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# Learning Computing at University: Participation and Identity

*A Longitudinal Study*

ANNE-KATHRIN PETERS



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### **Abstract**

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Computing education has struggled with student engagement and diversity in the student population for a long time. Research in science, technology, engineering, and mathematics (STEM) education suggests that taking a social, long-term perspective on learning is a fruitful approach to resolving some of these persistent challenges.

A longitudinal study has been conducted, following students from two computing study programmes (CS/IT) over a three-year period. The students reflected on their experiences with CS/IT in a series of interviews. Drawing on social identity theory, the analysis has focused on describing participation in CS/IT, doing, thinking, feeling in relation to CS/IT, as negotiated among different people.

Phenomenographic analysis yields an outcome space that describes increasingly broad ways in which the students experience participation in CS/IT over the years. Two further outcome spaces provide nuanced insights into experiences that are of increasing relevance as the students advance in their studies; participation as problem solving and problem solving for others. Problem solving defined as solving difficult (technical) problems seems predominate in the learning environment. Problem solving for others brings the user into perspective, but first in the human computer interaction (HCI) course in year three. Students react with scepticism to HCI, excluding HCI from computing, some are students who commenced their studies with broader interests in computing.

Demonstrating (technical) problem solving competence is the most vital indicator competence in the two study programmes and the students adapt their reflections on who they are as computing students and professionals accordingly. People showing broader interests in computing risk being marginalised. I identify a gap between conceptions of computing as interdisciplinary and important for society and constructions of computing as technical. Closing the gap could improve retention and diversity, and result in graduates that are better prepared to contribute to societal development.

*Keywords:* computing education research, engineering education research, computer science, higher education, engagement, diversity, equity, gender, competencies, culture, longitudinal, identity, participation, power, agency, uniformity, communities of practice, social theory of learning, phenomenography, student reflections

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# List of papers

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

- I Anne-Kathrin Peters and Arnold Pears, “Students’ Experiences and Attitudes Towards Learning Computer Science”, in *Proc. 2012 IEEE Frontiers in Education Conference (FIE)*, Seattle, IEEE, 2012, pp. 1–6
- II Anne-Kathrin Peters and Arnold Pears, “Engagement in Computer Science and IT – What! A Matter of Identity?”, in *Proc. 1st IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE)*, Macau, IEEE, 2013, pp. 114–121
- III Anne-Kathrin Peters, Anders Berglund, Anna Eckerdal, and Arnold Pears, “First Year Computer Science and IT Students’ Experience of Participation in the Discipline”, in *Proc. 2nd IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE)*, Malaysia, IEEE, 2014, pp. 1–8
- IV Anne-Kathrin Peters, Anders Berglund, Anna Eckerdal, and Arnold Pears, “Second Year Computer Science and IT students’ Experience of Participation in the Discipline”, in *Proc. 15th Koli Calling Conference on Computing Education Research*, Finland, ACM, 2015, pp. 68–76
- V Anne-Kathrin Peters, “Students’ Experience of Participation in a Discipline – A Longitudinal Study of Computer Science and IT Engineering Students”, submitted to *ACM Transactions on Computing Education (TOCE)*, under review

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# Comments on my Contribution and Publication Status

As the main author in all papers, I took responsibility for the work. Ideas and results were discussed regularly with the supervisors and Prof. Michael Thuné, particularly with the other authors of the papers.

- I I planned the data collection and discussed it with all supervisors. I gathered the data and did the data analysis. Results were discussed with all supervisors, especially with the second author. I wrote the paper with the feedback from all supervisors, in particular the second author.
- II As in Paper I.
- III The data collection was discussed with all supervisors. I collected and analysed the data. The third author also analysed parts of the data independently. Results were discussed with all supervisors. I wrote the paper with feedback from all supervisors.
- IV I collected and analysed the data as described in Paper III and discussed the results with my supervisors. I wrote the paper with feedback from all supervisors.
- V I am the sole author.

Publication status: Papers I to IV are published. Paper V has been re-submitted after it has been accepted with major revisions.

## Other Related Publications

- Carsten Schulte, Malte Hornung, Sue Sentance, Valentina Dagiene, Tatjana Jevsikova, Neena Thota, Anna Eckerdal, and Anne-Kathrin Peters, “Computer Science at School/CS Teacher Education: Koli Working-Group Report on CS at School”, in *Proc. 12th Koli Calling Conference on Computing Education Research*, Finland, ACM, 2012, pp. 29–38
- Anne-Kathrin Peters and Detlef Rick, “Identity Development in Computing Education: Theoretical Perspectives and an Implementation in the Classroom”, in *Proc. 9th Workshop in Primary and Secondary Computing Education (WiPSCE)*, Berlin, ACM, 2014., pp. 70–79
- Anne-Kathrin Peters, Waqar Hussain, Åsa Cajander, Tony Clear, and Mats Daniels, “Preparing the Global Software Engineer”, in *Proc. 10th International Conference on Global Software Engineering*, Spain, IEEE, 2015, pp. 61–70
- Päivi Kinnunen, Matthew Butler, Michael Morgan, Aletta Nylén, and Anne-Kathrin Peters, “Understanding Initial Undergraduate Expectations and Identity in Computing Studies”, in *European Journal of Engineering Education*, 2016, pp. 1–18
- Åsa Cajander, Mats Daniels, Diane Golay, Roger McDermott, Jonas Moll, Aletta Nylén, Arnold Pears, and Anne-Kathrin Peters, “Unexpected Student Behaviour and Learning Opportunities: Using the Theory of Planned Behaviour to Analyse a Critical Incident”, in *Proc. 2017 IEEE Frontiers in Education Conference (FIE)*, Indiana, IEEE, 2017

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# 1. Introduction

The fields of science, technology, engineering, and mathematics (STEM) are seen as important fields, which contribute strongly to global welfare. At the same time as we can be amazed by the innovation and knowledge that have been developed in these fields, they have also introduced new questions and societal challenges. In meeting these challenges, an inclusive and high-quality education is seen as a crucial component (United Nations, 2015).

There is a long history of concern about young people's engagement in STEM (Teitelbaum, 2003; Lövheim, 2014; Smith & Gorard, 2011). Certain demographics have been continuously under-represented in STEM, e.g. women and people with low socio-economic status (OECD, 2016a; Henriksen, Dillon, & Ryder, 2015), and have therefore been marginalised in the development of these fields and from using STEM to develop society.

Computer Science Education or Computing Education shares the same kinds of problems related to engagement as other fields in STEM, but there are also some peculiarities. Computing is a young discipline. It is not part of the high school curriculum in many countries, or it is just being introduced (Schulte et al., 2012). Society relies on technology of increasing complexity, and technology is increasingly utilised as a tool in other disciplines, which is why there is a great demand of computing professionals or competence (Giannakos, Pappas, Jaccheri, & Sampson, 2016; The ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013). Considering that technological innovations have changed the world we live in today, it is worrying if certain groups of people are not part of the development of those technologies (Margolis & Fisher, 2002). It is troublesome that computer science (CS) is found to be the only STEM major in which the representation of women has declined (Beyer, 2014; Sinclair & Kalvala, 2015).

This thesis describes a research project that has sprung from my own experience as a computer science student and teacher. As a student, I felt that education left me alone with questions about what being a computing person means. I dropped out of the CS study programme and found answers to my questions during an internship at a company. My industry experience caused me to re-enrol and pursue a degree both in computer science and in education. As a teacher, I was trying to develop learning environments that would provide various experiences with computing (Peters & Rick, 2014). My research results in a theoretical foundation which helps us to understand how the learning environment shapes and constrains becoming in computing. Issues in computing higher education are identified and discussed that I as a student and teacher could barely grasp.

## 1.1 Low Engagement and Under-Representation in Computing Education, Ways Forward

The history of concerns about shortfalls in the STEM workforce goes back to the 1950s (Teitelbaum, 2003; Lövheim, 2014; Smith & Gorard, 2011). Since then, educational policies and initiatives have been enacted to increase students' interest for and competence in STEM. The EU for example proclaimed in 2004: "The EU needs more scientists!" (Henriksen et al., 2015). Attracting more people from all backgrounds into scientific careers and raising the level of scientific literacy have become high level objectives since then (European Commission: Directorate-General for Research and Innovation, 2016). In 2009, the Obama administration launched a campaign 'Educate to Innovate' to improve participation and performance in STEM (Chen & Soldner, 2013). When it comes to computer science, shortfalls of computer scientists and women's lack of participation is highlighted in the media "nearly every day" (Lehman et al., 2016, p. 1).

However, researchers suggest we should treat these alarmist reports with caution (Teitelbaum, 2003; Lowell & Salzman, 2007; Charette, 2013; Smith & Gorard, 2011; Cappelli, 2014; Sharma, 2016). Most shortfall alarms are about future demand. Current workforce demands are hard to determine, future demands for the rapidly changing fields of STEM are even more difficult to predict. The current shortfall of STEM professionals has been questioned. Henriksen et al. (2015, p. 6) argue that not all STEM fields face workforce shortages, but that "there are predictions of shortages in most engineering disciplines".

Shortfall alarms can also be linked to economic interests (Metcalf, 2010; Smith & Gorard, 2011). A report for the G20 science, technology and innovation ministers meeting for example makes the connection between STEM workforce supply and economic growth explicit:

"Policy makers are particularly interested in the supply of scientists and engineers because of their direct association with technological progress, industrial performance and economic growth." (OECD, 2016b, p. 15).

The focus on STEM as opposed to the Humanities and Arts, and the way engagement in STEM is discussed and researched is found to be poorly aligned with achieving goals such as equity or sustainable development (Zeidler, 2014). No matter how STEM shortfall concerns are assessed, they have left "powerful imprints in political and educational discourse" (Lövheim, 2014, p. 1)

One such imprint is the model of the "leaky pipeline". It is the most popular model to illustrate, understand and address issues of participation in STEM, despite the criticism it has received in recent years (Metcalf, 2010; Cannady, Greenwald, & Harris, 2014; Mendick, Berge, & Danielsson, 2017). The model describes the supply of engineers and scientists as a flow of people that undergo

a linear sequence of educational steps. Certain points along the pipeline are especially leaky, meaning that many people leave the path towards becoming a scientist or engineer at that point. The transition from high school to university is one example (Henriksen et al., 2015; Briggs, Clark, & Hall, 2012), the first year of university education is another example (Tinto, 2010). Also, the pipeline is described as particularly leaky for “women” (Blickenstaff, 2005; Camp, 1997), people of colour (Metcalf, 2010), and students from lower socioeconomic backgrounds (Tinto, 2010).

The pipeline metaphor is criticised for being misleading, reproducing inequalities rather than fighting them (Stevens, O’Connor, Garrison, Jocuns, & Amos, 2008; Metcalf, 2010; Archer et al., 2013; Cannady et al., 2014; Mendick et al., 2017). STEM fields are dynamic, and career paths are not as linear as the pipeline model suggests. Several studies that apply the pipeline model fail to consider a large portion of people that actually end up working with STEM. The pipeline model directs our attention to leakages, de-emphasising alternative pathways into STEM, which are much needed for people from disadvantaged backgrounds. Also, most relevant for this work, it de-emphasises the importance of investigating STEM practices and people’s experience of being or not being a part of STEM.

Under-representation in Computer Science and Engineering has been described using various metrics, and in different ways in different institutions (Vossensteyn et al., 2015). According to the National Science Foundation (2017), 18% of the CS bachelor degrees and 20% of the Engineering bachelor degrees were awarded to women in the USA in 2014. In comparison, in the mid 1980s, CS reached a peak in popularity among women, 35% of the bachelor degrees in CS were given to female students (Lehman et al., 2016). The indicators used by the OECD (2016a) suggest that 75% of the engineering graduates are male, 25% are female, in average across OECD countries. At the same time, the percentage of female graduates across all study programmes is higher than the percentage of male graduates. However, there are countries where the number of female students in CS study programmes is close to equal to, or higher than the number of male students, e.g. in Malaysia (Michell, Szorenyi, Falkner, & Szabo, 2017) or Saudi Arabia (Alghamdi, 2017). I am not aware of general statistics on intersecting identities in computing, studies that consider a combination of gender, socio-economic status, and ethnicity.

After almost a century of initiatives and reforms intended to improve engagement and under-representation in STEM, the same problems still face us. So far, the focus has mostly been on understanding individuals, their lack of interest, attitudes, and motivations (Kinnunen, Meisalo, & Malmi, 2010; Ulriksen, Madsen, & Holmegaard, 2010; Vossensteyn et al., 2015). Researchers suggest moving beyond the deficit framework (Zeidler, 2014), a focus that is “blaming the victims” (Tinto, 2006), and propose that future initiatives should focus on understanding institutional conditions for students (Tinto, 2010), educational practices, and disciplinary cultures, as well as people’s journeys within

STEM (Mendick et al., 2017; Cannady et al., 2014; Hodkinson, Biesta, & James, 2008; Ulriksen et al., 2010; Shanahan, 2009). Feelings or emotions are seen as an important component of learning, but they have not received much attention in STEM education research (Zembylas, 2016).

Identity has been found to be the “missing link” in the effort to accomplish such a shift in focus (Sfard & Prusak, 2005; Tytler, 2014). It helps to integrate the two perspectives on the individual and the social (Hodkinson et al., 2008). Identity is increasingly used in STEM education (Ulriksen & Holmegaard, 2016), in various, sometimes incoherent ways (Jackson & Pozzer, 2015). One challenge is that identity is used in every-day language in a way that does not account for how social structure shapes and constrains individuals (Hall, 1996), which is central to understanding equity issues (Jackson & Pozzer, 2015).

## 1.2 Aims and Research Questions

The broader aim of my research has been to understand how learning environments in computing support and hinder students in experiencing their education as meaningful and empowering to grow as a person. In this work, the focus has been on achieving a better understanding of the university learning environment, specifically the parts that the students encounter in the first three years of their studies. By *university learning environment*, I mean social contexts that are connected to the university, in which learners get to know different ways of knowing and engaging in computing.

I have conducted a longitudinal study, in which students of two computing study programmes (CS/IT) reflected on their histories of experiences in computing at different times of the first three study years. The construct *CS/IT* refers to the study programmes that the informants were enrolled in, Computer Science (CS) or Computer and Information Engineering (IT), or the field of study that the students associate with their study programme. I use the term *computing* as an umbrella term referring to different academic fields such as information technology, information systems, scientific computing, and computer science, as it is done by Tedre (2015).

In the analysis, the focus has been on describing what the reflections reveal about doing, thinking, and feeling in relation to CS/IT as something that is negotiated among different people, which I call *participation in CS/IT*, and to reason about becoming in computing based on insights into participation in CS/IT. The following research questions have guided this work:

1. What are different ways in which the students experience participation in CS/IT, in the first, second, and third study year?
2. How do insights into 1. and social identity theory help to understand learning as a social, long-term process?
3. How can answers to 1. and 2. inform research in and development of computing education?

## 1.3 Purpose and Structure of the Thesis

The purpose of this thesis is to integrate the results of five research papers (Paper I-V) and to set them in a broader context. Paper V provides a systematic summary of the research, without elaborating on the broader context. The Thesis is structured as follows.

Chapter 2 describes the theoretical background for the research. The use of theory and the research approach is motivated and explained. It ends with an overview of the study design.

Chapter 3 describes related research. I argue that research that investigates learning, as it is done in this study, is sparse in Computing Education Research. However, there are quite a number of relevant studies in STEM education research and gender studies that provide a necessary background.

Chapter 4 summarises the study results. I describe how the theoretical underpinnings to investigate learning have developed. Insights into participation and how it constrains and affects individuals are reported.

Chapter 5 explains the measures taken to ensure the trustworthiness of this research. I present insights from having discussed the results of this research with the study participants.

Chapter 6 is a synthesis of arguments and findings, which explain the contribution of the research. Implications for educational research and development are described.

Chapter 7 explores possible avenues for future work. A summary of this research in Swedish is found in Chapter 8.

## 2. Theory and Approach

### 2.1 Learning

Three learning theories have had a major impact on education research and development (De Jong, 2007; Lövheim, 2014; Marton & Booth, 1997): behaviourism, cognitivism, and (social) constructivism. The recent shift in focus in retention research (Section 1.1), from understanding individual learners to understanding social structure, go along with modern learning theories that suggest to view learning as a social, long-term process.

Behaviourism sees learning as happening in a ‘black box’, only input and output are described and developed. Assignments that allow for direct feedback (e.g. multiple-choice questions), repetition, and rewards are seen as central. Researchers and educators have used this learning theory since the 1950s. At that time, research was mostly quantitative, investigating the student outside school, in psychological laboratories. (De Jong, 2007; Entwistle, 2009)

Since the late 1950s, the process of learning, that what happens inside the learners, came into the fore. Questions about the nature, acquisition and application of knowledge became central to psychology and education. Reflections have been used since then to understand different conceptions or understandings that students hold. Active and deep learning has been promoted as a result of research in this tradition. (De Jong, 2007; Marton & Booth, 1997)

Since the mid 1980s, a “somewhat heterogeneous movement” happened, referred to as “the situated cognition” or “the situated action” movement (Marton & Booth, 1997, p.11). Social constructivism has been used as an umbrella term for these diverse research orientations. It emphasises that learning should be seen as an active and a social process (De Jong, 2007). The learner constructs meanings from his or her prior experiences, and in relation to other people. How social surroundings or cultural forces make certain ways of acting and thinking possible for individuals is a common question asked in this tradition.

Insights into learners’ perceptions of learning and knowing complement these learning theories. Entwistle (2007) has developed a model that describes evolving conceptions of knowing and learning, that builds up on work by Perry (1988), Säljö (1979, 1982) and Marton, Dall’Alba, and Beatys (1993). An illustration of the model is included in Paper II (Figure 2, p. 117). At an early stage, learners perceive knowledge in terms of right or wrong, which is established by authorities. More mature learners see knowledge as provisional, they develop a relativistic stance on knowledge. The least mature conception of learning is to view learning as acquiring facts that have to be learnt. At

a later stage, learning is experienced as a process that aims at understanding and personal meaning. Entwistle proposes to see personal development, “developing a sense of identity” as the most mature conceptions of knowing and learning. Identity development seems to be seen as something that individuals do, individuals that have become independent from authorities. This seems to be somewhat contrary to identity as it is used in social identity theory and as it has been used in this work, to reason about how people are formed and shaped in social contexts.

## 2.2 Identity

Identity is a complex concept that has been theorised in different research communities and disciplines spanning education, psychology, philosophy, linguistics, sociology, and gender studies. Examples for frameworks that theorise identity are social constructionism by Burr (2003), symbolic interactionism by Charon (2010), and situated learning or social theory of learning by Lave and Wenger (1991); Wenger (1999); Trayner-Wenger (2014).

### 2.2.1 Social Theory of Learning

What is interesting about Lave and Wenger’s framework is that it is a learning theory, in which the concept of identity is central. Wenger describes identity as follows:

“[Identity is a] way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities.” (Wenger, 1999, p. 5)

Lave and Wenger argue that identity is formed in processes of participation and reification. Wenger describes participation as follows:

*Participation* is a complex process that combines doing, thinking, feeling, talking, and belonging. It involves our whole person, including our bodies, minds, emotions, and social relations. (Wenger, 1999, p. 56–57)

Participation is described as a social process, that involves the learners as a whole. Social relations are particularly important. Participants negotiate what it means to engage in something. For example, if two students sit together and program, they negotiate what it means to do programming, how to think to solve tasks, and how to feel about it. They may acknowledge each other as programmers and by doing so shape their histories of becoming, Wenger calls this ‘mutual recognition’ (Wenger, 1999, p. 56).

Reification is explained as follows:

[Reification is] the process of giving form to our experiences by producing objects that congeal this experience into “thingness”. In so doing we create points of focus around which the negotiation of meaning becomes organized. (Wenger, 1999, p. 58)

The result of the process of reification can be various, e.g. expressions, concepts, symbols, or tools that are used by a group of people.

Lave and Wenger describe participation and reification in the social context of a community of practice (CoP). What it means to engage or be involved in a CoP, the practice, evolves as a “combination of participation and reification over time”, it is a “shared history of learning” (Wenger, 1999, p. 72). A CoP is characterised by three dimensions: 1) “mutual engagement of the participants”, 2) “joint enterprise”, and 3) “shared repertoire” (Wenger, 1999, p. 73-85). Learning entails to learn to interact with the other members, to contribute to the joint endeavour, and to be able to use the resources of the community.

A community of practice is a rather specific social context. Wenger (1999) describes one example of a CoP, a community of claims processors in an insurance company. The members of the community share certain routines and tools to handle claims, they also share ways of handling work and private life. New-comers enter the community through “legitimate peripheral participation”. In the beginning, they observe the practices and take on simple tasks, then they get increasingly involved in processing claims to learn to perform as a full member of the community.

Lave and Wenger’s theory of learning originates from investigations of apprenticeship learning. Since its appearance, it has been applied in different education contexts including higher education, and its use has been debated (Nespor, 1994; Lea, 2005; Sfard & Prusak, 2005; Rogers, 2006; Danielsson, 2009; Shanahan, 2009; Ben-Ari, 2004; Knobelsdorf, 2015).

## 2.2.2 Two Approaches to Studying Identity

Jackson and Pozzer (2015) identify two approaches to studying identity, the possession approach and the negotiation approach. The possession approach to identity views identity as something that is possessed by an individual. It assumes that people have some kind of a “core identity” that is more or less stable over time and context. This view of identity corresponds to the everyday or intuitive use of identity. People talk about someone’s identity, meaning that the person is in a certain way (Gee, 2000; Sfard & Prusak, 2005).

The other approach to studying identity, the negotiation approach, views identity as something outside the individual, as something that is negotiated in interaction, which affects and constrains the individual. Such a view of identity allows to reason about behaviour, interests, and motivations in relation to social constructions. Certain ways of being are recognised and acknowledged,

while others are not. Such an approach naturally lends itself to understand marginalisation, inclusion and exclusion or equity.

Jackson and Pozzer (2015) argue that studying different forms of participation would be a natural focus to understand identity as negotiated. However, they do not explain what they mean by participation. In this work, I have explored the use of Wenger's (1999) notion of participation (Section 2.2.1) to understand identity as negotiated.

### 2.2.3 Power

Power relations are a central component in social identity theories. Power relations do not only constrain becoming, as is e.g. described by Foucault, power relations also form subjects, they can be seen as "the very condition" of the subject's existence according to Butler (1997, p. 2).

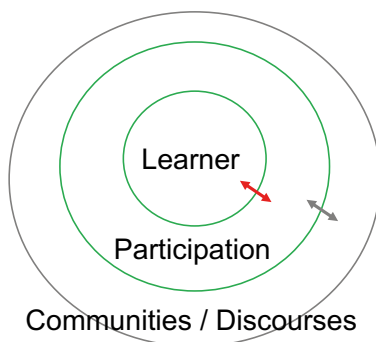
Wenger (1999, p. 189) reasons about issues of power "in terms of the negotiation of meaning and the formation of identities – that is, as a property of social communities". Nespor (1994, p.12) criticises that these communities are treated as bounded, strictly local settings. Danielsson (2009, p. 61) suggests to use the concept of a CoP in a "somewhat less strict sense" to understand identity and power issues in physics higher education. She suggests to reason about students becoming members of the "physics community as a whole". This community, she argues, is a "highly complex one", consisting of many interrelated communities. Danielsson's way of reasoning is also applicable to the context of computing education. Students could be seen as becoming members of a broader computer science community, which consists of many interrelated communities. However, as this community is so complex, it is difficult to reason about the different ways in which the community exercises power.

Another way to investigate power relations is to see that language or discursive practices shape individuals (Burr, 2003; Joseph, 2010; Gee, 2000). Language carries meaning, which is contested in interaction. Experience and self can be seen as a product of language and interaction (Burr, 2003).

In this work, I discuss how participation shapes and constrains individuals in the context of computing education. Discourses or communities certainly affect participation, but I focus on understanding participation and its effects on individuals (see Figure 2.1).

### 2.2.4 Uniformity

Another debate in identity research is whether a person should be seen as uniform and coherent, with an essence at the core that can be described (Burr, 2003; Hall, 1996). In general, the notion of an integral and unified identity has been criticised in a variety of disciplinary areas (Hall, 1996, p. 1). Sfard and



*Figure 2.1.* Illustration of power relations: Learners shape and are shaped by participation. Participation is shaped by and shapes discourses or communities. The red arrow illustrates what is in focus in this work, the interplay between participation and individual development.

Prusak (2005, p. 16) argue that “essentialist visions of identity” are untenable, even harmful to understand people’s actions.

The negotiation approach to identity (Section 2.2.2) allows to see people as “constantly in flux”, behaving and talking in ways that are required by social interaction. With such a view of identity, it is better to use the verb “identify with” instead of the noun identity (Hall, 1996; Jackson & Pozzer, 2015), or to say that someone performs an identity, because it makes clear that the way a person behaves may be different in another situation (Joseph, 2010).

Wenger describes identification in the following:

On the one hand, it [identification] is a reificative process of “identifying as” (and being identified as) something or someone – a category, a description, a role, or other kinds or reificative characterization. On the other hand, it is a participative process of “identifying with” something or someone – that is, developing an association whose experience is constitutive of who we are. (Wenger, 1999, p. 191)

The last part “is constitutive of who we are” signals an essentialist view of individuals and may perhaps better be expressed as “is constitutive of our sense of self”.

Researchers have also argued that people at least have the feeling or desire to be somewhat continuous and coherent over time and context (Sfard & Prusak, 2005; Entwistle, 2009; Holmegaard, Ulriksen, & Madsen, 2015). Group membership nurture our sense of who we are (Joseph, 2010, p. 12) and we test our sense and our stories of who we are against others (Brickhouse & Potter, 2001; Holmegaard, Ulriksen, & Madsen, 2015).

### 2.2.5 Agency

Another discussion in identity research is to what extent people are agents of their behaviour and becoming. Social constructionists assume that people have little agency over their behaviour and becoming and that language or discursive practices shape individuals (Burr, 2003). Lave and Wenger's framework has mostly been used to understand individuals as agents of their becoming (Nespor, 1994, p. 12), (Shanahan, 2009). However, such an emphasis on agency is not integral to the framework as I interpret it. For example, Wenger's (1999, p. 5) notion of identity de-emphasises agency (see Section 2.2.1).

As this work focuses on investigating participation, the question of how much agency people have is somewhat open. I discuss how participation confines agency.

## 2.3 Phenomenography

Phenomenography (Marton & Booth, 1997) is a research approach that was developed in the 1970s in Sweden, around the time when cognitive learning theories were guiding educational research and development (Section 2.1). Phenomenography has been developed to better understand questions such as the following: How do we gain or develop knowledge about the world? How do more advanced levels of knowledge evolve? In the present work, phenomenography is used in a new way, to understand learning in a broader sense that includes emotions and social relations.

At the roots of phenomenography lies the interest to describe phenomena in the world as others experience them and in "revealing and describing the variation therein" (Marton & Booth, 1997, p. 111). A phenomenon can be a concrete object but many phenomenographic studies describe learners' experiences of more abstract concepts that are to be learnt. In CER e.g., students' experiences of programming (Booth, 1992; Thuné & Eckerdal, 2010), recursion and correctness (Booth, 1992), network protocols (Berglund, 2005), or of the concepts "object" and "class" that are central to object-oriented programming (Eckerdal & Thuné, 2005) have been investigated. Those studies have investigated the WHAT aspect of learning, or the object of learning. Other studies have described the HOW aspect of learning, the act of or approach to learning. Examples are studies that describe what it means to learn programming (Booth, 1992) or programming thinking (Eckerdal & Berglund, 2005).

The focus of the present research has been to better understand the phenomenon "participation in CS/IT", drawing on Wenger's (1999, p. 56–57) notion of participation that includes doing, thinking, feeling, and social relations. It is a complex phenomenon because it consists of several parts, however these parts form a whole that can be described. Booth and Marton explain what a phenomenon is in relation to the term situation:

We refer to the wholeness of what we experience to be simultaneously present as a situation, whereas we call entities that transcend the situation, which link it with other situations and lend meaning to it, phenomena. (Marton & Booth, 1997, p. 83)

A way of experiencing a phenomenon can be characterised in terms of the structural and referential aspect. For example, if we enter a room, what do we see? In order to experience something as something, e.g. to see an object as a table, we need to discern the object from its surroundings, e.g. from the floor and the things on top of the object, we need to identify parts of the object and identify those as parts of a table (structural aspect). On the other hand, we also have to assign meaning to the object, the table, in order to see it as something (referential aspect). The structural and referential aspect are “dialectically intertwined”, “structure presupposes meaning, and at the same time meaning presupposes structure” (Marton & Booth, 1997, p. 87).

The structural aspect has two parts, the internal and the external horizon. The internal horizon includes the parts of a phenomenon and their relationships, together with its contours. The external horizon is that which surrounds the phenomenon experienced together with the contours. A table for example consists of legs and a table top (internal horizon). It can be experienced in different contexts, in a class room, in a park, or in a surgery theatre. Different contexts give different clues about the meaning.

The result of a phenomenographic study is an “outcome space”, a limited set of categories that describe the qualitatively different ways in which a phenomenon is experienced by the participants of the study. The categories stand in a logical relationship with one another, mostly a hierarchical relationship (Marton & Booth, 1997, p. 125). The logical relationship exists because each way of experiencing the phenomenon is a different perspective of the same thing (Berglund, 2005, p. 43). In this work, I talk about broader and more inclusive experiences of participation.

Applying phenomenography as a research approach to understand participation in CS/IT, I describe different ways in which the interviewees observe or experience participation in CS/IT. The result is a “second order perspective” on the phenomenon participation in CS/IT. Jackson and Pozzer (2015) argue that identity as something that is negotiated in interaction is typically studied through observations. Interviews by contrast are mostly used to understand identity as something that is possessed by an individual. When a researcher describes observations, he or she explains his or her own observation of something, i.e. a first-order perspective on that which is observed. In a phenomenographic study that uses student interviews, each interview can be interpreted as one observation of the phenomenon. Each student typically has observed, or is aware of, several ways of experiencing the phenomenon.

A phenomenographic study aims to describe the “totality of qualitatively different ways” in which a phenomenon is experienced within a cohort (Marton

& Booth, 1997, p. 121). One way of experiencing the phenomenon is commonly talked about by several individuals. However, even if a way of experiencing participation is only referred to by one individual, it is considered in the phenomenographic analysis. The results of a phenomenographic study “should be complete in the sense that nothing in the collective experience as manifested in the population under investigation is left unsoken” (Marton & Booth, 1997, p. 125).

The aim of a phenomenographic study is not to report on experiences that reside in an individual, but on the relationship between a phenomenon and the informants of a study. More precisely, it is the relationship between the researcher and the relationship between the experiencer and the experienced that is reported on. All parts of this setting affect and are affected by these relationships. For example, the researcher helps the learners to see the phenomenon from different angles, and thus affects what the learner is able to reflect on, which could in turn affect the phenomenon (Marton & Booth, 1997, p. 113,125). A way of experiencing something is therefore not a psychological entity, residing in the minds of individuals (Säljö, 1997, p. 175).

Phenomenography has received criticism (Tight, 2015). Particularly relevant for this work are Säljö’s (1997) concerns. He questions whether what a person tells about a phenomenon really should be seen as indicative for an individual’s experience, or if it should perhaps better be interpreted as a way of talking (discourse):

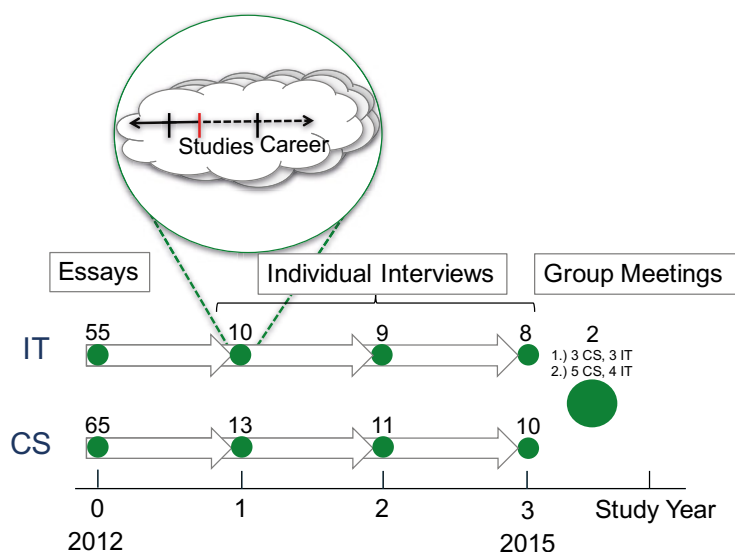
Conceptions of the world are not meaningful in and by themselves, they form a part of discursive practices and gain their meaning from their insertion into systematic discourses. (Säljö, 1997, p. 180)

Discursive practices are negotiated in participation. I would say that the students’ experiences of participation certainly do reflect discursive practices.

Hazel, Conrad, and Martin (1997) have critiqued phenomenography for its focus on the cognitive dimension of knowledge. They argue that the affective dimension of knowledge, which is “often associated with women’s ways of knowing”, is neglected. There are however a few recent phenomenographic studies that study learning in a more holistic sense. Thota and Berglund (2016) for example explored Chinese students’ learning of CS at Uppsala University in Sweden. They talk about values that students imbibe in different social contexts. Berglund et al. (2009) investigated CS learners’ difficulties as it is experienced by academic teachers. In the present study, feelings are considered as a part of the complex phenomenon participation in CS/IT.

## 2.4 Overview of the Study

Figure 2.2 illustrates the data collection of this study. Information on the CS and IT study programme can be found in Paper V, Section 4.1.



*Figure 2.2.* Illustration of the data collection (as presented in Paper V): The informants were either enrolled in the CS or IT study programme. The filled green circles represent the data collection instances. The numbers above the small filled green circles represent the number of collected essays or conducted interviews. Two group meetings were organised to discuss the results of this study with the participants (Section 5), the numbers behind 1.) and 2.) reflect the number of CS and IT students that participated in each group meeting. The big unfilled circle in the upper part of the Figure illustrates the kind of data that was collected: The interviewees reflected on CS/IT-related experiences prior to and during their studies until the interview (continuous line), as well as on their future engagement in CS/IT (dotted line).

	% DV	Female Students		% IT	(N <sub>o</sub> IT)
		(N <sub>o</sub> DV)			
2016	13	(8)	25	(15)	
2015	20	(13)	29	(21)	
2014	11	(8)	22	(16)	
2013	8	(5)	12	(9)	
2012	7	(5)	5	(4)	
2011	14	(9)	14	(10)	

**Table 2.1.** Percentage and number of female students accepted to the CS and IT programme in the years 2011 until 2016.

All students that commenced the CS and IT study programme in 2012 got a mandatory assignment to reflect on their choice of study, future career, as well as on their study expectations. The assignment was an early part of the first course introducing the students to their field of study (see Appendix A for details on the assignment).

Based on 123 essays that were submitted, I selected 25 students to follow through interviews, of which 23 agreed to participate. A detailed description of the selection process can be found in (Peters, 2014, p. 22-23). The goal of the selection process was to choose students that together cover the breadth of experiences in the essays.

The followed student cohort consisted of exceptionally few female students (see Table 2.1). Seven out of the nine female students that were accepted to the study programme submitted an essay. I invited all of those students to participate in the study, of which six students agreed to participate. As there were so few female students, I have chosen not to reveal the students' gender when quoting the students.

The interviews were semi-structured (Kvale, 1996). Each interview consisted of four parts, 1) choice of study, 2) future career, 3) study experiences, 4) perceptions of the discipline and studies as a whole. Each part began with an open question that allowed the students to talk about experiences that were important to him or her. I prepared follow-up questions that I anticipated could help the students to reflect on CS/IT-related experiences, particularly on the components of participation, doing, thinking, feeling, and social relations (Section 2.2.1). Examples for follow-up questions are: "What did you do that was particularly interesting or exciting to you?", "Whom did you do this with?". Details on the interview script can be found in the Appendix B.

Follow-up questions were also used to talk about changes the reflections. Before the interview, I read through all of the interviewees' previous reflections, which allowed me to note and ask about changes.

The phenomenographic analysis began by transcribing all interviews and reading all the transcripts. I marked sections that I interpreted as an experience of participation in CS/IT. I used labels to capture the meanings of the experiences. Then, I studied qualitative differences in these meanings. Several iterations of analysing the transcripts resulted in an outcome space.

The longitudinal design of this research is special, considering most other phenomenographic studies. I started by analysing year one data (Paper III), then I reported on second year students' experiences of participation (Paper IV). After having analysed year 3 data (Paper V), I revisited all data, this time going through and comparing the reflections of each individual student. The aim was to consolidate the insights into participation in CS/IT, and to understand the relevance of the results to describe trajectories into, within, and out of computing (Paper V).

## 3. Contextualising the Research

### 3.1 Identity in Computing Education Research

Computing education research (CER), also known as computer science education research or informatics education research, as a field of research, has been formed in the 1970s and has since then emerged into a discipline (Pears, Seidman, Eney, Kinnunen, & Malmi, 2005; Simon, 2015). It combines computing with the human sciences. The following two questions have been fundamental in CER according to Simon (2015, p. 81):

“How do people learn to program?”

“Why do many people find it so difficult to learn to program?”

That these two questions are the fundamental questions in CER points to an issue at stake. Researchers have for decades explained drop out and underrepresentation in CER with narrow perceptions of computing as programming (Biggers, Brauer, & Yilmaz, 2008; Yasuhara, 2008; Dempsey, Snodgrass, & Kishi, 2015). The ACM and the IEEE (2013, p. 47), two major advocates of computing<sup>1</sup>, for example state that students equate CS with programming, which raises “negative and incorrect stereotypes of isolated and rote work”. The problem here lies in the individuals, their conceptions of computing, the present study is raising the question what education does that may cause such limited conceptions of the discipline.

Kinnunen et al. (2010) reviewed 67 papers, published between 2005 and 2009, presented at the ICER conference, a leading computing education research conference. They find that the focus commonly is on the *how* aspect of learning, *what* is being learned is seldom questioned. A great amount of work in CER focuses on describing learners’ characteristics, conceptions, interests, motivations, and attitudes. None of the papers studied a student’s or a student community’s relationship to different actors in the teaching organisation, many papers investigate education at a course level.

The importance of theory is increasingly recognised. In 2004, Fincher and Petre find CER to be theory scarce. Of about 300 papers that were published between 2005 and 2010, about half include a theory, method, or a framework

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<sup>1</sup>ACM stands for Association for Computing Machinery and IEEE stands for Institute of Electrical and Electronics Engineers.

(Malmi et al., 2014). A small proportion of the papers, 15 out of 300, referred to constructivism or subfields (communal constructivism, constructionism, social constructivism, situated learning), which suggests that theories that view learning in a broader sense than cognitive development are being used. However, Tenenberg and Knobelsdorf argue in 2014 that cognitive views of learning dominate the CER literature.

Computing education has been argued to be connected to psychology, education, sociology, and anthropology (Pears et al., 2005). Of the 300 papers that Malmi et al. (2014) reviewed, education was referenced most frequently (30%), followed by computing (24%), psychology (20%), CER (16%), and other disciplines (12%). Sociology and gender studies, disciplines that have advanced social identity theory, were not listed.

The overall picture of computing education also describes the large body of research on retention and under-representation in computing, as is summarised in (Kinnunen & Malmi, 2006; Kinnunen & Simon, 2011; Kinnunen, 2009; Biggers et al., 2008; Dempsey et al., 2015; Yasuhara, 2008; Sinclair & Kalvala, 2015; Giannakos et al., 2016). The focus has been to investigate individual students' experiences and conceptions. For example, researchers have found that students drop out of the first programming course (called CS1), because they lose motivation or get interested in something different (Kinnunen & Malmi, 2006; Yasuhara, 2008). While several studies identify problems in the education system, our understanding of those is very limited.

## 3.2 Computing and Engineering Education Culture

A number of interdisciplinary studies exist that combine gender research and STEM education research, and that discuss under-representation of women. Reviews of such studies are provided in (Sinnes & Løken, 2014; Michell et al., 2017; Svedin & Bälter, 2016). Several of these studies investigate how disciplinary identity and gender identity is constructed and reproduced in education (Harding, 1986; Faulkner, 2001; Danielsson, 2009; Ottemo, 2015). Adopting the approach of using gender differences to explore under-representation of women is problematic (Björkman, 2005; Salminen-Karlsson, 2011; Mendick et al., 2017). There is a risk that differences between women and men are reproduced. Women's interests, self-esteem, motivation etc. are often rendered problematic. Researchers have discussed why feminist studies have not received more attention in STEM education research (Björkman, 2005; Phipps, 2006; Salminen-Karlsson, 2011). An explanation is different research traditions in gender studies and STEM or STEM education.

Computing, as it is constructed in education, centres around computers, machines, and programming or coding (Rasmussen & Håpnes, 1991; Margolis & Fisher, 2002; Garvin-Doxas & Barker, 2004; Ottemo, 2015; Kinnunen et al., 2016; Björkholm & Engström, 2017). Computing is constructed as something

difficult, something that requires being smart or clever (Margolis & Fisher, 2002; Varma, 2007; O'Connor, 2014). Mathematics is seen as important, applications and application contexts are of less relevance (Margolis & Fisher, 2002). Researchers have analysed textbooks and found that they focus on technical details and that they do not show the breadth of applications (Margolis & Fisher, 2002; Goldweber et al., 2012). Curricula in computing and engineering focus on technical aspects of programming and mathematics in early years, multidisciplinary projects are deferred to the end (Margolis & Fisher, 2002; Holmegaard, Madsen, & Ulriksen, 2015). Garvin-Doxas and Barker (2004) observed CS learning environments and found that they were primarily characterised by a defensive classroom climate, which means that discussions are competitive. The language used in computing includes many violent terms such as “brute force”, “number crunching”, and “hacking” (Cohoon & Aspray (Eds.), 2006, p. 145).

Having a passionate relationship to computers has been described as a stereotypical image of a computer scientist (Margolis & Fisher, 2002; Klawe, 2001; Cohoon & Aspray (Eds.), 2006; Varma, 2007). Terms such as “geek”, “nerd”, “hacker” have been used to describe stereotypes of computer scientists. Some researchers describe the “geek culture” as a minority culture (Margolis, Estrella, Goode, Holme, & Nao, 2010; O'Connor, 2014), while other studies suggest that stereotypical constructions of CS are common and reproduced (Rasmussen & Håpnes, 1991; Varma, 2007; Michell et al., 2017; Svedin & Bälter, 2016). Ottemo (2015) has investigated a Swedish CS programme and finds that the subject position of the “passionate student” is articulated mainly in informal student contexts. As the education fails to engage the students, it becomes the predominant way in which students make sense of their studies.

Engineering education researchers have applied social identity theory. Tonso (2006) investigated engineering campus culture through ethnographic studies. She finds three identity categories, “nerd”, “academic achiever”, or “social achiever”. Only the first two categories were recognised as engineers, but those identities were not accessible to women. Faulkner (2001, 2005, 2006) conducted interviews and did observations in higher education and at engineering workplaces. She describes two engineering identities, a technical and a more heterogeneous “sociotechnical identity” and argues that the dualistic nature of these identities (technical vs. social) is problematic.

Similar results are presented in mathematics and science education research. Mendick (2005b, 2005a) finds that mathematics is constructed based on dualisms or oppositions, in similar ways as masculinity is constructed in the western world. Likewise, science is often positioned as “value-neutral, objective, dispassionate, [and] disinterested” (Phipps, 2006) (quoting Harding 1987).

I am aware of three PhD studies that investigated computing education with a gender perspective. One study is the one by Ottemo (2015) described earlier. Björkman (2005) argues for the use of gender studies to critically understand the foundations of computer science as a discipline. Salminen-Karlsson

(1999) investigated reform processes at two Swedish Computing Engineering programmes that aimed at increasing the proportion of women. Even after the reform processes, the programmes still had problems accommodating students that diverged from the norm of the traditional male secondary-school graduate interested in computers.

Kolikant and Ben-Ari (2008) investigated student and teacher culture to understand programming difficulties in high school computing education. Their study suggests a “culture clash” between students, described as computer users, and computing teachers that are used to the academic CS world. Knobelsdorf and Schulte (2005) find that the students who enter the CS programme in Germany have typically come to experience CS as creating computer artefacts and expect to learn more about programming. They analysed computer biographies from novice CS students and compared them with computer biographies from psychology students (Knobelsdorf, 2011; Knobelsdorf & Schulte, 2005).

### 3.3 Implications of Culture for Individuals

Researchers that have come to the conclusion that discipline is constructed in similar ways to those in which masculinity is constructed in the western world discuss implications for individuals (Faulkner, 2001; Brickhouse & Potter, 2001; Björkman, 2005; Faulkner, 2005, 2006; Boivie, 2010; Ottemo, 2015). People who do not identify with masculinity have to juggle two conflicting identities, the gender identity and being a computing person. Appearing as a woman can imply being excluded from being recognised as competent (Rasmussen & Håpnes, 1991; Faulkner, 2001; Tonso, 2006; Michell et al., 2017). Faulkner finds that women feel ambivalence about technology which is “immobilising” or “polarising” (Faulkner, 2001, p. 90). Ottemo’s (2015) study suggests that students “adopt an instrumental approach to their education, emphasizing the future exchange value of their formal degree rather than subjective meaningfulness or the significance of the subject matter as such” if their education fails to engage them subjectively (Ottemo, 2015, abstract).

Stereotypical constructions of computer science can lead to drop out or rejection of CS (Varma, 2007; Margolis et al., 2010; Cheryan, Plaut, Davies, & Steele, 2009; Michell et al., 2017). They cause people to question whether they really (can) belong to the field of computing. Researchers have shown how removing stereotypical cues from the learning environment can improve retention (Cheryan et al., 2009; Svedin & Bälter, 2016). High school students are affected in their choice of study by stereotypical images of CS and computer scientists, and also by stereotypical constructions of what it means to be a woman or a man (Rommens, Overbeek, Scholte, Engels, & De Kemp, 2007; Wong, 2017; Wong & Kemp, 2017).

The stereotype threat can have an effect on students’ performance. Mathematics is seen as central in computing, and computing is constructed as some-

thing difficult (Margolis & Fisher, 2002; Varma, 2007; O'Connor, 2014). Steele (2011) has shown how women perform less well than men in a difficult math test, just because the women are aware that mathematics stereotypically is a “men thing”. Telling the woman that men and women tend to perform equally well in the test results in similar performances among men and women.

Researchers have described cases of student development in relation to insights into culture. Foor, Walden, and Trytten (2007) have conducted ethnographic studies in engineering education. Reporting the story of Inez, a student that “epitomizes individual diversity” (p. 103), they describe an example of how STEM education fails to include and support students with dis-advantaged backgrounds. Brickhouse and Potter (2001) have investigated science identity formation in high school. They describe the experiences of two female students of colour. One of the girls constructed an identity as a successful computing student, which seemed possible because she interacted with people from a variety of backgrounds and because of the students’ “desire to take on an identity that did not conform to conventional norms of femininity” (p. 978).

### 3.4 Longitudinal Studies

Research described in the previous Sections 3.2 and 3.3 mostly include a long-term perspective on learning. The following studies have a clear, explicitly stated longitudinal design.

McCartney and Sanders (2014, 2015) conducted a longitudinal interview study following computing students through their undergraduate studies, aiming to understand students’ professional development. They analysed first-year students’ social networks and find peers to be particularly important. They report on “critical incidents” that affected two students in particular ways. External job-related factors were of significant importance to these two students.

O'Connor (2014) followed women in CS during their senior year in college, and into work life. The aim of this study was to find out about how women persist in their studies and about their careers. The result is a description of the women’s experiences, e.g. of the culture of computer science, stereotype threat experiences, career pathways and career experiences.

Stevens et al. (2008) conducted a longitudinal ethnographic study in four undergraduate engineering programmes over four years. They propose three dimensions to understand the process of becoming an engineer: accountable disciplinary knowledge (ADK), identification, and navigation. By identification, they mean the double-sided process of identifying with engineering practices, and being positioned by other people and institutional practices. Their view of identity puts emphasis on the individual, his or her sense of self that is strengthened by others, rather than on that which the person identifies with, which is the focus in this work. However, the component ADK allows to reason about aspects of that. Stevens et al. describe a shift in the ADK component

in the upper-level courses, towards more open-ended problems that were closer to real-world scenarios. The most evident change related to identification was that students “demonstrated increasing solidarity with other engineering students and increasingly reported differences between themselves and other college students” (Stevens et al., 2008, p. 360).

Holmegaard, Madsen, and Ulriksen followed students during the final year in high school and the first year in university, collecting students’ narratives on their choice of study (Ulriksen, Holmegaard, & Madsen, 2013). They suggest that the choice of study programme should be seen as a process that lasts throughout the first study year (Holmegaard, Ulriksen, & Madsen, 2012). The students try to integrate their study experiences into their perception of self (Ulriksen, Madsen, & Holmegaard, 2015), students who struggle might switch their major. Students who chose engineering saw engineering as an alternative to doing science, being more hands-on, about real-life problems, and as including cross-disciplinary approaches (Holmegaard, Madsen, & Ulriksen, 2015). At university, the students met a kind of engineering that was more in-line with the views of engineering that the students who chose not to study engineering had (Holmegaard & Ulriksen, 2010). Ulriksen (2009) proposes the concept of the ‘implied student’ to discuss the kind of student that is implied by curriculum and social interaction. This concept appears to be similar to the notion of identity used here. It is constructed in the social realm and it affects and constrains the students (see Section 6.3). Ulriksen et al. (2015, p. 15) argue that students who are different from the implied student have to perform a more “extensive renegotiation” than students who are similar to the implied student.

### 3.5 Computing as a Discipline

Tedre (2006, 2015) provides a historical perspective on how computing has been developed in academia. He argues for three views of computing that arise from three fundamentally different intellectual traditions: the theoretical, the scientific, and the engineering tradition. These traditions “are based on different principles, they have different aims, they employ different methods, and their products are very different” (Tedre & Sutinen, 2008, p. 153).

Tedre describes these traditions as follows (Tedre, 2015, p. 12-15). Scientists aim to describe, explore and predict natural phenomena. Their knowledge is tentative (as approximations or models of the world) in the sense that scientists can produce results that conflict with previous knowledge. Mathematicians aim to discover the truth, developing new knowledge deductively based on previous results (proofs, axioms, rules). Engineers aim to produce useful things. Their knowledge is described as “tentative, contextual, and unlike scientific and mathematical knowledge, not concerned with truth but whether or not knowledge works. Much of engineering knowledge is prescriptive and tacit, such as technical maxims (rules of thumb)” (Tedre, 2015, p. 13). Engi-

neers acknowledge the value-ladenness of engineering knowledge, mathematics is considered to be value-free, scientists often claim to be value-free.

The driving force of the development of the field of computing has been its “dizzying variety of applications” (Tedre, 2015, p. 6). Interdisciplinarity is characteristic for computing, according to Tedre but also according to the ACM and IEEE. They promote a “Big Tent” view of computing in their computer science curriculum:

“As CS expands to include more cross-disciplinary work [...], it is important to embrace an outward-looking view that sees CS as a discipline actively seeking to work with and integrate into other disciplines.” (The ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013, p.13)

Constructions of computing as technical (Section 3.2) seem to be inward, not outward-looking.

## 4. Results

### 4.1 From Attitudes to Identity

As a point of departure, I studied students' attitudes towards learning about computing, or their inclinations to learn computing, and how learning experiences can change these attitudes (Paper I). I investigated students of a different study programme than in the rest of the PhD project, students in the Sociotechnical Systems Engineering (STS) programme at Uppsala. The programme offers courses in the humanities and in technology, so I was assuming that the students had a variety of different interests in technology. In the second study year, the students get to take an introductory programming course, upon which they get to decide whether they want to specialise in CS or energy systems. The introductory programming course has been developed informed by research aiming to enhance student engagement (Pears, 2010). What is special about the student group taking the course is that it is gender-balanced.

One result of the study reported in Paper I is that the students evaluated the course surprisingly positively, considering the great number of studies on retention in introductory programming courses. The students filled in a survey, marking checkboxes that best described their attitudes towards learning CS prior to and after the course, whether they found learning about CS rather interesting or uninteresting, boring or exciting, difficult or easy, useful or irrelevant. Then, the students described learning experiences that either supported or changed their prior attitudes towards learning CS. All of the 36 students that filled in the survey experienced the course as overall positive. The 16 students that were somewhat sceptical before the course (expecting learning CS to be rather uninteresting, boring or irrelevant) described a change towards a more positive attitude. Paper I presents themes that emerged from analysing students' explanations of how the course supported positive attitudes towards learning CS. One theme is "emotions" (programming is fun, challenging), another is "understanding of the discipline".

Interviews with five students that described a change towards more positive attitudes provided deeper insights into learning experiences of the course, as well as into how the students reasoned about future engagement in computing. Even though the students enjoyed the course, four out of five interviewees were expressing doubts about future engagement in computing. Computing, as they perceived it, was nothing for them. This finding relates to other studies that suggest that students cannot see themselves working in the discipline, despite positive learning experiences (Archer et al., 2010, 2013; Dempsey et al., 2015; Wong, 2017; Wong & Kemp, 2017).

Another result in Paper I is a summary of students' explanations, why they would probably not engage in computing in the future. The narrow focus on programming appears to be one issue. The students think that the course has given them an idea what computing is about (programming). Ulriksen et al. (2015) suggest that the students try to integrate their experiences of programming into their perception of self, and if they fail to do so, they choose not to take further courses. I began to learn about social identity theory and wondered about how CS and IT students make sense of their studies.

Paper II describes a theoretical framework for the longitudinal study which has culminated in this thesis. At that time, the plan was to follow students of three study programmes (STS, IT, and CS), with the purpose of understanding students' "identity development", and how it is supported in education. I suggest combining Entwistle's (2007) model of learner development (Section 2.1) with Lave and Wenger's (1991; 1999; 2014) social theory of learning (Section 2.2.1). Lave and Wenger argue that meaning making is critical for identity development. What it means to engage in an activity is negotiated in participation. Entwistle's model suggest that students with less mature conceptions of knowledge and learning are particular dependent on authorities to experience what they learn as meaningful. They do not seek meaning, but expect to be provided with all relevant knowledge.

Analysing the essays that the students wrote in the beginning of their studies (Section 2.4) with the framework proposed in Paper II, I found several statements that suggest less mature conceptions of knowing and learning. For example, a student wrote that he or she expects to learn everything needed for a career in computing. Students with such less mature conceptions of learning may more easily get irritated if what they learn does not make sense to them because they do not seek meaning. They may also adapt, more than learners with more mature conceptions of learning, to the ways of knowing and learning they encounter, because they believe that they are presented with the "right" or only way of doing CS/IT.

Applying the use of the concepts of participation and reification in Paper II, I also describe two foci in students' reflections. The students either wrote about computer and computer-related activities or about broader interests in "IT systems" and "technological development". The students who focus on the computer often state experiences that are about creating smaller computer artefacts. The students with a broader focus on information technology have (in general) not experienced development of such artefacts.

Papers III, IV, and V report on participation in CS/IT as well as how it affects individuals. I question how independent the learners really are allowed to be in this learning environment. Jackson and Pozzer's negotiation approach to identity (Section 2.2.2), the notion of power (Section 2.2.3) and discussions around uniformity (Section 2.2.4) and agency (Section 2.2.5) are useful to explain changes in student reflections as adaptations to how CS/IT is constructed in social contexts (Paper V). What can be studied as an attitude that an indi-

vidual possesses can also be described and discussed as a part of performing an identity that is recognised and acknowledged by other people.

## 4.2 Participation in CS/IT

Participation in CS/IT as first, second, and third year students experience it is summarised in my phenomenographic outcome space (Paper V). The categories are inclusive, i.e. the experience described by one category includes the experiences described by the previous category. Table I in Paper V provides an overview of the outcome space. Paper III and Paper IV present similar outcome spaces as a result of analysing year 1 data (Paper III) and year 2 data (Paper IV).

Three categories appear to be particularly relevant when discussing learning and becoming in computing education: participation as creating (category C), problem solving (category D), and problem solving for others (category E). The data contains few examples of participation as creating new knowledge (category F), and those examples are about future engagement in computing. I only find one example of participation as contributing to societal endeavours (category G) that is part of the third-year data, which is why this category only appears in the outcome space in Paper V (Section 5.1.7 in Paper V).

Participation as creating (category C) is about building new technical or digital artefacts that carry out tasks. Being able to create new artefacts is experienced as fun and fascinating {feelings}<sup>1</sup>. Participation as creating is shared among the students {social relations}. Several students told me that the students sit together in between or after classes and brainstorm ideas for different “mini projects” that they could do outside class, for instance apps or games. To give a concrete example, one of the students talked about an app that could raise and lower the roller blinds.

Participation as problem solving (category D) is about using methods and ways of thinking to approach difficult {feelings} problems. The aim is to create a solution, thus the experience described by this category includes the experience described by category C. In participation as problem solving, the students do not only create a solution, they also create and design the process to develop the solution. Many students talk about the method “divide and conquer” that they use to work on a problem. It entails identifying and working on sub-problems and integrating sub-solutions to achieve a complete solution.

Participation as problem solving is predominant in the learning environment {social relations}. When the students reflect on what they have learnt in a course, they commonly talk in ways that are associated with problem solving {social relations}. The students learn about how to solve different types of

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<sup>1</sup>As in Paper V, I use the markers {social relations} and {feelings} to emphasise these parts in the explanations that are seldomly discussed in CER (Section 3.1).

(technical) problems. Solving these problems often requires them to develop an algorithm and to implement the algorithm with program code.

Several informants explain that the education is about solving “back-end” problems, problems that lead to solutions that are not visible and not noticed by users (Paper IV, Section 8.1).

In study year two and three, the students reason more frequently and nuanced about participation as problem solving. Due to the relevance of the experience, I did a separate phenomenographic analysis aiming to provide more nuanced insights into participation as problem solving. Paper IV presents an outcome space describing the different ways in which the students experience participation as problem solving in their second study year. Paper V presents an outcome space that describes first, second, and third year students’ experiences of participation as problem solving. The two outcome spaces describing participation as problem solving are the same in principle, but the labels and explanations have slightly been changed in Paper V to achieve more clarity.

Table II in Paper V gives an overview of students’ experiences of participation as problem solving. The first category D.1 is about handling the problem to find any solution. Category D.2 describes problem solving as finding a solution that is optimal according to a criterion. Execution time, memory usage, and time complexity are quality criteria that the students often refer to. In participation as described by D.3, the students see that there may be several “optimal” problem solutions that optimise different quality criteria. Problem solving as it is described by D.4 includes the capacity to develop sub-solutions that can be re-used in the future for problems of the same type.

In study year three, the students get to be a part of participation as problem solving for others (category E). The user experience is in focal awareness, methods, ways of thinking, and best practices are applied to improve the usability of the product. The participants share positive feelings connected to doing something that can be of use for others.

Participation as problem solving appears to first be relevant in the human computer interaction (HCI) course in year 3 {social relations}. When the students reflected on the HCI course, they talk about experiences that are associated with participation as problem solving for others. However, several students reacted with scepticism or rejection to the HCI course, questioning whether what they learnt in the HCI course really falls into the scope of CS/IT (Section 5.1.4 in Paper V).

Due to the strong reactions to the HCI course, and the increased relevance of participation as problem solving for others, I did a separate phenomenographic analysis, aiming to describe different ways in which students experienced participation as problem solving for others. The resulting outcome space is presented in Paper V, Section 5.3.

The first category of the outcome space describing different ways in which students experience participation as problem solving for others, E.1, extends participation as problem solving in the way that the participants share an extra

motivation or positive feelings related to doing something of use for others. In participation as described by E.2, the participants also make use of best practices, rules, standards, etc. to improve the usability of the solution. For example, the students talk about rules for user-friendly graphical user interfaces. Participation as captured by E.3 includes interaction with the users to get a better understanding of what usability entails in a certain context. E.4 includes personal development to improve communication with the users, and thus the usability of the solution.

When the students reject or question the HCI course, they position CS/IT as something that centres around the technical, and HCI as something that is about people (Paper V). They argue that objectivity is important outside the HCI course, in the HCI course the students considered (subjective) user experience to understand the quality of a solution. The students refer to dualistic constructions of computing that have been described in previous work (Harding, 1986; Faulkner, 2001; Mendick, 2005a) (Section 3.2). Students also rejected HCI as “fuzzy”. Similarly, Stevens et al. (2008) found that engineering students position themselves as “the techies” and other students as “the fuzzies” (p. 360) (Section 3.4).

The outcome spaces describing participation as problem solving and problem solving for others can be used to reason about dualistic constructions of CS/IT (Paper V, Section 6.1). For example, categories D.2 and E.2 are both about developing problem solutions of quality. In D.2, the students talk about criteria that can be measured “objectively”, independent of the user, for example execution time. Category E.2 introduces a new quality criteria, usability, that is based on subjective user experience.

The back-end vs. front-end distinction is another dualistic construction of CS/IT (Paper IV, V). Back-end problems are seen as “the real” and the difficult CS problems. They can be considered as especially technical because the solutions cannot be perceived by the user. Doing the front-end, e.g. the graphical user interface, is seen as easy, something that one can learn by oneself.

In the following, as in Paper V, I use the term *technical problem solving* to refer to dualistic constructions of CS/IT as technical vs. social, in which objectivity and logic reasoning is central as opposed to considering subjective experience. I use *(technical) problem solving* to refer to participation as problem solving, category D of the outcome space, signalling that this could include dualistic constructions of CS/IT as technical problem solving.

### 4.3 How Participation Shapes and Constrains Learners

The second research question is about how insights into participation and social identity theory (Section 2.2) can be used to understand learning as a social, long-term process. I answer this question by discussing examples of student trajectories.

Many of the informants state an interest in creating digital artefacts, as it is also reported by Knobelsdorf and Schulte (2005) (Section 3.2). Analysing the data with the aim to understand doing, thinking, and feeling, as it is shaped and negotiated in different social contexts suggests that participation as creating is a common way of making sense of CS/IT among the students. That means that developing and showing an interest for creating technical artefacts helps to fit in and be recognised as a computing student (see e.g. mutual recognition, Section 2.2.1). Instead of viewing students' interests as individual interests, which is how they are usually studied in CER (Section 3.1), they can also be seen as interests that are shaped and reinforced in the student context. We should therefore consider that the student contexts have power (Section 2.2.3) in the sense that they can shape and possibly constrain individuals.

Two of the students who left the study programme<sup>2</sup> explained that they did not want to be a part of creating apps and games (Paper V, p. 20). This supports the idea that participation as creating, as it is shared among the students, can be seen as a constraining factor.

All students that remained in the study programme, either brought with them an interest in problem solving or stated such an interest in an interview at some point (Paper V). Several students explained that they have become better at solving difficult problems, as for example in the following quote:

I<sup>3</sup>: "Could you try to describe how you have developed during the last year?" Matthew (CS, year 2)<sup>4</sup>: "It can be quite scary. [...] 'Will I manage to solve this problem, I don't even know where to start!' I feel, I have overcome that fear quite a lot. You learn how to tackle a larger problem by dividing it into smaller segments." (quote from Paper IV, Section 7.1)

As I interpret this statement, Matthew says that he once thought that problem solving was scary. Nowadays, he is not or only a little scared of the problems he is asked to solve, he finds it fun and he is usually capable of solving the problem. This statement can be interpreted as an individuals' change of interest and experience, but it can also be seen as a statement to demonstrate competence in this learning environment, where participation as problem solving predominates.

Several students with broader interests drop these broader interest as they traverse through their education and only reason about (technical) problem solving in the second and third-year interviews. In Paper V, I present two examples, one is Matthew, the other example is Jaylin. Jaylin entered the study programme with the idea of combining art and computer science. Matthew

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<sup>2</sup>Four students followed in this study left the study programme. One student took a study break. See Paper V, p. 8 for more information.

<sup>3</sup>"I" stands for the interviewer, i.e. myself.

<sup>4</sup>I use names that are not the students' real names, names that I found to be gender neutral. I use masculine pronouns to not reveal the students' sex (see Section 2.4 for explanations).

was close to finishing a political science degree programme when he commenced the CS study programme. In the first-year interview, Matthew said that the connection between CS and politics comes naturally. In year 2, the students did not talk about their other interest anymore. Asking them about their initial plan, both students said that they now are more interested in back-end programming. I find these changes in reasoning dramatic, from doing art and politics to doing something that is not visible to or noticeable by other people. In year 3, Jaylin is confused and thinking about leaving the field of CS to engage in something that also includes aesthetics. Matthew still presents himself as someone interested in solving difficult technical problems. Coming up with the theory, the algorithm, is most interesting to him. He performs a technical problem solver identity, viewing political science as opposed to CS:

Matthew (CS, year 3): “Political science [...] is about discussion and argumentation without getting anywhere. [...] The only way to come to a point of right or wrong is to look at reality. [...] Whereas in CS] it often feels like, at least among students, ‘I want to do a better solution’ [...] ‘Can I do this algorithm slightly, slightly faster?’ As this is a theoretical, a natural science discipline, one can always test the solution [...] in a very small, secure environment.”

A relevant question is the degree of agency (Section 2.2.5) the students have in this development towards being a (technical) problem solver. The following quote suggests that people who show enthusiasm for aspects that fall outside the scope of (technical) problem solving risk being marginalised by people who perform a technical problem solver identity. This could explain why students show so little commitment to the HCI course, which has been investigated by Cajander et al. (2017).

Chris (CS, year 3): “The teacher [of the HCI course] was very interested in HCI. [...] We thought: ‘He is not a real computer scientist!’ (laughs) But then it turned out that he actually could program and that he was as good as we are, [...] just that he had an interest for that which was a bit fuzzy.”

Chris might not “possess” this attitude (Section 2.2.2), he may just talk the way he does because he was talking to me, a person who presented herself as a computer scientist, and because he has experienced that this way of talking gives recognition as competent. Perhaps he talks in different ways in other social contexts (see the debate on uniformity, Section 2.2.4).

The HCI course aims to foster broader experiences of participation in CS/IT. However, it also provides opportunities to perform a technical problem solver identity. People who perform a technical problem solver identity possibly hinder others from embracing broader ways of participating in CS/IT. For instance, such a statement as the one by Chris in the previous quote could prevent other students from showing an interest in HCI. Instead of broadening participation, the HCI course may reinforce the technical focus in this learning environment.

## 5. Trustworthiness

Lincoln and Guba (1985) propose four criteria to ensure the trustworthiness of qualitative research: credibility, transferability, dependability, and confirmability. These criteria have been accepted by many researchers (Shenton, 2004).

Credibility is seen as a key factor in establishing trustworthiness. It is concerned with the question whether or not the results provide a “true picture” of the phenomenon under scrutiny (Shenton, 2004). Different actions have been proposed to ensure the credibility of research (Shenton, 2004; Lincoln & Guba, 1985). As a part of this project, I have organised group meetings to discuss the results with the students (member check), and also as another source of data to understand participation and how it affects individual students (triangulation).

Fifteen students participated in the group meetings<sup>1</sup>, of which 14 students were followed all the way from the beginning of their studies over a three year period<sup>2</sup>. The two group meetings consisted of three parts:

1. In two groups (one CS, one IT student group), the students sorted 37 post-it notes with word groups describing my results on participation according to how often they encountered them in their education. The students got a poster with a scale ranging from “all the time / central” to “never / not at all central”. This phase resulted in two posters that were both put on a whiteboard. Figure 5.1 shows an example of a poster.
2. The students and I stood in front of the posters and compared them. I told the students about how the posters mirrored my results.
3. I presented my ideas on how participation affects individuals. This presentation was interwoven with joint discussions with the students and ended with an unstructured discussion on anything that was of interest.

Overall, the group meetings supported the findings of this study. It was interesting to see the students’ reactions on my results. Following an excerpt of a transcript showing the kind of discussions in phase 1:

Student 1 picks up a sticky note and says: “The user’s experience?” [an aspect of participation as problem solving for others] “Pfff, no!” (laughs and places the sticky note far on the bottom of the poster)

Student 2: “Do not place it that low, we did have the HCI course!”

Student 1: “Ah yes, HCI exists.”

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<sup>1</sup>16 Students had agreed to participate but one student that was followed over a three year period was sick on the day of the group meeting.

<sup>2</sup>The student that was not followed over a three-year period changed the study programme after the first study year. I interviewed him directly after that and a year later. I omitted to interview him after the third study year.

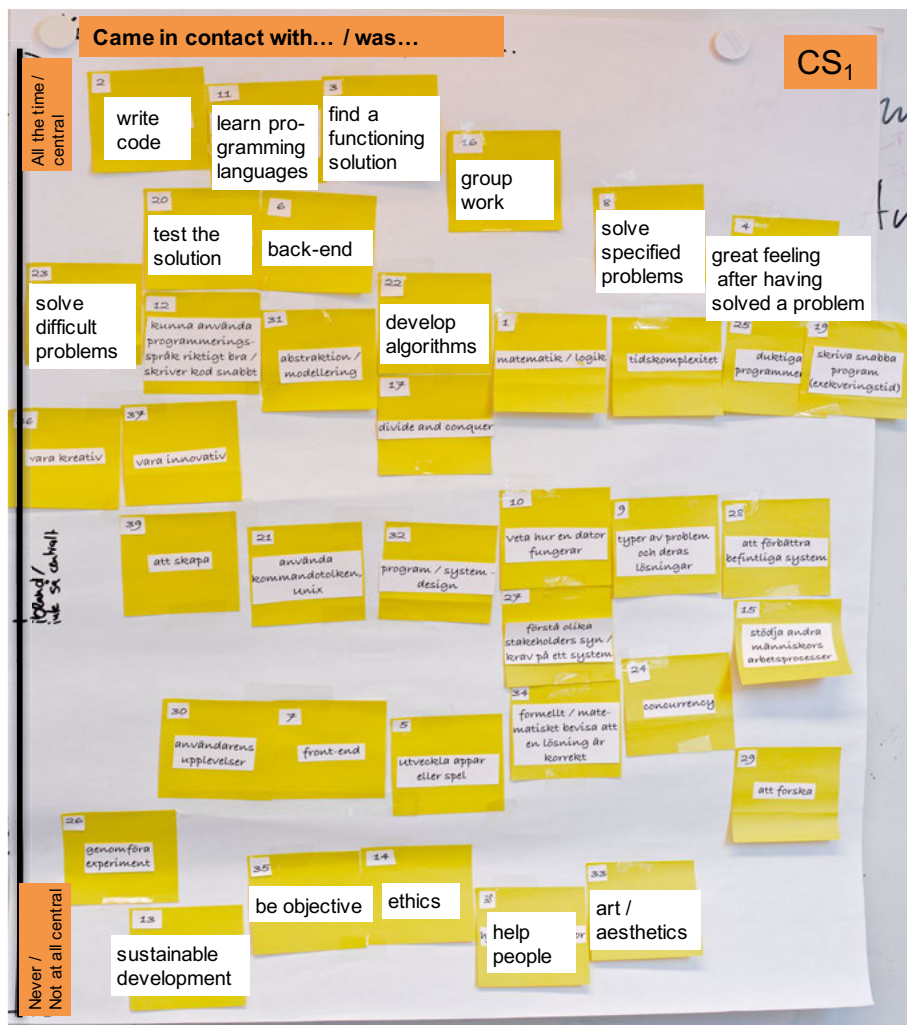


Figure 5.1. One of the posters resulting from phase 1 of the group meetings.  
 Note: According to the transcript, the students did not seem to know what is meant by “be objective” and therefore placed the sticky note in the bottom half.

Phase 2 helped to see and discuss differences in students' views and my descriptions. For example, one student group placed the note "helping others" relatively high up on the poster (got in contact with all the time), while the other student groups placed it relatively low. Asking the students about the difference, the group with the note further up explained that they had interpreted the note as being about helping other peer students e.g. with their assignments. Had they interpreted it as the other group (as creating solutions that would help other people), they would have placed it further down.

Interestingly, three out of four groups placed "develop apps and games" on the lower half of the poster. I was expecting the sticky notes to be further up. Discussing the difference, I understood that the students sorted the terms according to their relevance in the courses, not according to their relevance in other contexts, e.g. student contexts. The students agreed that many students are interested and engaged in doing apps and games in their spare time and that the students choose to do related projects if they have the choice.

Student 1: When you had the choice to do a garbage collector<sup>3</sup> or a game, then you chose to do a game.

Student 2: Yes (laughs), wouldn't you? You want to have fun, right?

Presenting my thoughts on how participation shapes and constrains individuals resulted in interesting discussions that confirmed and illuminated my line of argument. The following excerpt gives another example that demonstrates how showing an interest in HCI is not legitimate, it excludes the student from being seen as competent, moreover the student is associated with other students that display bad study habits. Competence entails demonstrating competence in programming, coding:

Kim (IT): When I chose my specialisation, I asked around a bit and then other students said: "Those who choose HCI, they are those who cannot code, those who slide through the first three years. Then they choose the little fuzzy part as a specialisation, as it does not show up in the certificate, and then one can say "I am a 'civilingenjör'<sup>4</sup>!", and others think "Shit, that guy can code!"

Students laugh.

Kim: ...but actually one has just slid through the first three years.

Charly (CS): That is the same for the CS programme.

Students agree.

Kim (IT): One looks down on those who choose HCI [...]. Because of that, someone might choose the wrong specialisation just because one thinks one would get a bad stamp. That is unfortunate.

Students agree.

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<sup>3</sup>The student is referring to a memory management process that makes memory space, occupied with objects that are no longer used, available again.

<sup>4</sup>"Civilingenjör" is the swedish degree of the IT program.

The longitudinal study design also allowed me to take actions to ensure credibility along the way. Conducting several interviews with the same student at different times allows us to triangulate insights. In each interview, I was prepared to note and discuss differences and similarities compared to previous interviews with the student (see Section 2.4).

Another activity to ensure credibility is prolonged engagement and persistent observations. Even though I did not collect observations of the student cohort, I am still an observant participant of the learning environment. As a PhD student, I have taken and taught several courses. I have discussed my results with different people in the learning environment, e.g. with people of the HCI division. I have contributed to understanding and improving teaching and learning at the department and learnt from the people that were involved in that (Peters, Hussain, Cajander, Clear, & Daniels, 2015; Cajander et al., 2017). The papers included in this thesis have been peer-reviewed, and most of them presented at conferences, this work has been discussed with several research groups including UpCERG, and not least in open discussions with my supervisors. It has certainly been peer-debriefed, another action that Lincoln and Guba (1985) suggest to ensure credibility.

Another criterion to ensure trustworthiness is transferability, which addresses the extent to which the study can be repeated in other learning environments or in the same learning environment at a later time. I offer descriptions of data collection and data analysis that are “thick enough” to repeat this study. To ensure dependability, it is sufficient to establish credibility, which has been described above. Confirmability refers to that which is called objectivity in quantitative research. Again, triangulation and member check help to reduce the effect of investigator bias. First year data has been analysed also by Anna Eckerdal, one of my supervisors. Also, the researcher should admit his or her own dispositions. Section 1 offers a brief perspective on my experiences that have contributed to forming this study.

## 6. Contributions

### 6.1 Learning Computing at University – What! a Matter of Identity?

This work contributes with a new framework to better understand the interplay between the social and the individual as a long-term process. It can be used to better understand inclusion, exclusion, and marginalisation in computing education. It does not just help to understand why people leave or stay in the field, a focus that dominates the retention discourse (Section 1.1), it allows us to understand how education supports students with different backgrounds to grow into computing students and future professionals.

The concept of participation in the discipline is found to be valuable to understand computing education. A way of experiencing participation in CS/IT can be interpreted as a way of making sense of CS/IT, which is collectively negotiated. The concept of participation allows to investigate learning and engagement in the discipline in more holistic ways than is commonly the case (Section 1.1). Emotions and social relationships are integral components of the learning experience, as it is studied in the present work.

Social identity theory has proven itself fruitful as a method to reason about learner development. The two approaches to studying identity (Jackson & Pozzer, 2015) (Section 2.2.2) are valuable to be clear about the focus of research, on social interaction (identity as negotiated) or individual characteristics (identity as possessed). The concepts of agency (Section 2.2.5), power (Section 2.2.3), and uniformity (Section 2.2.4) help to reason about individual development in relation to participation or social structure.

This study demonstrates how phenomenography (Section 2.3) can be used in a new way, to understand learner development beyond cognitive development. Investigating phenomena that include social relations and feelings can help to understand how experiences of the discipline or learning are enacted and negotiated in the learning environment, which forms and constrains individual experience. It sheds light on challenges in the learning process that are not considered in traditional phenomenographic studies (see Sections 6.2, 6.3).

Entwistle's (2007) model of learner development suggests that learners with mature conceptions of learning and knowing use their education to grow as individuals (Sections 2.1, 4.1). The findings of this study suggest that students are not free to make sense of their studies as it suits them. To fit in and be seen as competent, students need to learn to perform an identity as a (technical) problem solver. Broader interests are not relevant, they can even hinder students from being seen as competent (Sections 4.3, 5).

## 6.2 Competence as Negotiated

Demonstrating competence and being acknowledged as competent is a central component of learning. This study suggests that we should view competence as something that is negotiated in participation. Understanding participation helps to understand what it entails to be recognised as competent.

In the learning environment investigated in the present work, participation as creating digital artefacts and solving (technical) problems are predominant. Students are acknowledged as competent when they create digital artefacts or solve difficult (technical) problems. Programming, algorithms, and logical thinking are important tools that the students need to master.

Certain learning activities are particularly suitable as a means to reach competence as it is negotiated. For example, in the following quote, Kim gives advice to new students, on how to succeed in their studies:

Kim (IT, year 3): “It is important to be part of this from the beginning. Even if you are not interested [in programming] and if you find it difficult, sit 1.5 to 2 hours every day and program trivial things such as a mini-calculator or a little game. Sit down and program so that you learn the syntax and how to think in a programming-way.”

What Kim suggests that the younger students do is closely related to the predominant experiences of participation as creating and problem solving (learn how to think in a programming way). Kim commenced his studies with the idea of using his IT knowledge to make the world a better place in his future career. Kim struggled during the first two years to make sense of his studies. In the third year, having experienced participation as problem solving for others, he seems to have come to understand that the learning activities that he suggests are somehow required to become a computing professional.

I have also proposed to see that stating an interest in creating apps or games or in solving difficult (technical) problems can help one to be recognised as a competent computing student (Section 4.3). Competence development can be understood as learning to perform an identity as someone that shares and contributes to an experience of participation.

## 6.3 Inclusion, Exclusion, and Marginalisation

Insights into participation are useful as a way to reason about inclusion, exclusion, and marginalisation. Those students who can perform as a participant in participation as creating and (technical) problem solving are likely to be recognised as a computing student and future professional, they are included.

This provides one explanation for why students struggle to make sense of themselves as an app or game programmer or (technical) problem solver (Paper III, IV, V, Section 4.3). Two of the students that left the study programme did

so because they were seeking to study something that would be about helping other people and contributing to societal development. While previous research discusses narrow student conceptions and misconceptions of the discipline (Section 3.1), this study suggests that the students' conceptions in fact mirror well how CS/IT is constructed in different social contexts.

People who show an interest in less technical aspects risk being questioned as a (competent) computer scientist by people performing a technical problem solver identity (Sections 4.3 and Section 5). Performing a technical problem solver identity helps one to be recognised as competent, it also reinforces dualistic constructions, which excludes certain ways of being.

Gender research helps us to understand how the way computing is constructed in the CS/IT programme is associated with masculinity, masculinity as it is constructed and re-produced in the western world (Section 3.2). Participation as creating is related to construction work, which is associated with masculinity (Boivie, 2010). Solving difficult (technical) problems relates to the discourse "science is hard", which has been described as gendered, classed, and racialised (Archer et al., 2010). Dualistic constructions of CS/IT as technical problem solving draw on the same dualisms that masculinity is also established upon, e.g. technical vs. social, rational vs. emotional (Harding, 1986; Faulkner, 2001; Mendick, 2005a). By performing an identity as a technical problem solver, people perform in a way that is associated with masculinity. This is not to say that women or other demographics are excluded per se, but rather all people who are interested in, and who have been socialised with, different ways of knowing than those associated with masculinity.

## 6.4 Implications for Educational Development

Computing literacy and computing professionals are seen as important contributors to welfare in our society (Section 1) and computing is described as a discipline that is seeking cooperation with other disciplines (Section 3.5). These views stand in contrast to how computing is constructed in the first two to three years of the CS and IT study programme. The focus lies on the technical, computing is not seen as a tool with which to contribute to the sustainable development of our society. Considering different user perspectives in the development process is marginally relevant. This should however be an important aspect of working as a computing professional, considering that certain groups of people are under-represented in computing. Usability is central to the engineering tradition of computing (Section 3.5). Thus, it should be a natural part of computing education, especially of an IT engineering programme.

One can argue that the students in the CS/IT programme, as in many other STEM programmes, only take toolbox courses in the first three years and that they get exposed to broader ways of experiencing participation in later years (Ulriksen & Holmegaard, 2016). This study suggests that introducing broader

aspects later in the curriculum is not an alternative. Students decide to leave or stay in the study programme, based on whether or not they can integrate their study experiences into their perception of self (Ulriksen et al., 2015). Having (technical) problem solving as the predominant experience is a breeding ground for dualistic constructions of the discipline, which can exclude, marginalise or silence people with broader competences. Computing educators should consider that participation in CS/IT constrains and shapes learners. If CS/IT is predominantly constructed as (technical) problem solving, then learners are challenged to develop competence in (technical) problem solving. I have found several examples of students with broader interests who seemed to adapt and prioritise learning activities that focused on the technical. Those students may miss out on learning opportunities that are about less technical aspects, that would be valuable for them considering their interests and experiences. An important question therefore is how broader experiences of participation can be scaffolded.

The latter categories of the outcome space, participation as problem solving for others (category E), creating new knowledge (category F), contributing to societal endeavours (category G) can give inspiration in the process of identifying how to broaden participation. They can guide educators in everyday class-room activities, and they can also inform educational initiatives of greater scale, e.g. curriculum development. Aiming to broaden participation, it appears to be important to change participation as it is constructed in different social contexts of the learning environment. Many studies in CER aim at understanding education at a course level (Section 3.1), the present study shows the necessity to move beyond.

Many initiatives have been proposed to improve engagement and retention in computing education that could be revisited in the light of the findings of the present study. For example, Goldweber et al. (2012) propose a framework with which to support educators in order to “convey and reinforce computing’s social relevance and potential for positive societal impact” (p. 17). The present study underlines the importance of such initiatives such as the one by Goldweber et al.. Participation in CS/IT beyond the technical focus is important in order to better prepare students to consider human and societal factors in their careers as computing professionals. Another interesting idea to broaden participation in CS/IT is to think about more “feminine” ways of doing computing (Salminen-Karlsson, 2011), “feminine” as it is constructed in the western world, and to think about how to integrate those values into education.

Having followed quite a number of students over a period of three years, I have come to realise the power that the higher education has in terms of shaping the citizens of the future. The present study of two computing study programmes suggests that the potential for improvement of education is in a way that diverse people obtain greater support in order to develop as diverse computing professionals and making a contribution to the sustainable development of our society.

## 7. Future Research

Looking into the future, my hope is that this work will inform education research and development. The theoretical framework developed in the present work (Section 6.1) has been demonstrated to be useful in attempts to understand learner development and it could be utilised and developed further. For example, a better understanding of how participation shapes and constrains individuals could provide deeper insights into required or implied learning behaviour, as well as inclusion, exclusion, and marginalisation. In the present work, I have used the theoretical framework to make sense of interview data. It would be interesting to use the framework to observe, describe, and understand learning situations. The use of the concepts agency, uniformity, and power could be further explored.

It appears to be crucial to better comprehend the role of curriculum, teachers, and students in shaping the dynamics between social structure or participation and the individual. For example, it is interesting to study participation in other computing programmes that introduce broader aspects such as human computer interaction or open-ended projects early.

Another important extension of this work is to understand participation and identity in computing education in other education contexts, e.g. high school education, advanced university education, informal education, and in workplace learning. Education in these different contexts has different aims or purposes that should affect the interplay between participation in CS/IT and the individual. For example, computing education at high school is certainly more about developing computing literacy and understanding the world we live in, than developing professional competences.

One next step for the analysis of the present data is to do a systematic analysis of different individual student trajectories in relation to the insights into participation. A relevant question is how the reflections of students with different interests and backgrounds (e.g. previous work or study experiences) change, as well as to compare the CS and IT students.

Dualistic constructions of CS/IT appear to be an important focus of future investigations. The data reported in this study includes other dualistic constructions besides the one described in previous research (Section 3.2), e.g. the front-end vs. back-end dualism. Understanding these constructions and how they affect learner development could provide valuable insights into inclusion, exclusion, and marginalisation in the learning environment.

## 8. Summary in Swedish

Brist på personer utbildade inom matematik, ingenjörsvetenskap, naturvetenskap och teknik (MINT)<sup>1</sup> har länge varit ett orosmoment i västvärlden (Smith & Gorard, 2011; Teitelbaum, 2003; Lövheim, 2014). Det finns en stor mängd forskning som syftar till att bättre förstå och minska avhopp från sådana studieprogram (Ulriksen et al., 2010). Studier pekar på att unga människor inte kan tänka sig att jobba inom MINT, trots att utbildningarna har upplevts som intressanta (Archer et al., 2010, 2013; Dempsey et al., 2015; Wong, 2017; Wong & Kemp, 2017).

Det finns också forskare som ifrågasätter att det finns och har funnits brist på MINT-kompetens. De kritiserar att forskningen och utvecklingen av utbildningar har styrts av rapporter om brist på MINT-kompetens (Lowell & Salzmann, 2007; Metcalf, 2010; Cappelli, 2014; Cannady et al., 2014). Uppdelningen i MINT och icke-MINT och fokuset på att förbättra just MINT-utbildningar anses inte vara konstruktivt, t ex om målet är en utbildning som stödjer människor att bidra till samhällets utveckling (Zeidler, 2014).

Ett annat problem är att vissa grupper av människor är underrepresenterade i MINT. Inom datavetenskap<sup>2</sup> i västvärlden är kvinnor underrepresenterade, vilket leder till att de inte är med och utformar digitaliseringen av världen på samma sätt som män är (Margolis & Fisher, 2002; Lehman et al., 2016).

Forskare som jobbar med avhopp och underrepresentation anser att man bör förändra forskningens fokus, från att förstå studenternas intressen, attityder, kompetenser etc, till att undersöka lärandemiljön och studenternas interaktion med den som en långsiktig process (Hodkinson et al., 2008; Shanahan, 2009; Ulriksen et al., 2010). Identitetsteorier har i allt större utsträckning använts för att bättre förstå utbildningar genom ett sådant fokus inom MINT-didaktikforskning (Jackson & Pozzer, 2015; Ulriksen & Holmegaard, 2016). Forskare i datavetenskapens didaktik har hittills mest fokuserat på att bättre förstå studenten som individ, framförallt studenters svårigheter med och motivation att lära sig att programmera (Yasuhara, 2008; Kinnunen et al., 2010; Simon, 2015) (se Avsnitt 3.1).

För att bättre förstå högre utbildning inom datavetenskap som en social och långsiktig process har jag följt studenter från två studieprogram, datavetenskap på kandidatnivå (DV) och civilingenjörsprogrammet i informationsteknologi

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<sup>1</sup>MINT motsvarar engelskans STEM.

<sup>2</sup>Jag använder ordet datavetenskap på liknande sätt som ordet "computing" används i engelskan, dvs som ett paraplybegrepp för olika områden såsom informationsteknologi och datateknik (Avsnitt 1.2), men även för att diskutera informanternas studieprogram.

(IT), under de tre första åren. I intervjuer reflekterade studenterna kring sina DV/IT-relaterade erfarenheter och vad de har för tankar om sin framtida karriär (se Bild 2.2, Avsnitt 2.4, för en överblick över studiedesignen). Ett mål med intervjuerna var att förstå i vilka sociala sammanhang, med vilka människor, studenterna har upplevt DV/IT på ett visst sätt.

Jackson and Pozzer (2015) beskriver två sätt att studera identitet: identitet som någonting som en person äger, och identitet som någonting som skapas och förhandlas i interaktion mellan olika människor, som formar och begränsar individer. Den sistnämnda synen på identitet har använts i flera studier som syftar till att förstå inkludering och exkludering.

Den här studien utforskar deltagande i DV/IT för att bättre förstå identitet som någonting som skapas och förhandlas i interaktion mellan olika människor. Deltagande i DV/IT består av att göra, tänka, och känna i relation till DV/IT, och sociala relationer. Definitionen av deltagande är inspirerad av Wenger (1999, p. 56–57). Följande forskningsfrågor har väglett detta arbetet:

1. På vilka olika sätt erfar studenterna deltagande i DV/IT under första, andra och tredje studieåret?
2. Hur kan svaren på fråga 1. och identitetsteorier användas för att förstå lärandet i datavetenskap som en långsiktig, social process?
3. Vad är implikationerna för framtida forskning och för utveckling av utbildning inom datavetenskap?

Ett av resultaten är ett fenomenografiskt utfallsrum som beskriver sju olika sätt att erfa deltagande i DV/IT (se Tabell 1, Papper V). Ett sätt att uppleva deltagande i DV/IT, som är vanligt bland studenterna {sociala relationer}<sup>3</sup>, är att skapa (kategori C). Studenterna upplever det som roligt eller fascinerande {känslor} att skapa tekniska artefakter som utför någonting. De pratar om olika “mini-projekt”, små spel eller appar. Ett exempel på det sättet att erfa är en student som pratar om en app som kan lyfta rullgardinerna. En annan kategori i utfallsrummet är deltagande i DV/IT som problemlösning (kategori D), vilket verkar vara centralt i många sociala kontexter i den akademiska lärandemiljön {sociala relationer}. Deltagande enligt kategori D handlar om att hitta sätt att angripa svåra {känslor} problem, att skapa och genomgå problemlösningsprocessen för att komma fram till en lösning. Olika kriterier används för att prata om kvalitén av problemlösningen, t ex exekveringstid, minnesanvändning. Om studenterna reflekterar över vilka kriterier som är viktiga, så utgår de från problemspecifikationen. Ett annat sätt att uppleva deltagande i DV/IT är att lösa problem för andra (kategori E). Användbarhet, användarens upplevelse och användningskontexten är i fokus och styr hur man gör, tänker, och vad man känner (man gör nytta) när man löser problem. Det sättet att delta ver-

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<sup>3</sup>Jag använder samma markeringar som i Papper V, {sociala relationer}, {känslor}, för att markera de delar av erfarenheten, som inte diskuteras så ofta i forskning inom datavetenskapens didaktik.

kar först relevant i kursen människa-dator-interaktion (MDI) som studenterna läser i studieår tre {sociala relationer}.

Medan alla studenterna som stannade i utbildningen integrerade problemlösning i sin reflektion av vem de skulle bli som datavetare, verkade studenterna överlag tveksamma till aspekter som de mötte i MDI-kursen. MDI ansågs vara "flummigt" och väldigt annorlunda jämfört med allt annat studenterna hade gjort tidigare i sina studier.

Två fenomenografiska utfallsrum presenterades (Papper IV and V) som ger en djupare förståelse av deltagande i DV/IT som problemlösning och problemlösning för andra. Sättet som flera studenter positionerar DV/IT, i reaktion på MDI kursen, kan beskrivas som teknisk problemlösning, som en sorts problemlösning som utesluter aspekter som introduceras i problemlösning för andra. Till exempel utesluts användarens (subjektiva) upplevelse och kommunikation med användaren eller användningskontexten. Teknisk problemlösning pekar på dualistiska konstruktioner av MINT-ämnena vilket har diskuterats i tidigare studier (Harding, 1986; Faulkner, 2001; Mendick, 2005a). MINT-ämnena skapas som tekniskt kontra socialt, teoretiskt kontra applicerat, svårt kontra lätt, som något där objektivitet kontra subjektivitet är viktigt. Det sättet att positionera MINT är i linje med hur maskulinitet konstrueras i västvärlden (Harding, 1986; Faulkner, 2001; Mendick, 2005a).

De fenomenografiska utfallsrummen ger nya möjligheter att förstå lärandet i den studerade lärandemiljön. Att så många studenter visar intresse och berättar om sina erfarenheter inom att skapa digitala artefakter och lösa (tekniska) problem kan förklaras med att deltagande i DV/IT som att skapa och lösa (tekniska) problem är centralt i lärandemiljön. Att uppträda som någon som skapar och löser (tekniska) problem gör att man passar in och blir sedd som kompetent.

Två stora organisationer som stödjer utveckling av utbildning inom datavetenskap, ACM och IEEE<sup>4</sup>, skriver att datavetare bör blicka utåt och se datavetenskap som ett ämne som integrerar med andra ämnen (The ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013, p.13). I den lärandemiljön jag har studerat ligger emellertid fokus på det tekniska. Tvärvetenskaplighet verkar inte relevant eller ens legitimt. MDI kursen introducerar vikten av att ta hänsyn till användaren, personer som visar intresse kan bli ifrågasatta som kompetenta av andra som uppträder som tekniska problemlösare (se Diskussion i Papper V och Avsnitt 4.3 och 5). Det ger en möjlig förklaring till varför flera studenter ger upp idéer under studiernas gång att koppla DV/IT till andra intressen. Att det icke-tekniska inte är relevant eller legitimt indikeras även av förklaringar från studenter som lämnade programmet.

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<sup>4</sup> ACM och IEEE är organisationer som stödjer teknisk utveckling och forskning (Avsnitt 3.1).

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# Appendix A.

## Essay Assignment

The following is a translation of the reflection assignment that all CS and IT students that commenced their studies in 2012 got in the beginning of their study:

**Aim:** To make use of your studies and to make good study choices, it is useful to know who you want to become as a computer scientist and future IT engineer, as well as which goals you have with your education. This assignment can help you to think about your goals.

**Assignment:** Think about your choice of study and reflect on the following topics. Below each topic, you find several questions that can guide you in your reflection. You don't need to reply to each question. You can just write a couple of paragraphs about each topic.

1. *Choice of study programme:* Why have you chosen the CS or IT study programme? What about CS and IT interests you? What are you less interested in? You can tell about your experiences, interests, what you think is exciting or challenging and how you think that has influenced your choice. Perhaps other people have influenced you, e.g. family, friends, school etc.?
2. *Future career:* What are your plans for after your studies? What can you imagine to work with? Can you imagine and describe a situation that you can see yourself in? What do you do? Who do you work with? What do you get out of your work? What do you want your work to result in?
3. *Study expectations:* What is needed to reach your goals? What do you expect to learn? What are your strengths and how can you make use of it? What are your weaknesses and what can you do so that they won't hinder you?

## Appendix B.

### Interview Script

The opening questions for the four parts of the interviews (translated from Swedish to English):

1. *Choice of study programme*: I would like to go back to before you began your studies: How do you think you became interested in CS/IT<sup>1</sup>?  
In year 3, I asked a slightly different question: You have a friend who is thinking about studying CS/IT. He or she is wondering about what you find interesting about CS/IT and what it is like to study CS/IT. What would you tell him or her?
2. *Future career*: If you now, from your perspective today, try to imagine yourself as a computer scientist / IT engineer in the future – how do you see yourself in your future work life?  
In year 3, I asked a slightly different question: Your friend wonders, who he or she could become after having studied. He or she asks for your plans, ideas, and dreams for the coming years. What would you tell your friend?
3. *Study experiences*: If you think back to the past study year, about what you have done, what you have learnt, alone or together with others, what comes to your mind?  
In year 3, I asked more open: How did the past study year feel, what comes to your mind when you think about it?
4. *Perceptions of the discipline and studies as a whole*: If you think about your studies as a whole, how have you developed during your studies, as a person and becoming computer scientist / IT engineer?

The following follow-up questions served as an inspiration for me, the interviewer. I used only those questions that appeared useful in the interview situation, depending on what the interviewee talked about earlier.

1. *Choice of study*:
  - When did you become interested in studying CS/IT? Through what?

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<sup>1</sup>CS/IT in the following refers to the study programme that the interviewee was enrolled in, so either CS or IT.

- Did you have other ideas what to study? What made you decide to enrol in CS/IT?
  - Was there someone who has influenced your choice of study?
2. *Future career:*
- When you think about your future career, what seems especially important to you?
  - What activities would you like to carry out in your future job?
  - What would be important for you to know and be able to do in this area?
  - How would you like to work?
  - What would you like your role to be?
  - Do you have any thoughts about what should be the result of your work, what ideas do you have?
  - Is your future career something that you think about sometimes?
3. *Study experiences:*
- What have you learnt or done that was particularly interesting / exciting? Can you describe a concrete learning situation? Who else was a part of that situation? What knowledge, or concepts were central?
  - If you think about other people around you in the learning environment, what are they talking about? Was there anything you find particularly interesting, what?
  - What have you learnt or done that you find less interesting or relevant? Can you describe a concrete learning situation?
  - Which course was most or least interesting? What was it that made this course interesting / not so interesting?
  - What are you particularly good at / not so good at?
  - What do you think, in what ways have social contexts affected your views on CS/IT and how you feel about your studies? Your peers? Teachers?
4. *Perceptions of the discipline and studies as a whole:*
- How would you describe your interest in CS/IT today? Would you say your interest has changed during your studies? In what ways?
  - What competences would you say you have developed during your studies?
  - Would you say that there are different ways to look at CS/IT? If not, how would you describe what a computer scientist / IT engineer is? What knowledge does a computer scientist / IT engineer have? If yes, can you explain different ways of being a computer scientist / IT engineer?
  - Is there anything you look forward to learn?

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