarenheter av en passiv och elitistisk studiemiljö påverkar hur de kommer att skapa sina egna fysikklassrum i framtiden. Som framtida fysiklärare har lärarstudenterna möjlighet att påverka hur en ny generation elever uppfattar fysikdisciplinen. Här krävs verktyg för att utmana och bryta ojämställda mönster i fysiken. Ett sådant verktyg kan vara att lärarstudenter exponeras för en mängd sätt att förstå fysikämnets syften och mål, och detta behöver i så fall vara en del av fysikundervisningen på lärarutbildningen. Om lärarstudenter ges en smal bild av fysikämnet och fysikundervisning som endast syftande till forskning, så riskerar de att reproducera ojämlikhet i sina fysikklassrum.

Fysiklärare kan inte heller förväntas utmana bilden av fysik som kopplat till intellektuell överlägsenhet och maskulinitet om deras egna upplevelser av att plugga fysik uppfyller den här normen. När fysiklärare förstås som mindre kompetenta eller ambitiösa än andra fysikstudenter, så bekräftar det en hierarki där forskning i fysik har högre status än andra vägar inom fysiken. Det placerar fysiklärare i en underlägsen position där det är svårt att utmana eller förändra negativa praktiker i fysikundervisningen. Här kan den konstruktiva studiepraktiken som Trion skapar vara av vidare betydelse för att förstå hur fysiklärarutbildningen kan arbeta tillsammans med lärarstudenter för att lägga grunder för en inkluderande fysikundervisning.

För lärarutbildare pekar avhandlingens resultat på ett behov av en diskussion om målet att fysiklärarutbildningen utgör en koherent helhet. Här kan de fyra diskursmodellerna och fem antagandena, och hur de speglas av lärarstudenternas erfarenheter, vara en utgångspunkt för en sådan diskussion. Resultaten kan vidare inspirera lärarutbildare, även inom andra ämnesområden än fysik, att reflektera över sina antaganden om lärarutbildningen.

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