UPPSALA
UNIVERSITET

IT Licentiate theses
2014-004

The Role of Students' Identity Development in Higher Education in Computing

ANNE-KATHRIN PETERS

UPPSALA UNIVERSITY
Department of Information Technology

The Role of Students' Identity Development in Higher Education in Computing

Anne-Kathrin Peters
anne.peters@it.uu.se

April 2014

Division of Computer Systems
Department of Information Technology
Uppsala University
Box 337
SE-751 05 Uppsala
Sweden

http://www.it.uu.se/

Dissertation for the degree of Licentiate of Philosophy in Computer Science with Specialisation in Computer Science Education Research

ISSN 1404-5117
Printed by the Department of Information Technology, Uppsala University, Sweden

Abstract

Higher Education Research in science, technology, engineering, and mathematics (STEM) indicates that students are not well supported in the process of integrating their educational experience with their perception of who they are and want to become. This is associated with drop-out and also has consequences for student learning. Here, learning is defined in the broad sense of personal and professional development.

This thesis presents results from a research project that explores students' identity development during their first three years of studies. The analysis and results build on interview and essay data collected during a longitudinal study of students in two study programmes at Uppsala University, Computer and Information Engineering (IT) and Computer Science (CS). The main body of data analysed for this thesis was collected from the students at the beginning and end of their first study year.

A research framework to study identity has been developed. The notion of identity used in this work has been inspired by Lave and Wenger's social theory of learning, and theory of situated learning. Identity, in this work, refers to students' histories of experiences with a focus on how they negotiate meaning within the discipline of CS/IT.

The results describe aspects of CS/IT students' identities and provide a basis from which to discuss the implications of identity for learning and education, as well as to reason about how identity development can be supported in CS/IT education.

List of Papers

This thesis is based on the following three papers referred to as Paper I, Paper II, and Paper III.

I A.-K. Peters and A. Pears, "Students' experiences and attitudes towards learning Computer Science," in *2012 Frontiers in Education Conference Proceedings*. Seattle, WA. IEEE, Oct. 2012, pp. 1–6. doi: 10.1109/FIE.2012.6462238.

II A.-K. Peters and A. Pears, "Engagement in Computer Science and IT – What! A Matter of Identity?", in *Proceedings of the 1st IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE)*. Macau. IEEE Computer Society, IEEE Computer Society Press, Mar. 2013, pp. 114–121. doi: 10.1109/LaTiCE.2013.42.

III A.-K. Peters, A. Berglund, A. Eckerdal, and A. Pears, "First Year Computer Science and IT Students' Experience of Participation in the Discipline", in *Proceedings of the 2nd IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE)*. Malaysia. IEEE Computer Society, IEEE Computer Society Press, Apr. 2014. Accepted for publication.

Reprints were made with permission from the publishers.

Comments on my contribution:
As the main author, I took responsibility for the work in all of the papers. Ideas and results were discussed regularly with all supervisors and in subgroups.

I The data collection was planned with all of my supervisors. I gathered the data and did the data analysis. Results were discussed with all supervisors, in particular with the second author. I wrote the paper with the feedback from all supervisors, in particular the second author.

II The data collection was planned in collaboration with all of my supervisors. The data analysis was planned and results were discussed in

particular with the second author. I gathered the data and did the data analysis. I wrote the paper with feedback from all supervisors, in particular the second author.

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 of the data analysis were discussed with all of my supervisors. I wrote the paper with feedback from all supervisors.

Acknowledgements

I want to thank my supervisors Arnold Pears, Anna Eckerdal, and Anders Berglund from Uppsala University for their support. I am in particular thankful for the discussions we have had together, your critical questions, feedback, thoughts and encouragement. I am grateful to have found a research project that covers issues that have concerned me personally for a long time. Thank you for your guidance!

I also want to thank Prof. Michael Thuné from Uppsala University. Sometimes, you emphasised that you are not my supervisor, nevertheless you have supported me like one. Thank you so much for your contribution throughout this project in such a kind and thoughtful way!

This research project is part of the Uppsala Computing Education Research Group (UpCERG). It was a great experience to be part of many inspiring, thought-provoking discussions within this group. Thank you, dear members, for making UpCERG a safe, appreciative, and lively environment to test ideas and arguments in.

To the students that participated in this research project: Thank you for your openness, patience, and effort to describe your experiences and thoughts.

Furthermore, I want to thank other researchers for inspiring discussions of my research, in particular Staffan Andersson and Prof. Minna Salminen Karlsson from Uppsala University, Prof. Lauri Malmi from Aalto University, Prof. Marian Petre from the Open University, as well as Snorre Nordal and Ass. Prof. Aksel Hugo from the Norwegian University of Life Sciences.

Finally, I want to thank my family. Dear parents, grandparents, my dear siblings: I want to thank you for your strong, unconditional love and support during this time of often being far away from each other.
Jonatan, you have been there for me while I was trying to find myself here in Sweden, with so much patience, warmth, and love. You are so important for me.

Contents

Chapter 1

Introduction

> I: When you think of a computer scientist, [...] what does he work on?
> Olle: When you are a programmer, I think, you work with problem solving [...]. It is not that complex. You write this code and it is not like you have to think of society and economy and things like that. (From a student interview in 2011 [1])

Olle[1] seems to equate computer science (CS) with programming, which he experiences as something that is disconnected from society and economics. The quote is taken from an interview at the end of an introductory course in CS. The course was designed to increase learners' engagement and was based on recent results from computing education research [2]. Questionnaire data shows that the course was experienced very positively by the students, also by Olle [1]. However, Olle states that he will probably not take further courses in CS because learning CS is not relevant for him, since he is interested in solving complex problems and contributing to society.

In what ways does education support students to experience learning CS as personally meaningful? Which different ways of identifying with the discipline does education make accessible? Such questions have been raised by recent research on drop-out, which finds that students struggle in a process of trying to make sense of their educational experiences in respect to who they are and want to become [3, 4, 5]. Identity development has also been argued to be an important aspect of learning [6, 7]. However, research on learning in the broader sense of disciplinary and professional identity development is still in its infancy [6, 8].

[1]To preserve the anonymity of the informants, all names used are made up and do not reflect the gender of the student. The particular student is referred to as being male, using "he" and "him" instead of "he or she" and "him or her", for reasons of readability and to adhere to the rather masculine environment.

This project aims to get a better understanding of why students choose to engage in, or reject, CS as a field of study, and how they experience learning CS as meaningful as they proceed in their studies. The goal is to explore student identity development, how it affects learning, as well as how it is supported by education.

1.1 Background

Low numbers of graduates and drop-out have been stated to be of continuous concern by two major advocates of Engineering and Computing, the IEEE, Institute of Electrical and Electronic Engineers, and the ACM, Association for Computing Machinery [9, 10]. Another related problem is low diversity and underrepresentation of women [11, 12]. Björkman for example states:

> CS mainly attracts a fairly narrow group of students, mostly young males with a passion for, and also often experience with, computers and programming. [11, p. 136]

Recent literature on drop-out in STEM marks a shift in focus [8, 5, 4]. Ulriksen, Holmegaard, and Madsen conclude their literature review on drop-out as follows:

> The problem of retention should be rephrased from focusing on how to adjust the students so that they can meet the requirements of the existing science programme to a broader perspective on students' experiences with studying science, where not least the question is of how STM programmes can become part of students' identity formation. [8, p. 239]

Their suggestion is to study which identities are made available in education to students with different histories of experiences. This position is also supported by Johannsen who studied attrition and retention in physics [5].

A similar argument comes from research on initiatives for recruitment, which aim to increase the number of students enrolling in Technology and Engineering programmes. Ottemo [13] finds that these initiatives mostly assume the problem to be misconceptions and prejudices among students. Thus, the most common solution is to disseminate information about the "right image" of computer science and engineering. This approach excludes the perspective of the learners. Ottemo suggests to critically investigate where students' "misconceptions" and "prejudices" come from. Recruitment initiatives with a focus on gender have been criticized in similar ways [11, 10].

Björkman suggests that knowledge-processes within the discipline should be critically discussed in order to develop new understandings and interpretations of the discipline which could then be used to make different identities available to a diverse student body [11, p. 149].

The scope of what counts as a legitimate identity within CS/IT has been debated. Tedre, for example, finds that computer scientists disagree on the content, form and practices of the discipline [14]. This may cause friction in the students' process of constructing a legitimate identity.

Research on students' experiences studying STEM programmes, their relationship to the discipline, and their identity development is sparse. Ulriksen, Holmegaard, and Madsen are engaged in a longitudinal study [3, 4, 15] following students from high school to university. They find that students are continuously engaged in a process in which they try to integrate their educational experiences with their perception of who they are and want to become [4]. Their results show that students often struggle in this process and that many students relate to STEM areas in different ways than those conveyed in education [3]. Knobelsdorf and Schulte investigated CS major students' experiences prior to studying CS [16, 17]. They find that students' experiences influence what the students expect and are motivated to learn.

A better understanding of identity development has been found important to address issues of retention, but it can also contribute to better support for learning. Stevens et al. [6] argue that learning has mostly been studied with a focus on changing cognitive capacities. They argue for a broader view of learning as "becoming", which also includes other aspects that have to be supported. This relates to views of Biesta [18], who argues that learning should be about developing as a human, not just about acquiring knowledge and skills. Education in such broader terms and how identity effects learning is underexplored [6, 3].

1.2 Research Objectives

The overall aim of this research is to provide a better understanding of students' identity development when learning CS/IT at the university. The ultimate goal is to inform educational development and future research to address issues of retention and to better support learning.

The research is guided by the following goals:
G1: Describe aspects of CS/IT students' identities and identity development.
G2: Get a better understanding of how identity and identity development influence learning and engagement in CS/IT.

G3: Provide a nuanced analysis of the role of education in the identity development of learners.
G4: Develop a research framework with which to study key elements of identity development.

In Paper I, the research questions focus on students' experiences during an introductory course and how those affect the students' attitudes towards learning CS in the future. Results contribute to a better understanding of positive learning experiences during an introductory course, as well as insights into students' reasoning, why they will not take further courses in CS, despite positive learning experiences. These insights have a major impact on the objectives of this research project.

The research questions in Paper II concern how theory can be used to understand novice CS/IT students' reflections on their experiences prior to studying, envisioned future, and expectations of education. Contributions are a research framework with which to study students' identity development (G4), as well as insights on aspects of novice students' identities (G1).

In Paper III, the research questions target first year CS and IT students' experience of participation in the discipline. Results contribute to a better understanding of one aspect of student identity, participation (G1). They provide a basis from which to discuss educational implications (G3), as well as the role identity has for learning (G2).

1.3 Overview of Study Design

To explore long-term identity development, a longitudinal study has been designed. Students from two CS-related study programmes at Uppsala University, Computer and Information Engineering (IT) and CS, are followed from the beginning of their studies over a period of three years.

All of the CS and IT students that commenced their study in autumn 2012 received a mandatory assignment asking them to reflect on their choice of study, expectations for education, and envisioned future work life. Based on these written reflections, 23 students were selected to follow in the longitudinal study. I have interviewed all students individually at the end of their first study year. Further interviews are planned with the students at the end of their second and third study year.

Paper I presents a pilot study that was carried out before the longitudinal study commenced. The intention was to get an overview of students' experiences learning CS/IT. The participants in this pilot study were students of the Sociotechnical Engineering programme (STS) at Uppsala University.

These students commonly have a broad interest in technology, which provided an interesting starting point for this project.

1.4 Thesis Structure

Chapter 2 contains a summary of related research. It presents the broader research context that this work is a part of. It also highlights important aspects of identity that are considered in the remainder of the thesis.

Chapter 3 presents theories about identity. The focus lies on Lave and Wenger's social theory of learning, and theory of situated learning, as these theories have been utilised in the papers.

Chapter 4 describes the empirical work of this project.

Chapter 5 discusses the research contributions paper by paper. Then the contributions are integrated with respect to the goals listed in Section 1.2.

Chapter 6 draws overall conclusions and discusses future work.

Chapter 2

Related Work

Identity development is a relatively new area of study in STEM higher education research [6, 8]. However, there are quite a few studies that inform research on identity. The aim of this chapter is to collect and connect these different studies to the broader research context of which this research is a part.

Research on identity is motivated by a large body of research done on retention, which will be described in the following section. Then, I provide an overview of empirical studies that provide insights into students' experiences, engagement in CS/IT, and learning in the broader perspective of personal and professional development.

2.1 Retention

Graduation rates, completion, and drop-out rates have continuously been investigated by the OECD, Organisation for Economic Co-operation and Development [12]. Drop-out rates in science and technology have been reported among the highest in many countries in 2008 [19]. At the same time, there seems to be agreement in Western countries that the need for graduates in these areas are especially high [8], as for example stated by the two major advocates for engineering and computing, the IEEE, Institute of Electrical and Electronic Engineers, and the ACM, Association for Computing Machinery [20]. The OECD also reports a continuous underrepresentation of women in the field of mathematics, science, and technology, which, on average, has only improved slightly despite many initiatives to improve gender equality [12, p. 77].

The drop-out problem has been addressed in several quantitative studies

that aim to establish predictors of academic success, in particular for the CS1[1] course (see [21, pp. 25-25],[22],[16, pp. 24-27] for an overview). Considered factors are for example mathematical skills, prior programming experiences, gender, effort, learning approach, and comfort level [23, 24, 25, 26]. Kinnunen integrated the results to derive a list that describes "difficulty" and "success" related factors [21, p. 29]. The impact of these studies on initiatives addressing retention has been limited for reasons that are discussed in [16, pp. 25-27],[22]. In a review of these studies, Knobelsdorf concludes with the suggestion that drop-out should be viewed as a long-term process that is influenced by many factors [16, p. 25]. This alludes to Kinnunen's findings studying CS minor students' reasons for dropping out of a CS1 course using qualitative interview research [27]. She concludes that students' reasons for dropping out are very complex. Hence, research and interventions that only consider a single or few factors are likely not effective [27, 6].

Alternative perspectives on retention have been proposed. In their reviews of literature on students' leaving STEM study areas, Ulriksen et al. [8] find a shift in focus from research on students' deficits and how to overcome them to research on students' identity development. They suggest studying disciplinary cultures that make certain identities legitimate and recognizable, and others not, and students' experiences studying science. This is supported by research from Johannsen, who studied attrition and retention in physics. He suggests that one should "operationalize a socio-cultural and cultural-historical perspective on identity" to address issues of retention [5, p. 24]. Hence, research on retention moves away from focusing on the students' capabilities to considering the students' experiences and development in relation to institutional and disciplinary cultures.

2.2 Students' Engagement and Relation to the Discipline

Some research on students' engagement in CS/IT has been done with a focus on gender [10, 28, 11, 29, 30] and other underrepresented groups [31, 32]. A finding is that the image of CS has a major impact on women's engagement in CS [30]. This image and the students' choice of study programme may be influenced by stereotypes [28]. CS is often perceived to be a male field. A CS person can be associated with being a "nerd", male, "unattractive" and "not sociable" [28, p. 311]. Another finding is that women often experience themselves as less capable than men, while actually having the same skills

[1]The "CS1 course" is commonly referred to as the first course in a CS major study programme. It comprises an introduction to programming.

[10]. Danielsson [33], for instance, studied physics students' constitution of identity and practice in lab work. She finds that several women students took on a rather disempowered role when participating in lab work [33, p. 206].

Perceptions, conceptions and misconceptions of CS and how those can be addressed have been reported in [34, 35, 36, 37]. A prevalent perception among high school students is that CS is "boring, tedious or irrelevant" [34, 35]. Goldweber et al. [35] suggest a framework that aims to convey and reinforce computing's relevance and potential for positive social impact. Yasuhara [37] studied conceptions of high school students and designed a "CS exploration workshop" based on these results to support students in making a better informed decision about majoring in CS. An important question in this context is what causes and possibly reinforces "misconceptions" [13]. Buckley [36] observed that CS1 textbooks mainly deal with animals, games, and food instead of socially relevant problems. This may reinforce existing stereotypes and misconceptions [36, 35].

Students' choice of study programme is investigated by Holmegaard, Ulriksen, and Madsen in a longitudinal study following students from high school to university [3, 4, 15]. Using a narrative approach [15], their aim is to "explore how students perceive and ascribe meaning to their choice of higher education" [4, p. 2]. They find that students often choose to study STEM programmes because they want to engage in cross-disciplinary, real-life projects and be part of innovation. Students' who do not choose STEM programmes may be interested but they perceive education in STEM to be disconnected from the real world, and STEM areas to be "stable", "rigid", leaving no room for discussion [4, p. 1]. The students who do enter STEM study programmes often meet an image that corresponds to the image of the students that do not want to study STEM. They experience very little interdisciplinary and real life contextualisation in their education [3].

Holmegaard, Ulriksen, Madsen et al. conclude that educational choices must be seen as a process [4]. Students are continuously engaged in constructing a narrative over who they are and want to be, which is tested and validated in the student's social environment [4, p. 17]. They find that students are not well supported in this process of understanding who they are and will become. These results highlight the importance of the social environment for identity development.

CS major vs. non-major experiences prior to university, and their implications for learning and engagement have been investigated by Schulte and Knobelsdorf [17, 16]. They collected and analysed students' "computer biographies", in which the students reflect on experiences with the computer. They find that novice CS students commonly state experiences of design or

programming, while many non-CS students do not. Using the same data pool, Romeike and Knobelsdorf [38] argue that CS students relate to different aspects of creativity in their biographies. Creative expression could thus be seen as a possible pathway to CS [38].

Attention has been drawn to the role of space and time for learning and engagement. Through ethnographic studies, Nespor [39] investigated and compared how physics and management students move through their education. He finds that "spaces and times" are organised very differently in the two programmes, which has a strong effect on the students' learning and development. Knox and Fincher [40, 41] study the role of "place" for student engagement and learning. "Places" for them are spaces where students interact in a community and are engaged in practices. They explore how places can be taken into account, and designed, in order to provide professional experiences and to support students in developing professional skills.

Stevens et al. [6] investigated how engineering students progress through their education, also doing ethnographic studies. They study learning in the broader context of "becoming", and provide a framework to study learning in such a broader sense. The framework consists of three conceptual dimensions, (1) development of "accountable disciplinary knowledge", (2) forming an identity as an engineer, and (3) navigating through engineering. Identity is found to be central to students' commitment to meeting the challenges of moving through their studies. Stevens et al. conclude that it appears to be important that students get support in identifying with engineering in early years of their education. How identity can be supported in education is pointed out to be an open question.

2.3 Summary

This chapter described the broader research context of which this work is a part. It becomes apparent from this research that the following aspects are particularly important to consider in research on CS/IT students' identity development: (1) Students' study experiences and their relation to CS/IT, (2) students' long-term development and processes of becoming associated with, or moving away from the field, (3) social environments that influence the learners' perception of CS/IT and their construction of identity.

How can identity and identity development be conceptualised? Theories about identity development provide different answers to this question. Lave and Wenger's social theory of learning, and theory of situated learning includes the aspects identified as important here, and provides support for studying identity as developed through negotiation of meaning.

Chapter 3

On Identity

As indicated in the summary of the research review in the previous chapter, aspects of Lave and Wenger's social theory of learning, and theory of situated learning, are useful when studying learning in the broader sense of identity development [42, 43]. In the following, I present aspects of these theories and their relevance for this project. Furthermore, alternative theories about identity are briefly introduced.

3.1 Social Theory of Learning and Theory of Situated Learning

Lave and Wenger introduce identity, and identity development, as a major aspect of learning in their social theory of learning, and theory of situated learning [42, 43]. Wenger for example states:

> [...] the primary focus of this theory is on learning as social participation. Participation refers to [...] a more encompassing process of being active participants in the *practices* of social communities and constructing *identities* in relation to these communities. [43, p. 4]

What becomes clear from the quote is that Lave and Wenger provide a theory for learning in the context of Communities of Practices. A "Community of Practice" refers to an organisation of people who share "mutual engagement", a "joint enterprise", and "repertoire" [43, p. 73]. Wenger e.g. illustrates his theory using results from a study of a Community of Practice in an insurance company. Aspects of this theory have also been utilised in higher education research, e.g. by Danielsson [33].

In the following, relevant components of the theory are presented as Wenger describes them in the context of Communities of Practice. Then, their relevance for the context of higher education is discussed.

Wenger defines *identity* as follows:

> Identity: a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities. [43, p. 5]

The idea of identity as "personal histories of becoming" is interesting, because it focuses on something that has been found critical in recent research. Holmegaard et al. [4] find that many students struggle to integrate their educational experiences with their experiences prior to studying and their envisioned future work life which can lead to frustration and drop-out.

Wenger argues that identity is developed through negotiation of meaning in the context of Communities of Practices [43, p. 53]. This is interesting because it implies that identity can be studied through studying learners' negotiation of meaning. Wenger argues that *meaning* is construed through two processes, participation and reification.

The following quote summarises relevant aspects of *participation*:

> Participation refers to a process of taking part and also to the relations with others that reflect this process. It suggests both action and connection. [...] 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. [43, pp. 56-57]

Wenger argues that the social component of participation is important, as it provides opportunities for mutual recognition. Being recognized as an active participant in a joint endeavour supports the learner's sense of who he, or she is, or is becoming. Participants also shape each other's experience.

The following quote captures what is relevant about *reification*:

> [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. [43, p. 58]

Reification refers to a process of constructing abstractions, i.e. conceptions, symbols etc. that hold certain meanings, which are used in interactions or participation. Wenger provides the example "democracy". It is a term that can be used to refer to certain values and principles of social order.

Wenger states that participation influences reification, and likewise, reification influences participation. The interaction of these two processes account for negotiation of meaning [43, p. 62].

Figure 3.1 summarises Wenger's view of learning in the context of Communities of Practices (adapted from Wenger [43, p. 5]). Learning in this theory is about becoming a member of a Community of Practice (illustrated by the red smiles and the arrow towards the centre of the Community). This process entails identity development. As described previously, identity is developed through negotiation of meaning, i.e. processes of participation and reification. Negotiation of meaning and identity development is related to a "Community" and the Community's "Practice". Wenger associates these terms as "Community of Practice". It was explained above.

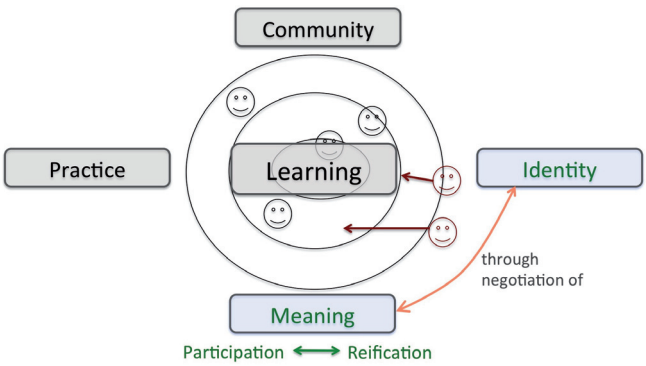

Figure 3.1: An illustration of learning in a Community of Practice, adapted from Wenger, [43, p. 5]

This view of identity as developed through negotiation of meaning, and meaning as construed through processes of participation and reification is also relevant for the context of learning CS/IT in higher education. Experiences of participation as experiences that involve the learner as a whole, doing, thinking, feeling and belonging are interesting, in relation to the goal of understanding students' experiences studying CS/IT. Reification aims to develop conceptions, objects, symbols etc. that are tangible and applicable, which certainly is a goal of higher education. Participation and reification complement each other and provide an interesting basis from which to understand aspects of students' identities. The aspect of identity as histories of becoming adds a time aspect. This image of identity hence captures all the aspects that have been identified as important in the conclusion of the review of related work (Section 2.3).

Participation and reification, in my interpretation of Lave and Wenger's theory for the context of higher education, are situated in interactions with different people, e.g. classmates, teachers, friends, parents, etc.. They are not restricted to a Community of Practice. This solves a problem stated by Nespor. He argues that Lave and Wenger's focus on the individual, learning in clearly bounded, local settings, communities, is too limited [39, p. 10]. However, he also sees the contribution of this theory, that it places learning and knowing in social interactions, instead of internal to an individual [39, p. 11].

In summary, my interpretation of Lave and Wenger's social theory of learning for the context of higher education provides a broader perspective on learning as identity development. It focuses on negotiation of meaning, which is described as experiences of participation and reification. Both of these processes are seen in the context of social interaction.

3.2 Alternative Theories about Identity

Social Constructionism and Symbolic Interactionism are alternative theoretical perspectives on identity development. I present a very brief overview of these theories, based on Burr's [44] interpretation of Social Constructionism and Charon's [45] interpretation of Symbolic Interactionism.

Social constructionists see language as the primary site for identity building [44]. Everything a person is, his or her experience, personality, structure and content of thoughts, are all a product of language. As language is a social phenomenon, the self, from a social constructionist perspective, must be seen as a product of social interaction. In these social interactions, people make use of Discourses. Discourses are for example meanings, metaphors, stories, or representations that are used to build, exchange and regulate meaning, knowledge, and truth. Discourses exert power on the individual's development. An open question in this theoretical perspective is whether or not an individual has "a core" or if a person should only been seen as fragmented, shifting, and temporary, depending on the situation. Another question is to what extent an individual can be an agent in his or her development.

Symbolic Interactionism [45] resolves open questions of the social constructionist perspective. The assumption here is that the individual possesses a self that he or she interacts with. The individual also interacts with others, which is seen as an important source of individual development. Others can be interpreted as any relevant (group of) person(s) that the student interacts with. It could be a community in Lave and Wenger's sense, or a group of students, family, teachers, etc.. Identity in this theoretical perspective is seen as a label, something we call ourselves, which is a rather limited notion

of identity. However, Charon describes three actions that the "I" can take in relation to self that appear interesting for this study: self-perception, self-judgement, and self-control [45, pp. 77ff].

3.3 Summary

Lave and Wenger's social theory of learning is useful because it provides a broader perspective on learning as identity development. I have interpreted their ideas for learning in the context of a Community of Practice in the context of learning in higher education. The resulting view of identity development and learning considers all the aspects that seem important considering other related work (Section 2.3).

The resulting framework refers to identity as a history of engaging in participation and reification, which entails the interaction with others and being part of different ways of negotiating meaning. This interpretation moves closer to what is suggested in alternative theories, to consider identity with respect to others and discourses.

Chapter 4

Empirical Studies

This research project is grounded in the results of Paper I. Although students describe their learning experiences as positive, they may not wish to take more courses within the field, since they do not perceive learning CS/IT as relevant. The central questions of this project thus become: What are different ways of experiencing learning CS/IT as relevant, and how do students "grow" in their relationship to CS/IT during their education?

In the following, I describe my longitudinal study of students' identity development. In Section 4.3, Data Collection, I distinguish between the first study (Paper I) and the longitudinal study (Paper II, III).

4.1 Overview

Figure 4.1 provides an overview of this project, which aims to understand students' identity development as they proceed through their studies (revised version of Paper II, p. 115). The longitudinal study follows students from two different study programmes, IT and CS (see Section 4.2). Data was collected from the students in the beginning of their studies and after one year. Further data will be collected at the end of their second and third year of study. The axis "Identification" represents the state of identity development. The green dots are placed at arbitrary heights. The lines connecting the dots represent the resulting process of identity development over time.

Two methodological issues are central in the study design: (1) How to understand identity and (2) how to study identity development over time. The first question has been explored in Paper II and III. Aspects of Lave and Wenger's social theory of learning, and theory of situated learning have been interpreted in the context of learning in higher education and their

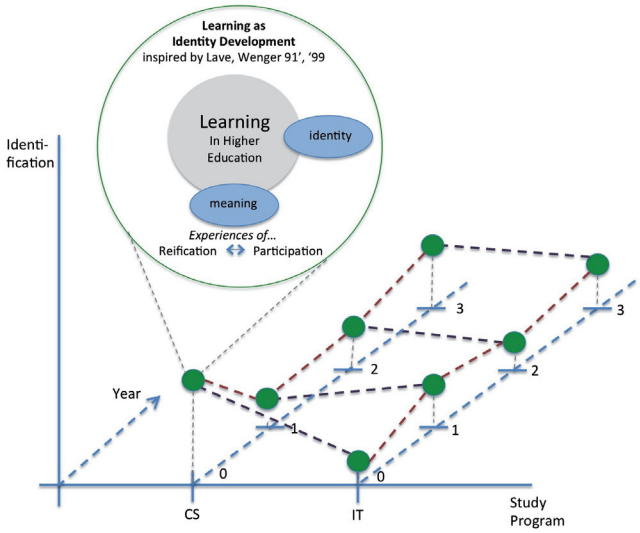

Figure 4.1: Overview of the research project that aims to understand students' identity development over time.

relevance has been argued for (Section 3.1). The big green circle in Figure 4.1 contains an illustration of these aspects. The next section summarises definitions of terms as they were used in the papers. Students' identity development over time (2) will be studied in the future. However, Paper II and III do contribute to understanding learners' development. Paper II applied Entwistle's model of learner development to relate insights on students' identity to their maturity as learners. Paper III applied phenomenography to understand qualitative differences in the students' experience of participation. Results provide a basis from which it is possible to reason about identity development over time (see Section 5.3). Entwistle's model and phenomenography are summarized in Section 4.1.2 and 4.1.3.

4.1.1 Explanation of Terms

Paper II and III utilise Lave and Wenger's social theory of learning, and theory of situated learning [42, 43]. My interpretation of these theories is described and discussed in Chapter 3. The following is a summary of definitions of the terms that were used in the papers:

Identity: A personal history of negotiation of meaning.

Negotiation of Meaning: Result from the interaction of two processes, participation and reification.

Participation: Process of taking part, which includes relations with others that reflect this process. "Participation combines doing, thinking, feeling, talking, and belonging. It involves our whole person, including our bodies, minds, emotions, and social relations". [43, pp. 56-57]

Reification: Process of giving form to experiences, resulting in objects and abstractions that hold certain meanings.

4.1.2 Entwistle's Model of Learner Development

Building on work by Perry and Säljö, Entwistle [7] describes and integrates two dimensions of learner development, development of conceptions of knowledge and conceptions of learning (see illustration in Paper II, page 117). In early stages of development, learners expect to be provided with all knowledge necessary from authorities. They do not seek meaning in what they learn, nor do they take a personal stance on knowledge. As learners mature, they increasingly seek meaning and take a personal stance on knowledge. The final stage of learner development is that learning is experienced as personal development.

In my interpretation, this model describing learner development provides insights on how dependent learners are on authorities. If a less mature learner does not perceive what is presented from the authority as relevant, he or she will not seek meaning in what is learnt, which certainly affects learning. Thus, less mature learners are dependent on authorities to presenting something that they can perceive as relevant.

4.1.3 Phenomenography

Phenomenography [46] is a research approach that has traditionally been used to study qualitatively different ways of understanding phenomena. The result of a phenomenographic study is a set of categories describing qualitatively different ways of relating to the phenomenon, called the outcome space. The different categories of an outcome space relate to one another. A typical relationship is inclusivity, i.e. more advanced categories include less advanced categories.

In Paper III, phenomenography was used to study the different ways in which students experience the phenomenon "participation in CS/IT". Utilising Wenger's notion of participation (Section 4.1.1), the results contribute to insights into students' negotiation of meaning.

4.2 Informants and Study Programmes

Data has been collected from students of the CS, Computer and Information Engineering (IT)[1], and Sociotechnical Engineering (STS) programmes at Uppsala University in Uppsala, Sweden. IT and STS are two engineering programmes that lead to a Masters degree after five years. CS is a three-year Bachelor's degree programme.

The goal of the CS programme[2], is to give students good and broad knowledge within CS and in at least one related area that the students can apply in industry and the public sector. The students should be able to contribute with knowledge and methods to research, development, and investigative work. The goal of the IT programme is to educate engineers that can, with a perspective on sustainability, create and use technology for the development of large-scale and complex systems, in which communication and regulation have a central roll. The STS programme aims to educate engineers that are capable of analysing, modelling, simulating, and regulating complex technological systems for society. Through courses in the humanities, a critical approach to developing technology should be acquired.

In the longitudinal study, the focus is on the students of the CS and IT programmes. These two programmes share similarities in the curriculum, especially in the first two to three years (see Paper III, Section IV.B for information on year one). The students do not only take the same courses, they actually take them together which means that the students from both programmes interact and work with each other in these courses.

4.3 Data Collection

Table 4.1 provides an overview of the data collection process. As explained in the beginning of the chapter, the first study was not part of the longitudinal study. In the next section, data collection for the first study will be

[1]The abbreviation "IT" derives from the Swedish name of the programme, "Civilingenjörsprogrammet i informationsteknologi"

[2]The description of study programmes is based on the information of the study handbooks 2012/2013 that are available at the IT department. Further information can be found on the IT department's website, `http://www.it.uu.se/edu`.

explained. The section after that describes data collection for the longitudinal study.

Informants	Aim	Data	Period
STS students at the end of an introductory course	Experiences and attitudes at the end of an introductory CS course	questionnaire, follow-up interviews	Nov 2011
CS, IT students in the beginning of year 1	Experiences prior to studying, expectations for education, envisioned future	written reflections	Sept 2012
CS, IT students at the end of year 1	Experiences prior to studying, educational experiences, envisioned future	interviews	May/Jun 2013

Table 4.1: Overview of data collection during the project.

4.3.1 First Study on STS Students

The goal of this study was to get an overview of STS students' experiences during an introductory course in CS, and how they affected the students' attitudes towards learning CS. A questionnaire was distributed during a lab session at the end of the course. Based on the results of the questionnaire, follow-up interviews were conducted with selected students to get a more nuanced insight into the students' experiences and reasoning about future engagement.

The questionnaire consisted of three parts. First, the students were asked about broader interests with respect to their study programme and programming experiences prior to the course. The second part included pairs of checkboxes labelled with attributes "Interesting – Uninteresting", "Easy – Difficult", "Exciting – Boring", "Useful – Irrelevant". From each pair, the students chose which attribute described their attitude towards learning CS/IT before the course best. This was a preparation of the last part, in which the students reflected on course experiences that either supported or changed the students' attitudes they espoused prior to the course.

Of the 57 students that were enrolled in the course, 36 answered the questionnaire. Based on the results of the questionnaire (Section 5.1), five students were selected for follow-up interviews. I selected students that described a positive change in attitude, e.g. from perceiving learning CS/IT as rather

boring to rather exciting, to find out more about the students' course experiences that supported this change of attitude.

The interview began by asking the students to explain their experiences and attitudes prior to the course. Then, the students reflected on their course experiences and how they affected prior attitudes. In the last part of the interview, the students talked about their career plans and whether or not they are planning to take more CS courses in the future.

4.3.2 Longitudinal Study on CS and IT Students

The longitudinal study follows CS and IT students that began their studies in September 2012. In the beginning of their studies, the students were given an assignment asking them to write a reflection on their choice of study, envisioned future work life, and expectations for education. The exact assignment can be found in the Appendix, A.1. Based on written reflections from 123 students (149 students were enrolled in the course), I selected students to follow through interviews. I conducted interviews with 23 students at the end of study year one. Further interviews with the same students are planned at the end of year two and three.

To select the students to follow in the longitudinal study, results of analysing the written reflections were used (see Section 5.2). One goal was to choose students that together cover the breadth of experiences and reasoning in the written reflections. In order to do that, a list of themes and examples that were found in the written reflections, was developed (see Appendix B). One theme, for instance, is "activities". Examples of "activities" are "create", "use", "understand". Another result of the analysis was that there seem to be two student groups, one focusing on computers in their reflections, and the other group focusing on technology (see Paper II, Section 5.2). Paper II concludes with a suggestion to follow these two groups.

The selection procedure is illustrated in Figure 4.2. Only seven students were women so I invited all of them. I sorted the remaining male students into a pile of IT and a pile of CS students. I continued with the CS students and sorted them into two piles, one pile with students who stated an interest in computer and one pile with students who did not state an interest in computer. Both of these piles were sorted into five piles, depending on which of the following experiences were reported in the reflection, (a) CS/IT related courses in high school, (b) study experiences (CS-related and not) (c) job experiences (CS-related and not), (d) several of the experiences before (e) neither of the experiences before. From each of the five piles, I chose one

or two students[3] that together cover all of the themes and examples in the list (see Appendix, B). The IT students were sorted in the same way.

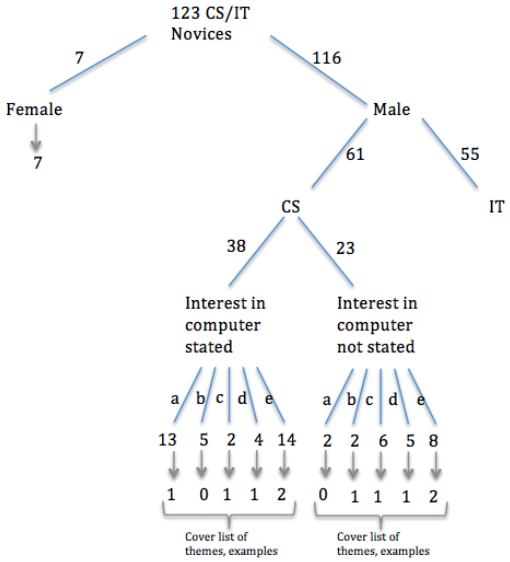

Figure 4.2: Illustration of the procedure used to select the students to follow in the longitudinal study. Letters a to e refer to experiences prior to entering the CS/IT programme, e.g. study or job experiences.

I conducted interviews with 13 CS and 10 IT students at the end of their first study year. Six of these students were female, of which one was enrolled in the IT programme.

The interview consisted of three parts, which were each introduced with an open question to the interviewee (see A.2 for details). The parts were about (1) experiences prior to studying, (2) envisioned future, (3) study experiences. The opening questions led to rich and long descriptions of experiences. These resulted naturally in a sequence of follow-up questions, mostly similar to what I had planned with the follow-up questions but more concrete, based on what the students said. Mostly, the follow-up questions aimed at a better understanding of what the student had said before. For example, if a student said that programming is fun, then I asked a question such as "What do you think, what makes programming fun for you?".

[3]In a few cases, I selected no students from a pile. I did that when I already had selected students with similar experiences from other piles.

4.4 Data Analysis

To get insights into students' experiences and negotiation of meaning, thematic analyses [47] have mainly been used to identify themes and thus to explore ways to answer the research questions (Section 1.2). In Paper III, a phenomenographic analysis [46] was applied (Section 4.1.3).

In Paper I, the aim was to understand STS students' experiences and resulting attitudes. Questionnaire and interview data were analysed using thematic analysis [47]. I identified themes describing what students' positive learning experiences were about. In the interview data, I also identified themes representing students' reasons not to take further courses in CS/IT. This focus emerged as four out of five students stated that they will probably not take more courses in CS/IT, despite positive learning experiences.

In Paper II, the aim was to explore theory, which could be used to understand and analyse students' reflections on experiences and relationship to the discipline. The written reflections were analysed here (see Section 4.3.2). I did a thematic analysis and related the results to Lave and Wenger's theories (see Section 3.1). I found that certain themes that were common in the data could be related to Lave and Wenger's notion of participation and reification. Furthermore, I did a deductive analysis using Entwistle's categories of learner development [7] (see Section 4.1.2). The results of these analyses were integrated to reason about students' experiences and relationship to the discipline with respect to their maturity as learners.

In Paper III, the aim was to understand students' qualitatively different ways of experiencing participation in CS/IT. A phenomenographic analysis of the interviews that were conducted at the end of year one was performed (see Section 4.1.3). The notion of participation used here is inspired by Wenger (see Section 4.1.1). Categories of descriptions of participation and relationships between these categories were identified.

Chapter 5

Contributions

Contributions are described paper by paper first. Then, they are integrated with respect to the broader goals of this project (Section 1.2).

5.1 Paper I: STS Students' Course Experiences and Attitudes

Study I is based on data from STS students, collected at the end of an introductory course (Section 4.3.1). A general finding is that even though all STS students reported very positive learning experiences in the questionnaire, four out of five students that were invited for follow-up interviews argued that they will probably not take further courses in CS/IT.

The results of this paper contribute to a better understanding of positive learning experiences. Some of the findings have been reported in previous research and have explicitly been considered in the course design [2], e.g. the experience of self-efficacy [48, 49] and the experience of creativity in doing CS [38]. Other experiences that were stated to have supported positive learning experiences were the experience that CS is something one does with and for others, as well as to learn what CS is all about.

Another result is a summary of reasons why students will probably not take more courses in CS/IT, despite their positive learning experiences. The students' reasoning indicates that identity may be an important factor. The quote given at the beginning of this thesis (p. 1) illustrates this. The student seems to equate CS with programming and experiences programming in a way that is not relevant to him, since he is interested in solving complex problems of society. The perception of CS as equal to programming may originate from an introductory course, which only introduces programming,

not CS, and the students' belief that they have learned what CS is all about (see previous paragraph). If students equate CS with programming, and experience programming in a way that is not relevant to them, then they might reason in a similar manner to the following quote from another interview, in which the student explains why he will probably not take more courses in CS: "I don't see why we have to learn every little detail in programming" (Paper II, p. 5).

In conclusion, the course succeeds in facilitating positive learning experiences. However, the students' explanations why they will not take further courses in CS raises questions about how this course and CS education in general supports students in experiencing CS as relevant.

5.2 Paper II: Towards Understanding Identity

Paper II presents the longitudinal study and introduces the aim of understanding students' identity development. The main contribution of this paper is a proposal for how Lave and Wenger's theories [42, 43] (Section 3.1), as well as Entwistle's model of learner development [7] (Section 4.1.2), can be utilised to understand novice students' written reflections on their experiences and expectations (data collection is described in Section 4.3.2).

Lave and Wenger's social theory of learning, and theory of situated learning [42, 43] turn out to be useful in the process of trying to understand aspects of student identity, particularly the terms reification and participation, which are described as processes through which meaning is construed (Section 3.1, 4.1.1). As a result of the analysis, two "objects of reification" are proposed, that describe different foci in the students' reflections: "computer" and "technology". Related to these objects, the students describe different experiences that can be interpreted in terms of participation. The analysis allows us to distinguish two groups of students, one group focusing on computers and the other focusing on technology in broader terms.

The results obtained, related to the group of students who focus on computers, are in-line with Schulte and Knobelsdorf's [17, 16] results concerning CS major students' computer experiences prior to studying (Section 2.2). These students often describe that they have enjoyed using the computer since they were little, e.g. playing games. This led to further explorations of the computer and the experience that one can design and create, e.g. programs, which often stimulated an interest in programming.

The other group of students states a rather general interest in technology, bigger systems, innovation, and society. This is in line with what Holmegaard, Ulriksen, and Madsen [3] find about students studying STEM

programmes (Section 2.2). CS/IT students with a more general interest in "technology" write little about programming experiences. In some examples, students refrain from programming (e.g. Paper II, p. 119, first quote).

A deductive analysis of the same data using Entwistle's categories of learner development (Section 4.1.2) indicates that many students have rather less mature conceptions of knowing and learning. Such conceptions imply that the students tend not to seek meaning in what is presented to them by authorities. Thus, in order for the students to perceive what is presented as relevant, education can try to present material in a way that it is relevant to the students.

In conclusion, the results of the analyses using Lave and Wenger as well as Entwistle complement each other. The analysis using Entwistle indicates that many students are dependent on the insight of authority figures into what the students view as relevant, if the students are to find themselves in a learning environment which they perceive as relevant. Analysing students' experiences of participation and reification provides insights into how learning can be relevant to the students. Results of this paper indicate that there are students who negotiate meaning with a focus on computers, and others with a rather broad focus on technology.

5.3 Paper III: First Year Students' Experiences of Participation

A general insight of this study is that many parts of first year students' reflections on experiences prior to studying, study experiences and future work life, can be interpreted and described in terms of participation (see Section 4.3.2 for information on data collection). Again, the notion of participation applied here is inspired by Wenger, who describes participation as a process through which meaning is construed (Sections 3.1, 4.1.1). Insights into students' experiences of participation provide a basis from which to discuss implications for teaching and learning.

A major result of this study is a hierarchical outcome space that describes students' qualitatively different ways of experiencing participation in CS/IT. The outcome space includes experiences of participation as "using", "understanding", "creating", "(systematic) problem solving", "creating for others", "continuous development", and "creating new knowledge" (see Paper III, Section VII.B for descriptions of categories). Every category of experience describes a way of negotiating meaning, i.e. relating to the field CS/IT. As the outcome space is hierarchical, more advanced experiences of participation (latter categories) represent richer ways of negotiating meaning.

The outcome space provides a basis from which to reason about how students try to integrate their educational experiences with previous experiences and envisioned future. Holmegaard et al. [4] find that many students struggle in this process, which can lead to frustration and drop-out. In some cases, the students' experiences seem to be in-line. For example, some students state that they enjoyed playing ("using") computer games and that they could imagine to "create" computer games in the future. These students seem to be positive about their education, having learnt to "create" programs and "understand" how a computer works. The paper also discusses one example of a student who struggled to integrate his experiences. The outcome space helps to illuminate the dis-alignment of experiences, which seems to be a major reason for the student to leave the study programme. The student is interested in "creating" hardware, getting different components to work together. However, CS in his experience, is about "creating" software, "apps". He seems to associate "doing of creation" with "hammering on the keyboard" (Paper III, Section VIII).

The outcome space provides a basis to consider participation in education, and thus to support students' negotiation of meaning. The informants all state experiences of participation in CS/IT as "creation". The "outcome", the "how", and "doing together with others" aspects are in the students' focus. In order to support students to experience what they learn as meaningful, education can facilitate diverse experiences that address these aspects. Furthermore, education should facilitate advanced experiences of participation to support richer ways of negotiating meaning. This appears to be important also for students' competence development as each category of experiencing participation actually represents a way of participating in CS/IT that the students should acquire competences in.

5.4 Summary and Discussion

Finally, the goal is to integrate the results of Paper I-III. This will be done based on the goals of this project (G1-G4, Section 1.2).

A research framework to investigate identity and identity development has been developed (G4). A component is a theoretical framework with which to understand and study identity. Lave and Wenger's social theory of learning, and theory of situated learning [42, 43] were interpreted in the context of higher education. The terms identity, negotiation of meaning, reification and participation have been explored and found useful in our efforts to understand students' reflections on study experiences (Paper II, III, see Section 4.1.1 for a summary of definitions).

All papers provide insights into aspects of students' identities (G1). Pa-

per I and III conclude that experiences of CS as "creating", "(systematic) problem solving", and "creating for others" support a positive relationship to the discipline. All papers also discuss issues related to students' identity development that should be considered in future research and educational development. One question, for example, is how students with an interest in complex problems of society develop through their education. Paper I presents an example of a student who experiences CS/IT as disconnected from society. Results of paper II indicate that there is a student group among CS/IT novices with a broader focus on technology, innovation, and society. At the end of year one, few of the informants' reasoning relate to the broader context of society (interpreted in terms of participation as "continuous development", see paper III, section VII, category F). This indicates that a broader perspective on technology and society is not prevalent in first year education. Notably, all papers point out examples in which students take a distant position to CS as programming (apps), coding, and hacking. As many students relate to creating apps or games in positive ways, such images of CS may be a result of students' collective negotiation of meaning. This implies that the collective students' negotiation of meaning is important for the individual's negotiation of meaning.

Results provide a basis from which to discuss the role of identity in learning (G2). Results in Paper II indicate that many novice students depend on learning what they perceive as relevant, as they will not seek meaning in what they learn. This work describes aspects of what the students perceive as relevant in terms of identity. Thus, students' identity can influence novice students' learning. Paper III raises the question, how students' negotiation of meaning influences how students contextualise what they learn. For example, learning to write specifications for functions may be contextualized differently by students who experience participation in CS/IT as "continuous development" of complex systems together with others, than by those who experience participation in CS/IT mainly as "creating" something that works. Different ways of contextualising likely imply different conceptual understandings.

All papers have discussed implications for education (G3). In general, it appears important that education facilitates rich, diverse experiences to meet different students' negotiation of meaning. Insights into students' ways of negotiating meaning described here can be used to consider students' negotiation of meaning in education. Previous discussions provide arguments that supporting advanced ways of negotiating meaning is important. Richer ways of negotiating meaning allow for richer ways of contextualising what is to be learnt. Furthermore, supporting rich ways of negotiating meaning among the student collective can help the individual student to experience CS as relevant, as the collective student community seems to have an influ-

ence on the individual student's negotiation of meaning. Paper III provides insights into experiences of participation that are increasingly advanced.

The poster presented in Figure 5.1 has been displayed in different places in the campus environment where the informants study and hang out together. It communicates a certain way of doing CS, i.e. hacking, doing apps. This may address students who are interested in "creating" programs, and who want to become a really good programmer, to which the notion of hacker is probably meant to allude. It also reinforces an image of CS that some students find problematic to integrate into their perception of who they are and want to be, in fact an image of CS upon which some students base their decision to leave. "Creating apps" hence is not just present in the negotiation of meaning among students, it is a meaning communicated in the spaces of education. This example sheds light on the fact that students' identity development is influenced by different meanings communicated in different contexts.

Figure 5.1: A poster in different places of the informants' study environment. It says: "Uppsala Hackathon. The best app wins a Surface Pro! Welcome to a mini hack under the sign of the app."

Chapter 6

Conclusion and Future Work

The analysis of recent research emphasises that too little is known about learners' experiences studying STEM, relationship to the discipline, and development of professional and disciplinary identity [8, 16, 5]. This thesis presents results of a longitudinal study that aims to explore CS and IT students' identity development during their first three years of study. Students' reflections on learning experiences and envisioned future work life during their first study year have been analysed.

Results of three papers are described and integrated in this thesis. Paper I described students' positive learning experiences during an introductory computer science course and reasons about why students do not choose to take further courses, despite positive learning experiences. Issues of identity were found to be important to students in making this choice. Paper II presents the longitudinal study and a theoretical framework with which to study identity development. The notion of reification and participation were explored to understand students' reflections on experiences prior to studying, envisioned future, and expectations for education. Two student groups were identified, one group that focuses on computers in their reflection and one group that focuses on technology. Paper III describes first year students' experiences of participation in CS/IT that range from experiences of participation as "using" existing artefacts to "creating new knowledge".

The results contribute to a better understanding of identity in four ways (see Section 5.4 for a more extensive summary). Lave and Wenger's social theory of learning, and theory of situated learning have been interpreted in the context of higher education which provides a way to study learning in broader terms of identity development and negotiation of meaning. Another contribution is insights into aspects of CS/IT students' identities. This provides a basis from which to discuss implications for learning and education. A major conclusion from these results and discussions is that it seems im-

portant that education should facilitate rich and diverse experiences to meet students' different ways of negotiating meaning, and further, that education should support advanced ways of negotiating meaning to support identity development. The results have also been discussed with respect to how identity development in CS/IT can be addressed in education.

Particularly interesting for the future development of this research are experiences that the students cannot integrate into their perception of who they are and want to be. Such experiences have been found to cause frustration and drop-out, both in the present and previous work. Examples of this are the experience that CS does not contribute to solving problems of society, and the experience that CS is only about "programming", "hacking", "coding", or "creating apps". Theories about identity imply that meanings are created in interaction or discourses. This work indicates that the collective student group has a strong effect on the individual's negotiation of meaning. The image of CS as "hacking", "creating apps" seems to also be reinforced in education. This discussion highlights the social character of identity – and learning, if learning is seen from the broader perspective of identity.

In future research, three areas of investigation seem particularly interesting. First, it is necessary to get a better understanding of how and in which contexts different meanings are produced, that the students reflect on. Second, an important aim for future research is to understand students' identity development over time. To do that, further interviews with the students at the end of their second and third year will be conducted. Third, it is interesting to try to associate the students' experiences and ways of negotiating meaning with a kind of professional understanding of the discipline. This can contribute to a better understanding of the students' experiences. Possibly, insights on the students' negotiation of meaning could even inform research about the discipline.

Bibliography

[1] A.-K. Peters and A. Pears, "Students' experiences and attitudes towards learning Computer Science," in *2012 Frontiers in Education Conference Proceedings*. IEEE, Oct. 2012, pp. 1–6, doi: 10.1109/FIE.2012.6462238.

[2] A. N. Pears, "Enhancing student engagement in an introductory programming course," in *2010 IEEE Frontiers in Education Conference (FIE)*. IEEE, Oct. 2010, pp. F1E–1–F1E–2, doi: 10.1109/FIE.2010.5673334.

[3] H. T. Holmegaard and L. Ulriksen, "Why students choose (not) to study engineering," in *Proc. of the Joint International IGIP-SEFI Annual Conference*, 2010, pp. 1–9. [Online]. Available: http://www.sefi.be/wp-content/papers2010/papers/1203.pdf

[4] H. T. Holmegaard, L. M. Ulriksen, and L. M. Madsen, "The Process of Choosing What to Study: A Longitudinal Study of Upper Secondary Students' Identity Work When Choosing Higher Education," *Scandinavian Journal of Educational Research*, vol. 58, no. 1, pp. 21–40, Jan. 2014, doi: 10.1080/00313831.2012.696212.

[5] B. F. Johannsen, "Attrition and Retention in University Physics," PhD dissertation, University of Copenhagen, 2012.

[6] R. Stevens, K. O'Connor, L. Garrison, A. Jocuns, and D. M. Amos, "Becoming an Engineer: Toward a Three Dimensional View of Engineering Learning," *Journal of Engineering Education*, vol. 97, no. 3, pp. 355–368, Jul. 2008, doi: 10.1002/j.2168-9830.2008.tb00984.x.

[7] N. Entwistle, "Conceptions of Learning and the Experience of Understanding: Thresholds, Contextual Influences, and Knowledge Objects," in *Re-framing the Conceptual Change Approach in Learning and Instruction; Advances in learning and instruction series*, S. Vosniadou, A. Baltas, and X. Vamvakoussi, Eds. Elsevier, 2007, ch. 11, pp. 123–143.

[8] L. Ulriksen, L. M. l. Madsen, and H. T. Holmegaard, "What do we know about explanations for drop out/opt out among young people from STM higher education programmes?" *Studies in Science Education*, vol. 46, no. 2, pp. 209–244, Sep. 2010, doi: 10.1080/03057267.2010.504549.

[9] ACM/IEEE-CS Joint Task Force, "Computer Science Curriculum 2008: An Interim Revision of CS 2001," ACM / IEEE CS, Tech. Rep., 2008. [Online]. Available: http://www.acm.org/education/curricula/ComputerScience2008.pdf

[10] J. M. Cohoon and W. Aspray, Eds., *Women and Information Technology: Research on Underrepresentation*. The MIT Press, 2008.

[11] C. Björkman, *Crossing Boundaries, Focusing Foundations , Trying Translations : Feminist Technoscience Strategies in Computer Science*, ser. Blekinge Institute of Technology Dissertation Series. Blekinge Institute of Technology, 2005.

[12] Organisation for Economic Co-operation and Development (OECD), *Education at a Glance 2012: OECD Indicators*, ser. Education at a Glance. OECD Publishing, Sep. 2012. [Online]. Available: http://www.oecd-ilibrary.org/education/education-at-a-glance-2012_eag-2012-en

[13] A. Ottemo, "Rekryteringsarbete : Rådande utgångspunkter och alternativa strategier," in *Proceedings från Den 2:a Utvecklingskonferensen för Sveriges ingenjörsutbildningar*. Institutionen för pedagogik och didaktik, enheten för Individ, kultur och samhälle, 2009, pp. 12–17. [Online]. Available: http://www.lth.se/fileadmin/lth/genombrottet/natutvkonferens2009/proceedings/12Ottemo.pdf

[14] M. Tedre, "The Development of Computer Science; A Sociocultural Perspective," PhD dissertation, University of Joensuu, Finland, 2006.

[15] L. Ulriksen, H. T. Holmegaard, and L. M. l. Madsen, "Weaving a Bridge of Sense : students' narrative constructions as a lens for understanding students' coping with the gap between expectancies and experiences when entering higher education," *European Educational Research Journal*, vol. 12, no. 3, pp. 310–319, 2013. [Online]. Available: http://dx.doi.org/10.2304/eerj.2013.12.3.310

[16] M. Knobelsdorf, "Biographische Lern- und Bildungsprozesse im Handlungskontext der Computernutzung," Ph.D. dissertation, Freie Universität Berlin, Germany, 2011.

[17] C. Schulte and M. Knobelsdorf, "Attitudes towards computer science-computing experiences as a starting point and barrier to computer science," in *Proceedings of the third international workshop on Computing*

education research - ICER '07. New York, NY, USA: ACM Press, 2007, p. 27, doi: 10.1145/1288580.1288585.

[18] G. Biesta, *Beyond learning: democratic education for a human future*, ser. Interventions (Boulder). Paradigm Publishers, 2006.

[19] Organisation for Economic Co-operation and Development (OECD), *Encouraging Student Interest in Science and Technology Studies*. OECD Publishing, Nov. 2008. [Online]. Available: http://www.oecd-ilibrary.org/science-and-technology/encouraging-student-interest-in-science-and-technology-studies_9789264040892-en

[20] ACM/IEEE-CS Joint Task Force on Computing Curricula, "Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science," ACM Press and IEEE Computer Society Press, Tech. Rep., Jan. 2013. [Online]. Available: http://dl.acm.org/citation.cfm?id=2534860

[21] P. Kinnunen, "Challenges of teaching and studying programming at a university of technology; Viewpoints of students, teachers and the university," Ph.D. dissertation, Helsinki University of Technology, 2009.

[22] R. Bornat, D. Saeed, and Simon, "Mental models, consistency and programming aptitude," in *Proceedings of the Tenth Conference on Australasian Computing Education - Volume 78*, ser. ACE '08, vol. 78. Wollongong, NSW, Australia: Australian Computer Society, Inc., 2008, pp. 53—-61. [Online]. Available: http://dl.acm.org/citation.cfm?id=1379249.1379253

[23] P. R. Ventura, "Identifying predictors of success for an objects-first CS1," *Computer Science Education*, vol. 15, no. 3, pp. 223–243, Sep. 2005, doi: 10.1080/08993400500224419.

[24] S. Bergin and R. Reilly, "Programming: factors that influence success," in *Proceedings of the 36th SIGCSE technical symposium on Computer science education*. ACM Press, 2005, pp. 411–415, doi: 10.1145/1047344.1047480.

[25] N. Rountree, J. Rountree, and A. Robins, "Predictors of success and failure in a CS1 course," *ACM SIGCSE Bulletin*, vol. 34, no. 4, pp. 121–124, Dec. 2002, doi: 10.1145/820127.820182.

[26] Simon, S. Fincher, A. Robins, B. Baker, I. Box, Q. Cutts, M. de Raadt, P. Haden, J. Hamer, M. Hamilton, R. Lister, M. Petre, K. Sutton, D. Tolhurst, and J. Tutty, "Predictors of success in a first programming course," in *Proceedings of the 8th Australasian Conference on*

Computing Education - Volume 52, ser. ACE '06. Hobart, Australia: Australian Computer Society, Inc., 2006, pp. 189–196. [Online]. Available: http://dl.acm.org/citation.cfm?id=1151869.1151894

[27] P. Kinnunen and L. Malmi, "Why students drop out CS1 course?" in *Proceedings of the 2006 international workshop on Computing education research - ICER '06*, ser. ICER '06. New York, NY, USA: ACM, 2006, p. 97, doi: 10.1145/1151588.1151604.

[28] E. Rommes, G. Overbeek, R. Scholte, R. Engels, and R. De Kemp, "'I'M NOT INTERESTED IN COMPUTERS': Gender-based occupational choices of adolescents," *Information, Communication & Society*, vol. 10, no. 3, pp. 299–319, Jun. 2007, doi: 10.1080/13691180701409838.

[29] J. Margolis and A. Fisher, *Unlocking the Clubhouse. Women in Computing*. The MIT Press, 2001.

[30] J. Teague, "Women in computing: what brings them to it, what keeps them in it?" *ACM SIGCSE Bulletin - Women and Computing*, vol. 34, no. 2, pp. 147–158, Jun. 2002, doi: 10.1145/543812.543849.

[31] J. Margolis, R. Estrella, J. Goode, J. J. Holme, and K. Nao, *Stuck in the Shallow End; Education, Race and Computing*. MIT Press, 2010.

[32] C. E. Foor, S. E. Walden, and D. A. Trytten, "'I Wish that I Belonged More in this Whole Engineering Group:' Achieving Individual Diversity," *Journal of Engineering Education*, vol. 96, no. 2, pp. 103–115, Apr. 2007, doi: 10.1002/j.2168-9830.2007.tb00921.x.

[33] A. T. Danielsson, *Doing Physics - Doing Gender: An Exploration of Physics Students' Identity Constitution in the Context of Laboratory Work*, ser. Uppsala Dissertations from the Faculty of Science and Technology, ISSN 1104-2516; 83. Acta Universitatis Upsaliensis, 2009.

[34] M. Guzdial, "EducationTeaching computing to everyone," *Communications of the ACM*, vol. 52, no. 5, p. 31, May 2009, doi: 10.1145/1506409.1506420.

[35] M. Goldweber, J. Barr, T. Clear, E. Patitsas, S. Mann, and S. Portnoff, "A Framework for Enhancing the Social Good in Computing Education : A Values Approach Categories and Subject Descriptors," in *Proceedings of the final reports on Innovation and technology in computer science education 2012 working groups. ITiCSE*. ACM, 2012, pp. 16–38. [Online]. Available: http://cse.proj.ac.il/Y13/WG2SocialGood.pdf

[36] M. Buckley, "Viewpoint: Computing as social science," *Communications of the ACM*, vol. 52, no. 4, pp. 29–30, Apr. 2009, doi: 10.1145/1498765.1498779.

[37] K. Yasuhara, *Viewpoints from the Doorstep : Pre-major Interest in and Perceptions of Computer Science*. University of Washington, 2008.

[38] M. Knobelsdorf and R. Romeike, "Creativity as a pathway to computer science," in *Proceedings of the 13th annual conference on Innovation and technology in computer science education - ITiCSE '08*, ser. ITiCSE '08, vol. 40, no. 3. New York, New York, USA: ACM Press, 2008, p. 286, doi: 10.1145/1384271.1384347.

[39] J. Nespor, *Knowledge in Motion: Space, Time, and Curriculum in Undergraduate Physics and Management*, ser. Knowledge, identity, and school life series. Routledge, 1994.

[40] D. Knox, "The role of place in affording different kinds of student engagement and learning," in *Proceedings of the ninth annual international ACM conference on International computing education research - ICER '13*. New York, NY, USA: ACM Press, 2013, pp. 177–178, doi: 10.1145/2493394.2493422.

[41] D. Knox and S. Fincher, "Why does place matter?" in *Proceeding ITiCSE '13 Proceedings of the 18th ACM conference on Innovation and technology in computer science education*. New York, NY, USA: ACM, 2013, pp. 171–176, doi: 10.1145/2462476.2465595.

[42] J. Lave and E. Wenger, *Situated learning: legitimate peripheral participation*, 1st ed., ser. Learning in Doing: Social, Cognitive and Computational Perspectives. Cambridge University Press, 1991.

[43] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*, 1st ed., ser. Learning in Doing: Social, Cognitive and Computational Perspectives. Cambridge University Press, 1999.

[44] V. Burr, *Social Constructionism*, 2nd ed. Routledge, 2003.

[45] J. M. Charon, *Symbolic Interactionism: An Introduction, An Interpretation, An Integration*, 10th ed. Pearson, 2010.

[46] F. Marton and S. Booth, *Learning and Awareness*, ser. Educational psychology series. L. Erlbaum Associates, 1997.

[47] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, Jan. 2006, doi: 10.1191/1478088706qp063oa.

[48] H. Margolis and P. McCabe, "Self-Efficacy: A Key to Improving the Motivation of Struggling Learners," *The Clearing House*, vol. 77, no. 6, pp. 241–249, Jul. 2004, doi: 10.3200/TCHS.77.6.241-249.

[49] P. Kinnunen and B. Simon, "CS majors' self-efficacy perceptions in CS1," in *Proceedings of the seventh international workshop on Computing education research - ICER '11*, ser. ICER '11. New York, New York, USA: ACM Press, 2011, pp. 19–26, doi: 10.1145/2016911.2016917.

Appendix A

Data Collection

A.1 Written Reflection Assignment at the Beginning of Year One

All of the students got the following assignment during the introductory course at the beginning of the study programme[1]:

> Reflect on your studies based on three aspects described below. For each aspect, you find several questions or inspirations that can help you in your reflection. You don't need to go through them one by one. Instead, you can just write a couple of paragraphs about each aspect that describe your thoughts.
>
> 1. *Choice of study programme:* Tell about why you have chosen the CS or IT programme. Tell about yourself, your experiences, interests, and what you think is exciting or challenging that has influenced you in your choice. Tell also about how you experience that others, for example family, friends, school, etc. have influenced you.
> 2. *After your studies:* What can you imagine to work with? Perhaps you can try to describe a situation or context that you could see yourself in? Who do you want to work with? What do you want to get out of your work? What do you want that your work results in?
> 3. *The journey there:* What do you hope to learn in your studies? What is needed so that you will reach what you want in you future? How do you think will you best get there? What do you expect education to contribute with?

[1]The questions were translated from Swedish to English.

A.2 Interview Script at the End of Year One

The opening questions for the interviews at the end of year one[2]:

1. I would like to go back to before you began to study: Can you please tell your story about how you think you became interested in CS/IT, which then led to your decision to study CS/IT?
2. 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?
3. Now, you have studied CS/IT for one year, can you tell me about how you have experienced your first year here at the university?

Follow-up questions for opening question 1 were e.g. "What do you think, what experiences have influenced your choice of study?", "What about CS/IT were you in particular interested in?", "Was there someone who has influenced your choice?", "Did you have other ideas what to study?", "When did you become interested in studying CS/IT?".

Follow-up questions for opening question 2 were e.g. "What could you imagine to do?", "What do you think, what could your work perhaps result in?", "How would you like to work?", "With who?", "For who?".

For question 3, I prepared three groups of follow-up questions, (1) on experiences during the courses, such as "Do you remember a moment that felt in particular good or bad?", "What do you think have you learnt that was in particular interesting/giving?", (2) on social contacts, the environment, such as "How do you feel in you class?", "Who do you like to hang out with?", (3) relationship between study experiences, experiences prior to studying, and envisioned future, such as "You said, you would like to work within ..., what do you think have you learned here at the university that helps you to be able to do that?", "How do you think have you developed during your first year?", "If you look back at the fist year, what do you think have you experienced that made you feel 'I have chosen right / wrong'?". Furthermore, I asked all the students what they experience CS/IT and programming to be.

Mostly the follow-up questions emerged naturally, based on what the students said. In most cases the questions where of the nature "you said ... was ..., what was it that made you feel that it was ...?". In some cases, I also referred back to what the students wrote in the reflections.

[2]The questions were translated from Swedish to English.

Appendix B

List of Themes in Novice Students' Written Reflections

The following list was used to select informants to follow in the longitudinal study. It contains themes and examples that the students referred to in their written reflections on experiences prior to studying, envisioned future, and expectations for education. The students wrote these reflections at the beginning of their studies. For explanation of the data collection and selection procedure, see section 4.3.2.

1. Objects: information, technology, computer, game, math, algorithm, security, network, hardware, software, program, project, industry, research, society, product, logic, system, app / smartphone / internet phenomenon (Spotify, Google)

2. Activities: use, create, build, solve problems, understand, develop, programming, lead, help / make a difference, to code, to not (just) code, do research

3. Study experiences: CS/IT related, not CS/IT related

4. Job experience: CS/IT related, not CS/IT related

5. Community experiences: friends, family, collegues

6. "Identity": students appear to have a relatively "strong" identity, i.e. prior experiences, in line with their future goals, students explicitly state that they are uncertain (e.g. if they have chosen right)

7. Goals for work life: Companies (small, big, own, global), career opportunities / good salary / secure, broad / many possibilities, teamwork, work with people with the same interests

8. View of discipline or profession in relation to student: CS/IT is perceived as interesting / fascinating / fun, challenging, leading to self-development, one can be creative / realize ideas, one can lead projects, be innovative / an inventor (e.g. Steve Jobs as role model), global, discipline which "lies close to me"

9. View of the discipline: CS/IT as a tool (e.g. for development), CS/IT as being something logic, CS/IT develops all the time, CS/IT, as optimising (less common)

10. Focus on discipline vs. profession: expectation to learn CS, or to be prepared to work in industry

11. Entwistle: High, Low conceptions of learning & knowledge

Paper I

Students' experiences and attitudes towards learning Computer Science

Anne-Kathrin Peters, Arnold Pears
Department of Computer Systems
Uppsala University
Box 325, 751 05 Uppsala, SWEDEN
Ph: +46 18 4711066, FAX: +46 18 55 02 25
Anne.Peters@it.uu.se, Arnold.Pears@it.uu.se

***Abstract*— Low enrollment and high drop-out rates in computer science (CS) have led to an alarming decrease in number of graduates in western countries. What are students' learning experiences, how do these affect their attitudes towards learning CS? This question was explored by investigating diverse students, of a broad study program with courses in humanities and technology, at the end of an introductory course in CS (CS1), which has been designed to enhance students' engagement. The results of a first questionnaire were remarkably positive: All students reflected their experiences as overall positive. Almost half of the students stated, that they had been skeptical towards learning CS before the course. All of these students described positive transformations of attitudes. These results provided an interesting starting point for further research using interviews: What exactly have these students experienced and how do they reason about future engagement? We point out students' experiences that were crucial for a positive transformation of attitudes as well as critical aspects in students' reasoning on future engagement in CS.**

I. Introduction

Computer science (CS) has become a driving factor for the development of todays' society. Why is it that the number of students that engage in learning CS is so low? Could it be due to unfortunate learning experiences or perceptions of CS?

A survey of research reveals gaps in the understanding of students' engagement. The Review Task Force, a working group of the IEEE and ACM, reviews low engagement in the latest CS curriculum in 2008, referring to the "computing crisis" [1]. The authors state that the curriculum seems to be unattractive for students and that it is vital to engage with the students to improve recruitment and retention [1, p. 29]. Several recruitment projects exist to attract students at upper secondary school [2]–[4]. However, non-completion and drop-out rates at universities are comparatively high [1], [5], [6], and research on drop-out concludes that the problem is very complex [7]. In this study, we focused on students' experiences and resulting attitudes towards learning CS as those have not received much attention in research [8], [9] and appear to be important in the endeavor to enhance engagement in CS.

The following research questions were important and central in this study. What is the role of students' learning experiences, how do they affect students' attitudes towards learning CS? What are students' experiences that lead to positive or negative attitudes towards learning CS? Are there students who do not decide to (further) engage in CS due to unfortunate learning experiences, perceptions, attitudes etc. – students that would engage if they had only experienced CS differently? Aiming at a better understanding of students' learning experiences that affect students' attitudes towards learning CS, our goal is to be able to plan further research and to inform the endeavor of enhancing students' engagement.

Based on our research questions, we decided to investigate diverse students, who have an interest in IT and technology but who have not decided to major in CS, as they take an introductory course (CS1), which was developed with the explicit goal to enhance students' engagement [10]. The study was carried out in two steps: A first questionnaire aimed to get insights in learners' course experiences and attitudes through collecting data of a greater number of students. Subsequent interviews were carried out with a smaller selected group of students to get a deeper understanding of learning experiences, students have made in the course and beyond.

The report begins with a summary of related research. After that, the first part of the study follows, its research questions, the questionnaire, and the results, which were the basis for the follow-up study. We then state research questions for the second part of the study, describe the selection of students, the interview questions, and results. Finally, we summarize results and conclude with issues for future research.

II. Related Studies

Students' computer-related experiences before university and resulting attitudes and expectations were studied by Magenheim, Schulte and Knobelsdorf [8], [11], [12]. Knobelsdorf distinguishes between "users" and "designers" to describe students' experiences and resulting expectations, that are very different for these two groups of students [8]. However, in her summary of related research in 2011, she concludes that the learners' backgrounds, their understanding of the subject, and their individual interests have not received much attention in research so far [8, p. 31].

Why are some students interested and others not? A lot of research has been done with a focus on gender [13] or minorities [14], [15]. A general finding is that conceptions of

978-1-4673-1352-0/12/$31.00 ©2012 IEEE

CS and attitudes towards learning CS have a major impact on girls' engagement [16]. Overall, CS is often perceived to be a male field [17], [18] and women often perceive themselves as less capable than males while objectively having the same skills [13]. Further findings lead to the following suggestions to enhance womens' engagement: It is important to arrange a positive climate, to foster positive experiences, to convey a broad, relevant image of CS, and to make use of teaching concepts that provide pathways into CS [19].

Providing pathways into CS points towards the theory "community of practice" and the terms "outsiders" and "insiders" [20], [21], that are rooted in social theories of learning. Wenger considers "identity" as one component of learning, which Ulriksen et al. find to be a key aspect to explain students' drop-out [9] and students' decision to choose or not choose engineering as a study program [22]. Holmegaard and Ulriksen state that students do not choose engineering because they do not see opportunities for constructing attractive identities. In contrast, students that do choose the study program see themselves as someone engaging in a cross-disciplinary and innovative subject. However, this is often not conveyed during the first year of education and can lead to drop-out [22].

Kinnunen gives a review of literature on students' drop out in CS and investigates CS minors' reasons for drop out of a CS1 course using qualitative interview research [7]. Her overall conclusion is that reasons for drop-out are complex, thus the most frequent reasons reported by Kinnunen's informants were "lack of time" and "low motivation". Simon et al. furthermore state that non-majors, contrary to majors, more likely experience the course as miserable or pointless [23]. Another important aspect related to students' motivation is "perception of self-efficacy", which is considered in gender studies and also recently by Kinnunen [24]. She gives recommendations on how to enhance self-efficacy and argues that this would likely improve academic performance and persistence. Furthermore, she recommends that more research should be done on how students experience different parts of the course, e.g. assignments and lectures, to understand students' orientation and persistence within their studies.

III. Part 1: Aiming for an overview

The aim of this part of the study was to get an overview of students' course experiences and how those affect their attitudes. We purposefully focused on course experiences here, to target interesting related experiences beyond the course in the second part of the study.

A. Research question

A general conclusion from the literature review is that students' experiences are not well understood and that they affect students' perceptions of CS and future engagement. In view of this conclusion and the aim of this part of the study, we state the following research questions (RQ):
RQ 1.1: What do students experience in the introductory CS course that supports or changes their prior attitudes towards learning CS?
RQ 1.2: How do the students' attitudes towards learning CS relate to their broader interests?
The intent of the second research question is to find out about students' interests and how learning CS could be meaningful to them. Are there students that have positive course experiences and attitudes towards studying CS that do not relate to their broader interests? Are there students that have unfortunate negative course experiences or attitudes, meaning that those could be positive, if they had just experienced CS in another way, e.g. more conform to their interests?

B. Data collection

A questionnaire [25] is an efficient method to collect data of a greater number of students. To collect data with which to explore the research questions, we designed a survey consisting of four sections: First, the students were asked for their interests that made them choose their study program. Hereby, we hoped to get broader interests that, through the focus on the study program, are informative to explore RQ 1.2. In the second part of the questionnaire, the students briefly stated their prior programming experiences. This question, contrary to the others, explicitly focuses on programming experiences rather than experiences in CS in general. With this focus, we hoped to get precise information on students prior experiences, that we assumed have a big influence on students' experiences when being introduced to CS, which is commonly done through teaching programming. In the next section, the students were asked to check one of two checkboxes for each contradictory pair of attitudes: Had the students thought that learning CS is rather interesting or uninteresting, boring or exciting, difficult or easy, useful or irrelevant? The idea of this part was to make students decide whether their feelings or attitudes were rather negative or positive. This is helpful for the last section, in which the students were asked to describe two to three of the most important experiences during the course that either supported or changed these feelings or attitudes which aims at exploring RQ 1.1.

C. Sampling

As the goal of this study was to explore different experiences and their affect on attitudes, we decided to investigate diverse students, that have an interest in technology, but that have not decided to major in CS, at the end of an introductory course in CS (CS1). The students of the "Sociotechnical Systems Engineering" program at Uppsala University are an adequate group: Their study program offers courses in both, the humanities and technology. The ratio of male and female students is balanced in that program. The students take CS1 in their second year. About half a year later, they choose whether they want to specialize in CS or energy systems. The CS1 course was designed in recent years, explicitly with the goal to enhance students' engagement, taking into account various results from Computing Education Research [10]: The students work in pairs in the lab. The pairs and assignments change every week. Lab assistants are present to help when it is needed. At the end of every week, the students explain

their results to the teaching assistants who grade the students immediately. There is no final exam. Towards the end of the semester, the students work on a project.

D. Results

Altogether 36 students have filled in the questionnaire using English language[1]. Two datasets were excluded because one student did not fill out the last, most informative question and the other student copied the answers from the neighbor. Contact information were provided by 25 students. According to these students' names, 15 of the these respondents are male, 10 female. More than two thirds, 26 students, state that they had no prior programming experiences.

In view of the findings reported in related research, the overall impression of the students' experiences is surprising: All of the students have experienced this course as overall positive. Even the students that have experienced the course as relatively difficult, mostly state that it was "fun" and "useful". The most notable result was that all of the 16 students that thought of themselves as rather skeptical before the course (learning CS is rather uninteresting or boring or irrelevant) describe a change towards a more positive attitude. Some statements contain prior stereotypical thinking or prejudices, such as[2]:

> *Before, I thought of computer science as very boring and like it was all about sitting in a dark room in front of a computer drinking coca cola. (Anna)*[3]

In other descriptions, this can be found rather implicitly:

> *Before the course, I thought learning about computer science was difficult and nothing I had done before, thought it was for people who had been programming since they where little, having it as a hobby. (Sofia)*

In the last statement, Sofia describes her perception that learning CS is for certain people. It seems as if she doesn't see herself as such a person. Frank expresses this even stronger:

> *Before the course, I thought learning computer science/IT would be boring, difficult and irrelevant. That it wouldn't fit me. (Frank)*

These statements point to "identification", which Ulriksen finds to be an important aspect to explain drop out [9].

Overall, emotions were very often reflected on. Furthermore, the students describe that they now understand how learning CS can be useful or relevant and what CS is all about. The descriptions of students' experiences are relatively short (up to about 100 words). They do not contain details on what exactly the students have done or seen, that made them feel the way they describe it. However, it is possible to categorize the students' descriptions of course experiences using content analysis. Through that, we can distinguish different foci of experiences. Four categories emerged, which can be summarized and further explained through students' statements, mostly from students that describe a positive attitude transformation.

Emotion: Experiences are described through emotions, such as CS being "fun", "challenging" etc., as it was also described by Simon et al. [23]. Examples are:

> *Before, I thought of computer science as very boring [...] But since I started this course, I think it's a lot of fun, though difficult. I think, it's a good feeling to be able to do a program. (Anna)*

> *First I thought, it would be boring, something that only a real geek could enjoy. But I think it's intriguing, it's like a challenge and I get honestly happy when the code is not red. So, I'm positively surprised. (Ulrika)*

Usefulness of learning about CS: Experiences of how learning has been useful are described. Such experiences are often pointed out to be important for females [13], [19]. However, in this data seven male students and only three females as well as four students that we don't have information on their gender, write about how they have experienced CS as useful. Examples are:

> *Even though it's hard and I sometimes feel like crying during the lessons when nothing works out, it's very necessary for my learning experience. (Anneli)*

> *It's still very difficult according to my opinion, but I could really be working with this in the future. I also believe that it can be useful when I'm starting to work to know a little about programming and computers. (Karl)*

> *Before the course, I didn't see courses in computer science as important as I see them now. It's really important to create good programs, that are easy to understand for others to make work easier for the masses. (Andreas)*

Understanding of the discipline: The students' descriptions focus on having gained an understanding of the discipline CS as a whole. The fact that we find this focus underpins the recommendation to convey a broad and meaningful image to recruit and retain students [1], [13], [14], [19]

> *Now, I think computer science is interesting because learning about it has made me understand what it is all about and I know the structure. (Rebecca)*

> *I have noticed that there is a whole world around computer science. Its much wider than I thought and its interesting to be a part of it. (Emil)*

Social aspects doing CS: The students focus on the social setting, in which activities in CS are carried out. Kalle is the only student that states this explicitly. However, according to his choice of checkboxes, he seemed to have had a positive attitude towards CS already before the course.

> *Before the course, I had the picture of computer science that it was a thing you did on your own, and not in groups. That it only was a non-social job. (Kalle)*

E. Summary and Key Aspects for Follow-Up Study

The results of this study are surprisingly positive. Almost half of the students seemed to have undergone a positive transformation of attitudes and no student seemed to have made "unfortunate learning experiences" (see section III-A). Through the different categories, we point out different foci in students' experiences. Overall, the course experiences seemed to have had a relatively strong and positive influence on students' attitudes towards CS. Furthermore, we got the

[1]The students' mother tongue is Swedish, but the students are usually relatively fluent in English.

[2]A few minor spelling corrections were made in the students' statements.

[3]All student names were changed and chosen in accordance to the respondents' gender. The same names were used for the same student, also for the second part of the study.

impression that the students infer from their specific course experiences, mainly in the area of programming, to more general perceptions of and attitudes towards CS as a whole. Noticeable are the statements in the category *understanding of the discipline*. Both students express that they now know "what CS is all about". Fortunately, their new image of CS seems to be attractive to them. However, the course is not designed to convey what CS is all about and could thus lead to inappropriate perceptions or attitudes. However, this could have been fostered by the question in the questionnaire, which asked for students' attitudes towards learning CS/IT.

Unfortunately, the descriptions of experiences were not very detailed (up to about 100 words). Hence, we used the second part of the study to aim for a better understanding of those experiences. Also, the students were not asked whether or not they plan to engage in CS in the future. However, this is an important information. Maybe these students do not plan to engage in CS in the future. One observation that supports the relevance of this question is that the students seldom relate their course experiences to their broader interests that they were asked to describe in the first part of the questionnaire.

IV. Part 2: Aiming for deeper insights

In view of the results of the first part of the study, a follow-up study was conducted to get a better understanding of the students' course experiences that led to a positive transformation of attitudes. This is interesting, because existing research mainly aims at understanding negative experiences, attitudes, or drop-out. Furthermore, we get the opportunity to explore how these students, that have had very positive learning experiences, reason about future engagement in CS.

A. Research questions

Based on the results of the first study, the aim stated above, and the overall goal of the study described in section I, we pose the following research questions:

RQ 2.1: What have the students experienced that has led to a change of perception: From learning CS is boring or uninteresting or irrelevant to learning CS is useful or interesting or relevant?

RQ 2.2 a: Do the students plan to engage in CS in the future, and during their study by choosing more CS courses?

RQ 2.2 b: How do the students reason about future engagement?

B. Data collection and analysis

The students' descriptions of experiences in the questionnaire brought up questions such as: How exactly is CS useful to the student? What exactly was interesting, fun etc. about it? Those questions can be best elaborated on in a dialogue with the student. Hence, we decided to use semi-structured interviews that allow follow-up questions [25]. Four lead-questions were prepared. We started the interview by asking the students to explain their experiences and attitudes prior to the course, referring to their choice of either option in the questionnaire, i.e. CS is rather boring vs. exciting or useful vs. irrelevant. Then, we asked the students to describe their course experiences that affected these prior attitudes (RQ 2.1). The second part of the interview dealt with future engagement (RQ 2.2 a, b): First, we asked the students for their career plans. From there, we moved on to the question whether or not the students are planning to take more IT courses and why.

The categories that were developed in the first part of the study were used to select five students, that described a positive transformation of attitude, but with different foci in their descriptions of experiences. The interviews were transcribed. Then, we did a thematic analysis to explore the research questions. In-depth analysis of the data, as well as further investigations are currently being worked on.

C. Results

First, experiences that led to a positive transformation of attitudes (RQ 2.1) are summarized. Then, reasoning about future engagement in CS will be reported (RQ 2.2 a, b).

Building up students' self-efficacy is one important aspect that was considered in the course design [10]. Indeed, in the interviews, the students often describe their attitudes before the course similar to Sofia:

> I thought, it was gonna be hard and I thought, I shouldn't be able to understand anything.

The feeling of being capable has strengthened positive emotions, e.g. programming is fun or challenging. Working in pairs that change every week, hence having a partner to find and discuss solutions with, was reported to be very supportive. Furthermore, reflections of last weeks' lab assignments in the lecture and the increasing difficulty of the lab assignments every week, "starting from zero", were reported to be helpful.

The experience to be able to create a program that others can use has also led to positive attitudes towards learning CS. Lina for instance states that she thought she would have to study a lot about the computer before being able to write a program, that she would study something that she is not able to use. She says:

> I've changed now. [...] we actually produced a couple of games, clocks and stuff.

Furthermore, Andreas describes that he has become aware that programming is a creative activity:

> First you have to think about how do I solve this problem, then you have to put input parameters, then you have to create the interface. I think that it's creative work actually – do something and get something real out of it. [...] You can see results that actually I have created and that works. I like that."

Providing opportunities for creativity was another aspect, that was explicitly considered in the course design [10].

A central and important experience that was reflected on by all interviewees in different ways is that problem solving is an important aspect in programming. Sofia, a student who had not "really anything to do with programming before" and who was thinking that programming is "kind of a nerd thing", reflects that she has learnt a new way of thinking. After having

made many mistakes by just typing code without planning in the first two labs, she realized:

> You had to work in another way, you had to sit down and talk to each other and you had to maybe write down on a paper before, like I wanna do, I have five steps that I have to do: I first have to make this matrix [...]

The importance to communicate was fostered by programming assignments in pairs and groups. Working out problem solutions on a piece of paper before typing was also an important experience for Anneli, a student with a prior attitude of CS being rather uninteresting and boring. Before the course she had the impression that "programming is something that you can only do if you are spending a lot of time in front of the computer". The importance of a systematical approach was emphasized by the teacher. According to Sofia, he said:

> Programming is not just about coding, it's about thinking how to structure the code before you write it on the computer and that's maybe 90% procent of the programming. That's one of maybe the greatest lesson I have learnt from this course.

Usefulness was elaborated on several times, both usefulness of learning CS and usefulness of CS in different contexts.

> In the beginning, I just thought we can learn code [...], but after being through the course [...] we actually learned how to create interfaces that people can use – you can feed in your numbers, then get answers.

Here, Andreas refers to programs that are used in research. Further applications mentioned were programs for a bank or ticket system in a bus. When reasoning about socially relevant applications of CS, the students often referred to the internet, which allows people to speak freely. However, only Sofia seems to be able to relate her course experiences to a broader, relevant meaning of CS: "All solutions in the future will have something to do with computers and connecting things". Sofia finds the fact that she can learn a special way of thinking to solve problems, such as structuring programs, appealing, and argues that all future computer systems will be constructed through such a process of problem solving.

Four of five students express doubts about engagement in the future (all except Sofia). Anneli relates to capabilities: "It's kind of hard for me, or I don't think, that I'm really good at it, yet". Lina, a student that has worked at a company before, has doubts about the people that she will work with in CS:

> I don't think that open mindedness and computer science go very much hand in hand.

To Lina, it seems as if computer scientists often accept only one solution and are sometimes very rude to each other.

Andreas and Kalle are relatively certain that they will not take more courses in CS. Andreas described that, before the course, he expected to just learn how to code. In the course, he experienced that he could learn "how to actually create stuff that others would use". However, he argues:

> I would pick energy because it's interesting and I see the relevance and I would pick the other [CS] mainly because I think it's fun.

How would he reason if he had experienced the relevance of CS for our society on the same level as he can think of the relevance of energy systems?

Kalle argues that he does not want a job where he "sits with a computer and programs". Asking what computer scientists do, he states:

> Solving problems all day long [laughs]. And [...] it's like - [...] if you are an engineer, you work with problem solving. When you are a programmer, I think, you work with problem solving but in, I don't know, like easier way. It's not that complex. You write this code and it's not like you have to think of eh I don't know society [laughs] and eh economy and eh things like that.

How would he reason, if he had experienced the complexity and potential of CS to address current societal problems? Furthermore, Kalle argues:

> Personally, I would like to learn more about it [CS]. Programming is fun, [...] but for the relevance of our course, the STS course, I don't see why we have to learn every little detail in programming. There are a lot of programmers out there. There are guys that are really good at programming so for me, for our course, I don't see the relevance of learning any more.

Kalle seems to understand CS as programming and doesn't see himself as a programmer. Hence, he does not see the relevance in taking more courses in CS. Sofia, the only student that is certain about taking further CS courses, who has experienced CS as meaningful to solve future societal problems, also takes a distant position to the "real guys". However, she is able to see herself working with CS in a certain way:

> Since computer science is the future, I want to work with it [...], maybe I don't wanna be like this hacker, coding, [...] but I wanna be maybe the person deciding what to code or making it work in society and if someone, maybe a computer student, is doing code, you have to figure out where to use it and how and that's what I wanna work with. Maybe be a consultant?

D. Summary and Conclusion

According to the interviewees, the experience of CS being a fun, social, creative activity, that they are capable of, through which problems are solved, turned out to be an important experience. This was supported through assignments to develop different programs, that were worked on in pairs, that changed every week, as well as group work during a project, and through emphasizing the importance of systematically approaching programming problems.

However, one critical aspect is a limited understanding of CS, reduced to programming. Other areas, such as networks and databases, as well as aspects of complexity and relevance of CS to solve societal problems have not been experienced in most cases. This however seems to be of importance for the interviewees. Accordingly, they argue that, since they do not want to become programmers, they do not need to learn more CS than the basics in programming that they learned in the course, and hence they will not take more courses in CS.

This points out the importance of two aspects in students' reasoning about engagement: identification and understanding of CS and its meaning. These aspects seem to relate and appear to be specific for this student group. However, these findings emerge from five interviews with students that belong all to the same study program and that have stated skepticism before

the course. Further research is needed, as existing research has not dealt with identification in relation to understanding of CS.

V. Conclusion and Future Work

The aim of this study was a better understanding of students' learning experiences that affect students' attitudes towards CS. Therefor, we investigated diverse students of a broad study program at the end of an introductory course in CS (CS1).

The study was carried out in two steps. Data, collected through a questionnaire, convey a favorable image: All students describe overall positive learning experiences. Almost half of the students state that they were skeptical before the course (CS being rather boring, irrelevant, or uninteresting) and point to experiences that supported them to revise their attitudes. Aiming for a better understanding of those experiences, the descriptions of experiences were categorized by the students' foci. This served as a basis to select five students with possibly different experiences for subsequent interviews. The interviews revealed a better understanding of course experiences, that have fostered positive transformations of students' attitudes, and critical aspects in students' reasoning about future engagement.

Two aspects appeared to be significant in these students' reasoning about future engagement: Students understanding of the discipline CS and its meaning and their ability to identify with engaging in the area of CS. Overall, we found a relatively narrow and meaningless understanding of CS being programming. Since the students do not see themselves as future programmers, learning more CS appears useless in many cases.

In conclusion, we believe that more research is needed on how students identify with CS and IT. The ability to relate to the discipline appears to be an important factor for student retention and continued engagement. In particular, we recommend investigation of what students believe a "real computer student" is. Research on these issues will help us to develop meaningful education in CS and IT, and enhance student engagement in these, and related, educational programs.

Acknowledgment

We would like to thank Anders Berglund, Anna Eckerdal and Michael Thuné for their inspiring contributions in various discussions throughout this study.

References

[1] ACM/IEEE-CS Joint Task Force, "Computer science curriculum 2008: An interim revision of CS 2001," ACM / IEEE CS, Tech. Rep., 2008.

[2] P. Henderson, "Computer science unplugged," *Journal of Computing Sciences in Colleges*, vol. 23, no. 3, pp. 168–168, 2008. [Online]. Available: http://dl.acm.org/citation.cfm?id=1295109.1295146

[3] D. Gibson and S. Grasso, "Online recruitment and engagement of students in game and simulation-based STEM learning," in *Proceedings of the 4th International Conference on Foundations of Digital Games*, ser. FDG '09. New York, NY, USA: ACM, 2009, pp. 285–290. [Online]. Available: http://doi.acm.org/10.1145/1536513.1536563

[4] I. Jormanainen and P. Korhonen, "Science festivals on computer science recruitment," in *Proceedings of the 10th Koli Calling International Conference on Computing Education Research*, ser. Koli Calling '10. New York, NY, USA: ACM, 2010, pp. 72–73. [Online]. Available: http://doi.acm.org/10.1145/1930464.1930476

[5] J. Bennedsen and M. E. Caspersen, "Failure rates in introductory programming," *SIGCSE Bull.*, vol. 39, no. 2, pp. 32–36, June 2007. [Online]. Available: http://doi.acm.org/10.1145/1272848.1272879

[6] M. Morgan, R. Flanagan, and T. Kellaghan, *A Study of Non-Completion in Undergraduate University Courses*. Dublin: Higher Education Authority, 2001.

[7] P. Kinnunen and L. Malmi, "Why students drop out CS1 course?" in *Proceedings of the 2006 international workshop on Computing education research - ICER '06*, ser. ICER '06, Canterbury, United Kingdom, 2006, pp. 97 – 108. [Online]. Available: http://dl.acm.org.ezproxy.its.uu.se/citation.cfm?id=1151588.1151604&coll=DL&dl=ACM&CFID=38828087&CFTOKEN=45405301

[8] M. Knobelsdorf, "Biographische Lern- und Bildungsprozesse im Handlungskontext der Computernutzung," Ph.D. dissertation, Freie Universität Berlin, 2011.

[9] L. Ulriksen, L. M. Madsen, and H. T. Holmegaard, "What do we know about explanations for drop out/opt out among young people from STM higher education programmes?" *Studies in Science Education*, vol. 46, no. 2, pp. 209–244, Sept. 2010. [Online]. Available: http://informalscience.org/research/show/5243

[10] A. N. Pears, "Enhancing student engagement in an introductory programming course," in *Frontiers in Education Conference (FIE)*. IEEE, 2010, pp. F1E–1–F1E–2.

[11] C. Schulte and J. Magenheim, "Novices' expectations and prior knowledge of software development." Seattle, Washington, USA: ACM Press, 2005, pp. 143–153. [Online]. Available: http://dl.acm.org/citation.cfm?id=1089800

[12] C. Schulte and M. Knobelsdorf, "Attitudes towards computer science-computing experiences as a starting point and barrier to computer science," in *Proceedings of the third international workshop on Computing education research - ICER '07*, Atlanta, Georgia, USA, 2007, p. 27. [Online]. Available: http://dl.acm.org/citation.cfm?id=1288585

[13] J. M. Cohoon and W. Aspray, Eds., *Women and Information Technology Research on Underrepresentation*. MIT Press, 2006.

[14] J. Margolis, R. Estrella, J. Goode, J. J. Holme, and K. Nao, *Stuck in the Shallow End; Education, Race and Computing*. MIT Press, 2008.

[15] S. E. Walden, D. A. Trytten, and C. E. Foor, "'I wish that i belonged more in this whole engineering group:' achieving individual diversity." *Journal of Engineering Education*, vol. 96, no. April, pp. 103–115, 2007.

[16] J. Teague, "Women in computing: what brings them to it, what keeps them in it?" *SIGCSE Bull.*, vol. 34, no. 2, pp. 147–158, June 2002. [Online]. Available: http://doi.acm.org/10.1145/543812.543849

[17] C. D. Martin, "Draw a computer scientist," in *Working group reports from ITiCSE on Innovation and technology in computer science education*, ser. ITiCSE-WGR '04. New York, NY, USA: ACM, 2004, pp. 11–12. [Online]. Available: http://doi.acm.org/10.1145/1044550.1041628

[18] P. Moorman and E. Johnson, "Still a stranger here: attitudes among secondary school students towards computer science," in *Proceedings of the 8th annual conference on Innovation and technology in computer science education*, ser. ITiCSE '03. New York, NY, USA: ACM, 2003, pp. 193–197. [Online]. Available: http://doi.acm.org/10.1145/961511.961564

[19] J. Goode, R. Estrella, and J. Margolis, "Lost in translation: Gender and high school computer science," in *Women and Information Technology Research on UnderRepresentation*. MIT Press, 2006, pp. 89–114.

[20] J. Lave and E. Wenger, *Situated learning : legitimate peripheral participation*. Cambridge [England]: Cambridge University Press, 1991.

[21] M. K. Smith, "communities of practice," http://www.infed.org/biblio/communities_of_practice.htm, 2003.

[22] H. T. Holmegaard and L. Ulriksen, "Why students choose (not) to study engineering," *Proc. of the Joint International IGIP-SEFI Annual Conference*, 2010.

[23] B. Simon, B. Hanks, R. McCauley, B. Morrison, L. Murphy, and C. Zander, "For me, programming is ..." ACM Press, 2009, pp. 105–116. [Online]. Available: http://dl.acm.org/citation.cfm?id=1584335

[24] P. Kinnunen and B. Simon, "CS majors' self-efficacy perceptions in CS1," in *Proceedings of the seventh international workshop on Computing education research*, ser. ICER '11. ACM Press, 2011, pp. 19–26. [Online]. Available: http://dl.acm.org.ezproxy.its.uu.se/citation.cfm?id=2016911.2016917&coll=DL&dl=ACM&CFID=50932975&CFTOKEN=26748377

[25] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*, 7th ed., 7, Ed. Routledge, 2011.

Paper II

Engagement in Computer Science and IT – What! A Matter of Identity?

Anne-Kathrin Peters, Arnold Pears
Department of Information Technology
Uppsala University
Box 325, 751 05 Uppsala, SWEDEN
Anne.Peters@it.uu.se, Arnold.Pears@it.uu.se

***Abstract*—In this paper, we develop and illustrate the use of a new theoretical framework to systematically investigate the development of student identity in Computer Science and IT. Identity has been identified as a critical issue in the endeavour to increase students' engagement in Computer Science and related areas. Findings from earlier studies indicate that students' doubts about future engagement are often due to an unfortunate perception of the discipline, that it lacks meaning, which leads to a tendency to dissociate themselves from IT and Computer Science as an area of further study. To understand different ways of experiencing engagement in the discipline as personally meaningful, we have integrated aspects of Lave and Wenger's social theory of learning, especially Wenger's notion of meaning, with a model developed by Entwistle that describes how conceptions of learning and knowledge expand and evolve in the context of the educational experience. We explore the use of this theoretical framework on reflections that we collected from all novice students of the Computer Science and IT engineering programme at Uppsala University, in which the students reflect on their choice of study program, goals, and expectations for education. The theoretical framework is furthermore discussed with respect to our broader research project to study students' identity development in Computer Science and IT as well as the role of education, how it supports or hinders students and how this can be used to inform educational development.**

***Index Terms*—engagement, identity, meaning and perception of the discipline, Computer Science, IT.**

I. Introduction

> "When you are a programmer, I think, you work with problem solving [...]. It's not that complex. You write this code and it's not like you have to think of [...] society and economy and things like that."

This statement was made by a student in the Sociotechnical Systems Engineering degree programme at the end of an introductory course in Computer Science (CS) [1], [2], explaining why he will probably not choose CS as an area for further study. Unfortunately the student's utterance paints a relatively narrow picture of what a computer scientist is, and, apparently, one that the student cannot identify with. This is one of many examples of student reasoning we have collected in our research on trajectories leading to future engagement in CS and IT.

Low engagement and high dropout rates in CS and IT degrees continue to cause concern in Western countries [3]. Two major advocates for engineering and computing, the Institute of Electrical and Electronic Engineers (IEEE) and the Association for Computing Machinery (ACM), continue to champion initiatives to enhance engagement among school and university students [3]. Recent research in science, technology, engineering and math (STEM) education suggests that students' ability to identify with their chosen area of study is a critical aspect affecting retention and recruitment [4], [5]. An aspect broached by these studies is that many novice students now seem to relate to STEM disciplines as being cross-disciplinary and innovative. This view is often not confirmed by early university experiences which leads to disillusionment and doubt. As a conclusion, research on how identity formation can be supported in university education is recommended. However, what should be the focus when investigating students' identity formation in CS-related areas?

Results of our pilot study [2] as well as of our preliminary data analysis of novice students' reflections indicate that students in different CS-related study programs reason, engage, and define themselves in relation to the knowledge content of the discipline. In the introductory example, the student is interested in complex problems, that relate to society. He can see engineers working on such problems, but not computer scientists, programmers, that in his understanding only do coding.

Based on these observations, we wish to describe and explore identity formation as students pursue their studies. In this paper, we suggest a theoretical framework to study identity formation in relation to students' conceptions of a discipline and its meaning. Furthermore, we explore how to utilise this framework in the context of empirical analysis of reflective texts, and interview data. Our aim is to develop and demonstrate the power of a system within which it is possible to qualitatively describe the evolution of conceptions of discipline and identity at the cohort and individual level.

We commence with the specification of our research aim and questions. The description of the theoretical framework follows. Subsequently, we describe our data collection and analysis methodology. Then, we describe the results of our data analysis with a focus on how the theoretical framework helps to reason about students' identity development. After that, we discuss the results of our analysis in relation to related results and to emerging research questions. A summary of the study outcomes and directions for future work is the focus of

978-0-7695-4960-6/13 $26.00 © 2013 IEEE
DOI 10.1109/LaTiCE.2013.42

the concluding section.

II. Research Framework and Questions

This paper presents a theoretical framework for our research project on students' identity formation in CS and IT. We will follow students from the beginning of their studies over a period of two to three years. Furthermore, we want to compare different ways of identifying with the discipline, by investigating students from three different study programs: Computer Science (CS), and two engineering programs, Information Technology (IT) and Sociotechnical Systems Engineering (STS).

Our objective is to inform educational development, e.g. curriculum design. This, in addition to investigating different student identities, necessitates an understanding of how education supports or hinders students in perceiving their education as relevant.

In this paper, we describe and discuss a first version of a theoretical framework specifically developed to study identity formation. We combine aspects of Lave and Wenger's social theory of learning as well as aspects of Wenger's theory of Community of Practice with a model on learner's development proposed by Entwistle. We explore its application based on reflections we collected of all novice students of the CS and IT engineering program. We aim to answer the following questions:

R1: What aspects of Lave and Wenger's theory appear to be relevant to understand students' identity formation in CS and IT?

R2: In what ways can Entwistle's theory complement the notion of identity we describe in R1?

R3: How do the answers of R1 and R2 inform our endeavour to understand students' identity formation and the effect of the university education experience?

Figure 1 gives an overview of the study design. We will study and compare identity development of students of three different study programs – CS, IT, and STS. We are interested in the students' ability to relate to the discipline, which is presented by the vertical axis. The graphs illustrate the development of identity, at this time generalized speculations. As research indicates that students in CS struggle to identify with the discipline due to educational experiences, we have illustrated this through a descending graph. For the STS students, we assume rather growth of their identity in CS and IT as the students have not chosen IT and CS in the beginning. The image in the circle illustrates the theoretical framework for the investigation of students' identity formation.

III. Theoretical Framework

Investigating development of identity is a complex undertaking. It has been pointed out as a critical aspect in recent research [2], [4], [5], but it has hardly been explored in higher education research so far [6], [7]. How should identity be understood so that research on identity development addresses problems such as low engagement in CS and IT? In his recent thesis on attrition and retention in physics, Johannsen argues

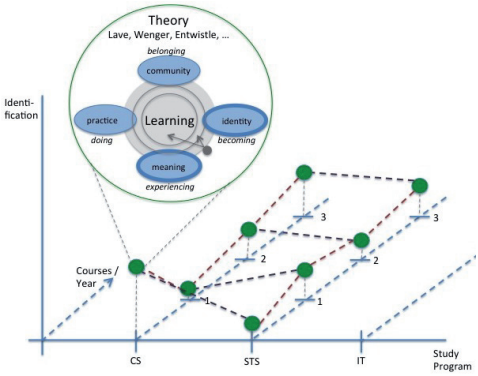

Fig. 1. Illustration of the Broader Research Framework

that it is necessary to "operationalize a socio-cultural and cultural-historical perspective on identity" [7, p. 24].

A socio-cultural perspective is also incorporated in theories of community of practice [8], [9]. Lave and Wenger develop a view of learning as being situated in a community of practice. The epistemology of the group, that is to say, their beliefs regarding knowledge and meaning are defined by and through the members of that community. Accordingly, the main purpose of learning is to work towards acceptance as a member of a community, as opposed to the traditional view of learning as being apprenticeship. Lave and Wenger then define identity as a long-term, living relationship between a person and his or her place and participation in a community of practice [8, p.53]. Consequently, identity formation can be understood as establishing such a relation and place in a community of practice, and thus is a major focus of learning activity.

Wenger's social theory of learning [9] gives concrete support for investigation of identity development. It integrates four components: Identity, Meaning, Practice, and Community [9, p. 5]. Wenger argues that identity is formed through the negotiation of meaning, through practice, in the context of a community. Hence, all of the four components can be seen as linked through meaning. Meaning is central to Wenger's theory as he stresses that "human engagement in the world is first and foremost a process of negotiation of meaning" (p. 53). Wenger describes meaning as the interaction of two constituent processes, which he calls "reification" and "participation" [9, p. 55-62].

The term participation refers to two aspects, to taking part in something, and to the reflection this arouses from interaction with others. Hence, participation and the meaning thereby construed, always have a social character. Even if the activity is carried out in isolation, it is given meaning through social participation. As an implication, Wenger argues, participation cannot be turned on and off erratically. Furthermore, partici-

pation involves the whole person – body, mind, emotions, and social relations as well as doing, talking, thinking, feeling and belonging.

Reification refers to both, the process and the product "of giving form to our experiences by producing objects that coalesce experience into thingness" [9, p. 58]. It attributes substance to abstractions, such as "justice" or "economy". Through reification, we "project construed meaning into the world". Reification is central to every practice, and expresses itself through tools, symbols, formulas, stories, terms, and concepts. As much as we produce reification based on our experiences, reification also influences our experience of the world as well as our ability to act, and our identity.

In addition to Wenger's components of meaning, Wenger reasons that patterns of engagement are also a means to understand negotiation of meaning and thus formation of identity. Patterns are activities that we engage in more or less regularly, e.g. a conversation during lunch with our colleagues. Producing these patterns anew gives rise to meaning since we "extend, redirect, dismiss, reinterpret, modify or confirm - negotiate anew - histories of meanings" [9, p. 52-53]. This history of meanings mirrors a learning trajectory, and is another aspect of identity formation.

The aspects of Lave and Wenger's theories presented here provide a structure to reason about students' identity formation and how they experience engagement as meaningful. However, the application of Lave and Wenger's ideas and concepts to our problem is not straightforward for several reasons. Wenger illustrates his theory with examples of an ethnographic study in a medical claims processing center operated by an insurance company in the US, which is a very different context to that of an academic learning environment in CS and IT. Furthermore, he uses the theory foremost to describe the characteristics of a community of claim processors.

Lave and Wenger's theories provide a context with which to describe becoming a member of a community in a way that appears meaningful, and developing a relation to the knowledge content of the discipline. This is complemented by Entwistle's theory of learner development [10] as it describes students' development of conceptions of knowledge and learning (see Figure 2). In both dimensions, development leads to "changing as a person", and developing a "sense of identity".

Development proceeds as the learner recognizes different forms of knowledge and learning processes. Entwistle draws on work of Perry [11] to describe the development of conceptions of knowledge, i.e. students' epistemological development, until they reach the ways of thinking characteristic for academic discourse. The main threshold that has to be overcome is the change from "Dualism" to "Relativism". Thereby, the students refrain from thinking in terms of knowledge as right or wrong but instead accept uncertainty in knowledge and values and reason based on evidence and testing alternative explanations. This opens up the subject in new ways, but also the learning.

To describe the development of conceptions of learning, Entwistle integrates results from research by Säljö [12]. There, a threshold is described between the conceptions of learning as "Reproducing knowledge" and "Seeking meaning", which entails monitoring the learning progress towards an own understanding, in which knowledge takes on personal meaning. Hence, the learner in these mature stages tries to understand the meaning of what he is learning, thereby relating to what he has learnt so far, and sees things in different ways as he is learning.

As the two dimensions of conceptions of knowledge and learning are seen in parallel, the potential of Entwistle's theory is to help to develop an understanding of how students come to perceive and construct knowledge in a way that is personally meaningful to them and how they choose to go about learning. This adds another perspective to the notion of meaning as described by Wenger. Concluding, we argue that Lave and Wenger's theory together with Entwistle's theory provide an interesting initial theoretical framework with which to explore students' identity formation and their conception of the discipline and its meaning.

IV. Data Collection

In order to explore ways to apply the theoretical framework, we collected empirical data.

A. Instrument

To answer the research questions stated in section II, we developed three open questions for a reflection. All of the questions had sub questions that were meant to inspire the students in their reflections, not to be answered one by one.

In the first question, we asked the students to reflect on their choice of study program: How have their experiences, their interests, and what they think is exciting and challenging influenced their choice. Have others, like friends, family or school, influenced them? In the second part, we asked the students to reflect on their prospects of their future work. In which situation or context can they see themselves? What do they want to work on, and with whom? What do they want their work to result in? In the third part, we asked the students for their expectations on their education. What do they expect to learn? What is needed to reach their goals described in the second part? How can the university support them in that?

B. Collection Procedure

For this explorative application of the framework, we focused on the novice CS and IT students, that entered their study program at the start of the Autumn term of 2012. The questions for reflection were given to the students in the beginning of an introductory course, which introduces the students to different aspects of the discipline and studying. The students received the assignment to do the reflection in the second week of the course and semester.

V. Data Analysis

In the following section, we aim to describe how the theoretical framework (section III) helps to understand different ways of identifying with the discipline, in particular how engagement in CS and IT is perceived as meaningful.

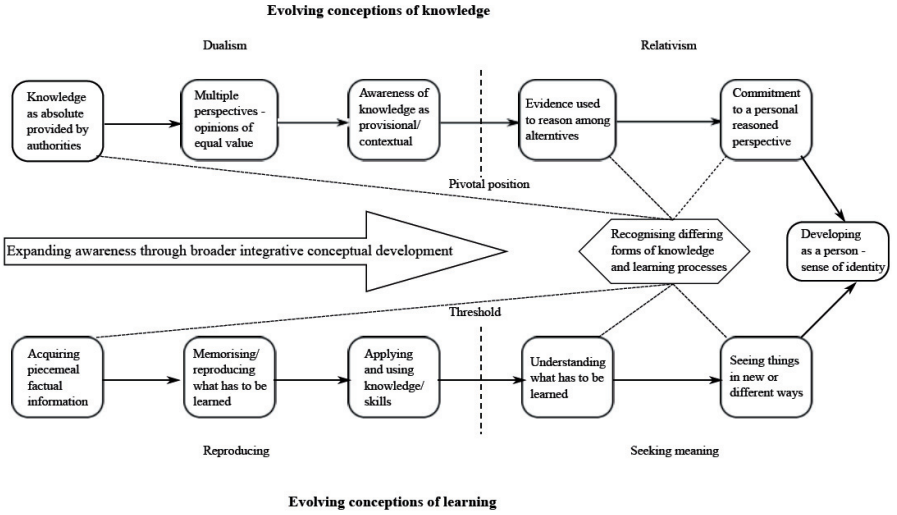

Fig. 2. Slightly Adapted Version of Entwistle's Theory of Learner's Development [10]

A. Methods

We collected 123 reflections in Swedish from 149 registered students in the study programs IT and CS. The lengths of the reflections vary a lot, between a couple of paragraphs to two pages. The average number of words per reflection (that might contain the questions also) is 380 words. To get an overview of the data, we did a thematic analysis [13] of 30 randomly chosen reflections (25 male, 5 female). From that, we developed ideas on how to use Lave and Wenger's theory to understand students' relation to the discipline, i.e. as described in section III, how they perceive their engagement as meaningful, how they identify with it. We developed tentative categories that relate to Wengers' four components of learning, identity, meaning, practice, community, and coded the chosen reflections, using these tentative categories and subcategories, that we identified while we were doing the coding. This coding was done in several iterations. Furthermore, we did an explorative deductive analysis [14] based on the conceptions that Entwistle describes in his model of learner development (section III, Figure 2).

As we are aiming at testing and discussing the use of this framework rather than making claims about students' identity formation, the analysis has been explorative, preliminary. However, further more rigid analysis of this data will be worked on after the framework and its actualization has been discussed.

B. Results

The results of our explorative data analysis are presented in three parts: first, in respect to Wenger's theory of Communities of Practice, then based on Entwistle's model of learners' development. In the third part, we integrate the results. The quotes given are translated from Swedish to English, as much as possible preserving the students' connotation.

1) Using Wenger to Explore Student Identity: Aspects of identity are common in students' reflections on their engagement in CS and IT.

> "Computer Science is that which lies closest to me." (student in CS, male)

Identity, according to Wenger, develops through (re)negotiation of meaning during a trajectory of learning. Further, meaning can be studied through its two constituent processes reification and participation. In the following, we explore ways to concretize this theory with empirical data.

> "My computer interest was the reason for my choice of study program. Everything began with my father who works as a consultant [...] and thus has a 'computer oriented' work. Like for many other young people, my father was the first ideal to strive for, he was my hero. One day, he took with him, an installationdisk for a programming language and asked if I was interested. The answer was of course yes. Ever since then, my computer interest has escalated." (student in IT, male)

Many reflections invoke "interest in the computer" as a reason for the choice of study program. In fact, as it is the case here, many reflections begin with a statement of that nature. We find many stories, such as the one above, that describe computer-related activities with friends and family, such as playing games, maintaining the computer, or programming. In these stories, the computer seems to be *the* object that the students base their stories on. Hence, we suggest that the

computer can be seen as an object of reification.

Meaning in connection to the computer is construed in different ways:

> "The choice was quite obvious- I like to work in a computer environment, where I feel home." (student in CS, male)

Feeling home in a computer environment hints to everyday activities with computers. Indeed, later on in the students' reflection, the student writes that "of course", a dream is to work in the computer game industry, which indicates that this student enjoys playing games which has led to the feeling of home when dealing with computers. In fact, many students that write that they like to play games write that they are interested in game development.

Furthermore, we find statements that express fascination over what computers can "do":

> "It has always puzzled me how things, such as computers, can 'think' when you can not see anything special with the naked eye." (student in IT, male)

Similarly, we find other students that express fascination over what one can create with code, e.g. in relation to computer games. This hints to computer programs and programming.

> "I chose IT because I have always been interested in computer, have sat much in front of the computer, and have done things like programming." (student in IT, male)

This student talks about how he has later chosen the "technical line" (program) at high school that has reinforced his orientation towards IT. In fact, when students write about their interest in computer, we often find stories about programming, in many cases in relation to programming websites, which is for example done with PHP.

> "I began early with PHP and am quite good at it now but I don't do any larger things with it for the moment. The reason for why I want to become better at programming is that I have two friends through the internet that are working on a very big project, and to fully understand how the project works would be a big challenge. The fun of programming is when you get it to work, according to me." (student in CS, male)

In this case, early experiences in programming have let to a kind of participation in what the student perceives as a big project. As the student mainly reflects on programming and why it is fun, it is presumably the aspect of the project that he has in mind, that he thinks is a challenge to fully understand, and that he wants to become better in. As emotions, mutual recognition, social interaction and reflection are involved, we can interpret this as participation in Wenger's sense, more specifically "partial participation", and envisioned "full participation". The student writes that he wants his future work to be challenging, and that he wants to learn programming. Hence, previous experiences and ideas for future work as well as education appear well aligned.

We also find rather hardware-related experiences:

> "Since I was small, I have always been very technological, I have always loved to fiddle with electronic and learnt how they function. I have also used at least a pair of headsets per year, but when they are broken, I want to take them apart, only to see what they look like inside. I have always been a 'gadget geek' who wants to read about new things, at the same time as I have had friends who were interested and could do more than me, so it was just to ask them." (student in CS, female)

The computer is of special interest, fascination for this student as she starts the section on what she is interested to learn with:

> "One of my goals in live is to build a whole computer on my own." (student in CS, female)

Consistently, she says that she can imagine to work within the field of computer architecture in the future. She chose CS instead of IT because:

> "CS is more hardware and in depth of a Computer." (student in CS, female)

In summary, this student also negotiates meaning in relation to computer. Her story of earlier engagement indicates experiences of participation, as emotions and mutual recognition are included. Her experiences in taking apart devices thereby relates to her goal to build a computer (put together parts to a whole).

We have argued that one example of reification is the computer. In relation to that, we find experiences that can be interpreted as participation as they involve activities, feelings and emotions, as they are carried out in a social group, with friends and family in mutual recognition, and as meaning is construed through these experiences. These experiences of participation have been meaningful to these students, as they are described to explain engagement in CS and IT and as they determine future trajectories of engagement.

Another way meaning is construed is with a broader focus on technology, often in relation to society:

> "I chose Computer Science because my whole life, I have been interested in IT and ways computer have been integrated in our society." (student in CS, male)

This student also uses the term computer, but in a broader social context. In the rest of his reflection, he does not write "computer" or any other computer-related term, such as "programming", "application" etc.. Instead, he writes about "IT-solutions" and "technological development". He states that he wants to work as a consultant. He does not write about any previous experiences or activities that relate to that.

Another quote that relates to this way of meaning making:

> "I hope and believe that my work will lead to a better world where technology and society interact in a more effective and gentle way." (student in IT, male)

This student sees technology embedded in society and wants to contribute to improving this interplay. How does this goal relate to earlier experiences, possibly participation in a social environment? The student begins his reflection by stating that he has been interested in technology, everything in his environment from a TV to a microwave, and in how these things work. He states that he has friends that are similarly technology interested and that are like him well-informed about technological development.

> "And that has shown me that the world of technology is fantastic and not driven of limits, but free for speculation and imagination." (student in IT, male)

Reading and talking about technology with friends could be seen as a kind of participation, as it includes emotions, mutual recognition and as it has had an influence on the students' engagement. In his future job, the student hopes to be creative, to solve problems, or to develop new technology that does not yet exist, together with innovative people with similar interests. In line with this, he wishes to learn how things work and how to solve problems with "IT-structures". In regard to development of IT-systems, he does not state experiences. He seems to have a relation to programming though:

> "Maybe I do not want to program things for the rest of my life, because that seems to be quite boring." (student in IT, male)

It is unclear how this view relates to earlier experiences.

The following quote is taken from the reflection on the choice of study program:

> "The biggest obstacle to continue is that I do not like to program, but I still want to have a deeper understanding of our technology in society." (student in IT, male)

Unfortunately, the student does not write about why he does not like programming and where he got his experiences from. In his reflection, he does not write about other earlier CS and IT related experiences but that he dropped out of the engineering physics program. He writes that he has done a lot of thinking before he chose IT, he sat down with the catalogue of study programs and crossed out everything he wasn't interested in – IT and Multi Media remained. He envisions his future engagement in the following:

> "My dream is to lead an own company that works on some kind of IT solution. If I may dream freely, I would like to become an inventor, I want to develop a product from the beginning to the end. [...] If I choose a role model, then it would be Steve Jobs and his development of Apple." (student in IT, male)

This student writes about who he wants to become. As he uses "dream" and "dream freely", this appears to be quite detached from experiences he has had so far. Indeed, he does not state any earlier experiences. His expectations for education relate to his future ideas:

> "From my studies, I want to carry with me knowledge that I can compete with on an international level, and that lies on the edge of what technology has to offer." (student in IT, male)

The previous quotes illustrate negotiation of meaning with a broader focus on technology, often in relation to society and innovation. This can be seen as another object of reification. It has become visible in the students' stories and it appears to be a projection of construed meaning, as it is used to explain engagement in CS and IT.

Wenger states that reification refers to giving form to our experiences. The students' experiences related to the two objects of reification, "computer" and "technology in society", appear to be very different. The students with a focus on computer have often experienced a kind of participation as the computer is relatively accessible. Further, they have often experienced development, e.g. computer programming. The students that focus on technology in society have less likely had hands-on experiences. Hence, their envisioned future participation (e.g. consulting, development) and their expectations for their education do less likely relate to previous experiences of participation and concrete activities. As meaning, according to Wenger, is the interaction of reification and participation, this observed difference between the two different ways of negotiating meaning is remarkable.

Also, we find students with a broader focus on technology that have a "striking" relation to programming. Maybe they have experienced programming in a way that does not relate to what they perceive is meaningful? This could be the case as early programming probably relates to programming applications for computers.

2) Conceptions of Knowledge and Learning Based on Entwistle: Analyzing student discourses using an adapted version of Entwistle's model of learner development allows us to gain insight into students conceptual maturity as they negotiate their professional identity in a broader social framework. Overall, we find expressions that indicate lower conceptions. The following quote is an example for knowledge being dualistic:

> "First of all, I hope to learn to program correctly." (student in CS, female)

This statement indicates a dualistic conception as the student assumes that there is a right way to program and that she will be told what that is, which is directly related to knowledge as provided by authorities. Further evidence of this conception can be found in statements such as:

> "I believe, that the university will teach me what is required for a career as a programmer, computer scientist. [...] First and foremost to program, both programming language and how to organize a project with programming, including how a computer works." (student in CS, male)

> "I hope to be able to learn everything that is needed to be active in the labor market. To reach that, I will finish all my courses." (student in IT, male)

We surmise that students with this type of conception also fall, presumably, into the lowest conception of learning "acquiring factual information".

The higher conceptions of Entwistle are not so easy to identify at this stage, as the students are mostly not so experienced. Quite some students appreciate the developing character of the discipline: faster technology, new programming languages etc.. This suggests a conception of the discipline as being provisional. Furthermore, we find very few statements that indicate a conception of learning as seeking meaning, e.g. by one student that hopes to learn how programming languages are built up to be able to learn new programming languages.

3) Integration of the Results: So far, we have explored the use of Wenger's theory to better understand how students experience their engagement in CS and IT as meaningful. We gave two examples of reification and in relation to that interpreted students' experiences, in some cases in terms of participation. In our analysis based on Entwistle, we found overall lower conceptions of learning, especially the expectation to "be provided" from the university with what is needed

for the career. Based on these results, we can give a possible explanation of the following quote:

> "In the first week, it suddenly struck me: Computer Science is perhaps not what I expected and if I did right or wrong when I chose the program. [...] During the weekend, I just sat and read deeper about CS, what it actually is and what future it has."(student in CS, female)

The student might have been confronted with CS and IT in a way that does not match what she perceives is meaningful. This leads to strong doubts about her choice of study program as she expects to learn what she will need and use after her studies. Furthermore, her meaning making may be relatively weak, as she does not have earlier experiences of participation.

Previous examples of students with broader interests in "technology in society" indicate problems in relating programming to students' negotiation of meaning. We found one example of a student, male, enrolled in the CS study program, that seems to be more successful in that: After the student had thought about studying medicine, microbiology and politics, he finally decided that:

> "Computer Science is that which lies closest to me. I have always been interested in technology, even if I have not always understood how it worked. [...] Looking into the future, I know, that our world needs more computer scientists and developers." (student in CS, male)

This indicates a rather broad perspective in his negotiation of meaning. He does also state an interest in computer, "especially in gaming". Furthermore, he says:

> "I have always been interested and fascinated over what one can create with code." (student in CS, male)

Through his friends, that have studied the same study program at the same university, he knows about the versatility of different jobs for computer scientists, which leads to a positive view of the future:

> "A future, that can involve another great interest I have, namely in an international perspective and in security. Therefor I hope to work in security related programming. That which I also hope for is an international work, that I will be involved in a project [...] that leads to global development." (student in CS, male)

The student relates programming to global development, which the other students with a broader reification don't do. This however is not based on the students' own experiences, but maybe partly on his friends' stories of participation. Furthermore, the student has a high conception of learning, that has presumably supported him also:

> "I know that the education will be useful. Maybe not that I will learn exactly what my dream job comprises, but what I will learn is a way of working and thinking that will be useful to me." (student in CS, male)

Although the student states that he knows this from his friends that are already working in the field, we can assume that he himself has such a view and does not expect to be provided with exactly what is needed for him. One argument that supports this assumption is that he is able to link programming to his broader interests.

Concluding, the two examples above summarize how the theoretical framework presented in this paper could help to better understand students' negotiation of meaning in CS and IT. The examples above furthermore show how the components of the framework add on to each other, i.e. Lave and Wenger's theory of social learning, especially Wenger's concepts "reification" and "participation" to study meaning, and Entwistle's model of learner's development.

C. Discussion and Questions for Future Research

Our results are related to Schulte and Knobelsdorf's research on novice students' attitudes towards CS [15], [16]. According to them, trajectories of experiences that lead to engagement in CS often begin with usage of computer. Furthermore, they describe an important shift from usage to creation and development (programming) that leads to future engagement in CS. They collected data through "computer biographies", in which they explicitly asked the students to reflect on their experiences related to the computer. As computers are so prevalent nowadays, Schulte and Knobelsdorf assume that those have the biggest affect on students' attitudes towards CS. Our work suggests that students also construct meaning with a broader perspective on technology in society and innovation.

Ulriksen et. al. [4], [5] investigated drop out in STEM. They find that students that are interested in innovation and interdisciplinary work are often confronted with a different image in their education. This throws light on the student group in CS and IT that negotiates meaning with a broader perspective on technology. We have found possible problems as some of the students express a conspicuous relationship to programming. The way the students learn programming in the beginning of their education presumably addresses a rather narrow perspective on computer (applications).

Concluding, it is important to understand students' negotian of meaning and its development during education. Are there other focuses in student's negotiation of meaning? How do students' negotiation of meaning relate to earlier experiences? How do participation and reification develop during their studies? Are students' conceptions of learning and knowledge developing and how does that influence students' negotiation of meaning? What is the role of education in all these aspects?

VI. Summary, Conclusion, and Future Work

In this paper, we described and explored the application of a framework that provides a theoretical basis with which to study students' identity formation in order to understand how student perceive learning CS and IT as meaningful, and how they are supported or hindered by their education. In order to study personal development, we combine Lave and Wenger's theory, which provides a way to understand becoming a member of a community and negotiation of meaning, with Entwistle's theory of learners' development that describes growing conceptions of knowledge and learning. Based on data gathered from novice students, we tested the use of this theoretical framework to illustrate how students' reflective utterances can be used to chart identity formation in CS and IT.

We find Lave and Wenger's concept of meaning useful when trying to understand students' relationship to the discipline, and how they envision their future participation and learning. The concepts reification and participation have been particularly useful in helping to reach an understanding of students' trajectories in this respect. Analyzing the data based on an adaptation of the developmental model proposed by Entwistle, we find (not unexpectedly) that students in our study express collectively conceptions of knowledge, as being absolute and provided by the university, which implies a less sophisticated conception of learning, i.e. reproducing of facts.

There appear to be two student groups with different negotiation of meaning that could be valuable to follow. One group of students makes meaning with a focuses on computer and applications. Such students often have participated in programming and envision their future participation in alignment with their earlier experiences of participation. They expect to learn more in this respect. The second student group focuses on bigger systems and technology in society. These students have often not participated in development and envision their future participation differently from the first student group, and it appears unlikely that their stance is based on previous experiences of participation.

As the students now have overall low conceptions of learning and knowledge, they often expect to be equipped with what they need for their career. The role of higher education and curriculum is clearly significant for the second group. Most engineering and computer science degree programmes introduce programming subjects early, and focus on programming skills in the early parts of the curriculum. This addresses the computer perspective more than the systems perspective. Consequently, our theoretical framework will be helpful to study how students re-negotiate meaning, thereby improve our understanding of their evolving conceptions of knowledge and learning.

References

[1] A. N. Pears, "Enhancing student engagement in an introductory programming course," in *Frontiers in Education Conference (FIE)*. IEEE, 2010, pp. F1E–1–F1E–2.

[2] A.-K. Peters and A. Pears, "Students' experiences and attitudes towards learning computer science," *Frontiers in Education Conference (FIE)*, 2012.

[3] ACM/IEEE-CS Joint Task Force, "Computer Science Curriculum 2008: An Interim Revision of CS 2001," ACM / IEEE CS, Tech. Rep., 2008.

[4] L. Ulriksen, L. Madsen, L. Moller, and H. T. Holmegaard, "What do we know about explanations for drop out/opt out among young people from STM higher education programmes?" *Studies in Science Education*, vol. 46, no. 2, pp. 209–244, Sep. 2010. [Online]. Available: http://informalscience.org/research/show/5243

[5] H. T. Holmegaard and L. Ulriksen, "Why students choose (not) to study engineering," *Proc. of the Joint International IGIP-SEFI Annual Conference*, 2010.

[6] W.-M. Roth, "Emotion at work: A contribution to third-generation cultural-historical activity theory," *Mind, Culture, and Activity*, vol. 14, no. 1-2, pp. 40–63, April 2007.

[7] B. F. Johannsen, "Attrition and Retention in University Physics. A longitudinal qualitative study of the interaction between first year students and the study of physics," Ph.D. dissertation, University of Copenhagen, 2012.

[8] J. Lave and E. Wenger, *Situated learning : legitimate peripheral participation*. Cambridge [England]: Cambridge University Press, 1991.

[9] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press, 1999.

[10] N. Entwistle, "Conceptions of Learning and the Experience of Understanding: Thresholds, Contextual Influences, and Knowledge Objects," in *Re-framing the conceptual change approach in learning and instruction*, S. Vosniadou, A. Baltas, and X. Vamvakoussi, Eds. Amsterdam, The Netherlands: Elsevier, 2007, ch. 11.

[11] W. G. Perry, "Different worlds in the same classroom," *Improving Learning: New Perspectives*, pp. 145–161, 1988.

[12] R. Säljö, "Learning in the learner's perspective," *Some Common-Sense conceptions.*, 1979.

[13] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2008.

[14] K. Sanders, J. Boustedt, A. Eckerdal, R. McCartney, L. Thomas, J. E. Moström, and C. Zander, "Threshold concepts and threshold skills in computing," *ICER*, 2012.

[15] C. Schulte and M. Knobelsdorf, "Attitudes towards computer science-computing experiences as a starting point and barrier to computer science," in *Proceedings of the third international workshop on Computing education research - ICER '07*, Atlanta, Georgia, USA, 2007, p. 27. [Online]. Available: http://dl.acm.org/citation.cfm?id=1288585

[16] M. Knobelsdorf, "Biographische Lern- und Bildungsprozesse im Handlungskontext der Computernutzung," Ph.D. dissertation, Freie Universität Berlin, 2011.

Acknowledgment

We would like to thank Michael Thuné, Anna Eckerdal, and Anders Berglund from our research group for many inspiring discussions, comments, and feedback since the beginning of this research project in August 2011.

Paper III

First Year Computer Science and IT Students' Experience of Participation in the Discipline

Anne-Kathrin Peters, Anders Berglund, Anna Eckerdal, Arnold Pears
Uppsala Computing Education Research Group
Department of IT, Uppsala University
Uppsala, SWEDEN
firstname.lastname@it.uu.se

***Abstract*—Previous research in STEM education demonstrates that students are engaged in a continuous process of identity development, trying to integrate their educational experiences with their perception of who they are, and who they wish to become. It appears increasingly apparent from this body of research that students are not well supported in this process by the education they currently receive.**

The goal of this paper is to analyse a specific aspect of the student experience, participation, in order to gain a better understanding of how computer science (CS) and information technology (IT) students engage with CS prior to and during their studies.

Drawing on student interview data we describe and discuss students' qualitatively different ways of experiencing *participation* in CS and IT. The notion of participation applied here is inspired by Wenger's notion of participation in his social theory of learning. A phenomenographic analysis identifies a spectrum of qualitatively distinct ways in which the students experience participation in CS and IT, ranging from "using", to participation as "continuous development", and "creating new knowledge".

***Index Terms*—engagement, identity, meaning, participation, perception of the discipline, Computer Science, IT.**

I. Introduction

Personal and professional development can be seen as major goals of higher education [1]. Studies in science, technology, and math (STM) education indicate that development of identity can be problematic for many students, and that they struggle to integrate their study experiences with their perception of who they are and want to become [2]. Identity has also been found critical for retention, and is an important underexplored research area [3], [4].

This study contributes to research on identity by exploring students' experiences of participation, by which we mean experiences that involved the student as a whole, their doing, feelings, thoughts, and social relationships. This notion of participation is inspired by the work of Wenger, his social theory of learning [5].

We use interview data in which the students reflect on their choice of study program, their future career, and their study experiences after their first study year. This data was collected as part of a broader research project that aims to understand computer science (CS) and information technology (IT) students' identity development [6].

We used phenomenography [7] as a research approach to analyse and describe qualitative differences in the students' experiences of participation. The outcome space reveals a spectrum of ways in which the students experience participation, ranging from participation in CS/IT as *using something* to participation in CS/IT as *creating new disciplinary knowledge*. This outcome space contributes to a better understanding of students' engagement and negotiation of meaning. We argue that it is important that education facilitates experiences of participation in a way that it relates to the students' previous experiences and in a way that it supports more advanced experiences of participation, thus richer ways of negotiating meaning. The results of this study provide important insights into how participation can be considered in educational development and further research.

The remainder of the paper is structured as follows. In the next section, we describe our theoretical underpinnings, in particular the notion of participation used in our study. We then summarise relevant related work and situate this study in relation to the broader research project. We proceed to briefly describe the research approach phenomenography, data collection, analysis, and the results. The paper concludes with a discussion of the implications of the results.

II. Theoretical Underpinnings

This study focuses on getting a better understanding of how students experience *participation* in CS and IT. The notion of participation is central to social theories of learning, for example Wenger's theory of "Communities of Practice". Wenger writes [5, p. 55-56]

> *Participation* refers to a process of *taking part* and also to the *relations with others* that reflect this process. It suggests both action and connection. [...] 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.

The social component is an important aspect of participation. Even if something is done in isolation, it gains meaning through the presence, reaction or feedback of others.

Wenger argues that participation provides opportunities for mutual recognition, which supports identity development [5,

p. 56]. Participants shape each other's experience of meaning [5, p. 56]. Negotiation of meaning, in Wenger's theory, is the major source for identity development. Participation is one of two major complex processes through which meaning is construed, reification is the other process. [5]

Different theoretical perspectives exist for research on identity, e.g. social constructionism [8], symbolic interactionism [9], or narrative psychology [10]. Work on Communities of Practice belongs to a broader research area, social theories of learning [5], [11]. Its use and applicability to study identity development in higher education has been discussed and criticised [12], [13]. What seems to be agreed upon is that meaning and identity is actively constructed, in interaction with others and the learning environment.

III. Related Work

Ulriksen, Holmegaard et al. follow students with an interest in science, technology, and math (STM) from their last year of High School to university over a period of three years. Using a narrative approach, they conclude that the choice of study program can and should be seen as a continuous process. All of their informants experience a gap between expectations and educational experiences. They develop negotiation strategies to bridge the gap and construct a coherent sense of identity. As this is currently not well supported in education, the students rely on their social environment. [2], [10], [14]

Schulte and Knobelsdorf [15], [16] have studied students' prior experiences and resulting attitudes and expectations, by analysing novice students' computer usage biographies. They find that CS affiliated students often make a transition from users to designers. As designers, they often have positive attitudes towards learning to program. Schulte and Knobelsdorf focus on experiences with the computer, prior to university. Peters and Pears find that students' interests in CS/IT can be broader, about innovation and technology development for society [6]. This conforms with Ulriksen et al.'s findings in their study of STM affiliated students' perceptions and interests [14].

Yasuhara has studied pre-major undergraduates' expectations, taking into account gender issues. Based on their findings on pre-major interests and perceptions of CS, they deploy and evaluate an educational intervention. [17]

The endeavour to understand students' perceptions and support students to develop an "appropriate" perception of or a relation to CS/IT, raises questions about the scope of CS/IT. Björkman and Tedre discuss the meaning of CS/IT and find it controversial [18], [19]. This may constitute a difficulty, both for students trying to make sense of CS/IT and for educators who try to support different students in this process.

In summary, some research exists on entry-level students' perceptions of and experiences in CS. Some interventions have been conducted aiming to convey a broad image to students. However, as previous research shows, identity development needs to be supported continuously. A better understanding of students' experiences and reasoning beyond the first year is vital to support the students in that process.

IV. Study and Research Context

We give an overview of the study in relation to the research project and information about the two study programs.

A. Study and Research Project Overview

The goals of the broader research project are: (1) Investigation of the role of identity for learning CS/IT (2) description of CS/IT students' identity and negotiation of meaning as well as students' development in this respect (3) development of a research framework, (4) description, how education supports or hinders identity development and implications for CS/IT education and research.

In this broader research project, we are engaged in a longitudinal study, following students from two degree programs at Uppsala University, Computer Science and IT Engineering. The students commenced their studies in 2012.

In the study presented here, we analyse interviews that the first author collected at the end of the students' first study year. The informants for the interviews and longitudinal study were selected based on an assignment to all students at the beginning of their studies. The students were asked to reflect on their choice of study program, their envisioned work life, and their expectations for education. From 123 reflections, we chose informants with different prior experiences (such as job and/or study experiences) and with different focuses, e.g. on computer, system, hardware, software, etc.. All of the six female students that handed in the reflection assignment were invited, of which five agreed to participate. Interviews with 13 CS students and 10 engineering IT students were conducted and available for this study.

The research questions for this study are:
R1: What are qualitatively different ways of experiencing participation in Computer Science and IT?
R2: How do the result of R1 contribute to our broader research aims?

B. Computer Science and IT Engineering Study Program at Uppsala University

The IT engineering program is one of the engineering programs at Uppsala University that leads to a Master degree after five years. The Computer Science program is categorised as a natural sciences program, a three years Bachelor's degree program.

With minor variations the IT and CS programmes share a common curriculum for the first year of studies. An introductory course introduces the area and its constituent parts, providing an overview of areas such as software design and implementation, hardware, operating systems and compilation. This is followed by courses in introductory programming and mathematics. The final block in the first year deals with digital electronics and low level programming. More information can be found on the IT department's website [1].

[1] http://www.it.uu.se/edu

V. Phenomenography

Phenomenography is a qualitative research approach that aims at eliciting and describing "the totality of ways in which people experience" a certain phenomenon and present these experiences "in terms of distinctly different categories that capture the essence of the variation" from the participants' perspective [7, p. 121–122]. The different experiences or understandings identified can be described in hierarchically ordered qualitatively different *categories of description* which are further analysed with respect to logical relationships and form an *outcome space* of the phenomenographic analysis. Each category is the researcher(s)' description of a qualitatively distinct way of understanding the phenomenon studied. The analysis is done on a collective level not aiming at categorising individuals since an individual can hold several of the understandings expressed in the categories.

VI. Data Collection

A common method for data collection in phenomenographic research is semi-structured interviews [20]. In this study we analysed a selection of interviews that were conducted for our broader research project.

A. Research Interviews

The interviews were conducted by the first author, in all but one case in Swedish, as all but two students' mother tongue was Swedish. English was used in the other interview.

Before the interview, the students were told that the interview consisted of three parts, their choice of study, envisioned work life, and study experiences. They were told that each interview section commenced with an open question, so that the students could speak freely about anything they might experience as relevant. The main interview questions were[2]:

1) I would like to go back to before you began to study: Can you please tell your story about how you think you became interested in CS/IT, which then led to your decision to study CS/IT?
2) 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?
3) Now, you have studied CS/IT for one year, can you tell me about how you have experienced your first year here at the university?

Follow-up questions were prepared, based on the theoretical framework described by Peters and Pears [6]. However, the follow-up questions emerged relatively naturally based on what the students talked about when answering the opening questions. Most commonly, questions were asked that aimed to expose a better understanding of what it was that made the students experience something the way they did. For example, if a student said that he was interested in programming, a typical follow-up question was "What do you think, what was it that made programming interesting to you?"

[2]All translations from Swedish to English were made in a way that the connotation is retained as much as possible which may lead to slightly uncommon English sentences.

B. Informants for this Study

We conducted 23 interviews with students' at the end of their first year of study. Six interviews were used for the current phenomenographic analysis. The interview transcripts that form the pool of meaning for this study were chosen to represent a breadth of experience and focus. Three interview transcripts from each study program were selected. Two informants had CS/IT related industry experience prior to studying. One informant had previous CS-related study experiences and also other study experiences. One informant had CS-unrelated work experience, and had taken courses at the university prior to enrolling in CS. Two informants came directly from school. Two informants had a focus on hardware, the others focused more on software and programming. Two of the informants were female. However, in the quotes and explanations provided in this paper, we do not want to reveal the gender of the students for reasons of anonymity, as the number of female students in the cohort is very small. We use masculine forms throughout the paper to retain the overall masculine atmosphere.

VII. Data Analysis

We describe the process of the analysis and our results.

A. The Phenomenographic Analysis

The data analysed in this paper consists of a series of student utterances resulting from the questions in our interview script (section VI-A). The students talked quite freely, and in long passages, which provides a rich pool of data. They spoke a lot about experiences that can be interpreted in terms of our definition of *participation* as explained in section II. The first author did an initial categorisation of the students' descriptions of experiences. The other authors read selected parts of the transcribed interviews. The authors discussed and agreed upon a final categorisation over several iterations of analysis.

When talking about their experiences of participation, the students related to different objects of the discipline, such as "computer", "technology", "programs", "hardware", "software", "algorithms", etc.. In this analysis, we prescind from those objects. For example, the students talk about developing hardware, programs, and technology in general. This all falls under one category "development".

The goal of this study was to obtain insights into students experiences that influenced them in their thinking, feeling or social interactions in the context of learning CS. The results are not an investigation of students' overall understandings of participation in CS/IT.

B. Outcome Space

Student utterances analysed in this paper deal with experiences prior to, during, and after their studies. However, it was possible to structure the students' experiences of participation in a way that they can be described by one single outcome

space. Table I gives an overview of the hierarchical outcome space. It contains a short description of each category, each of which describes a qualitatively different way of experiencing participation in CS/IT.

Table I
CATEGORIES DESCRIBING QUALITATIVELY DIFFERENT WAYS OF EXPERIENCING THE PHENOMENON PARTICIPATION IN CS/IT

Participation in Computer Science is experienced …
…A. as *using*, i.e. to make use of what exists for various purposes.
…B. as *inquiry*, i.e. activities that aim at understanding, learning, informing.
…C. as *creating* things, i.e. to produce things that were not there before. Related to this are three aspects, the *outcome*, *process of doing* and *doing with others*.
…D. as *(systematic) problem solving*. This includes using methods, ways of thinking and (systematically) working with others to create things.
…E. as *creating for others*. This includes taking into account the user's perspective in the process of creating and problem solving.
…F. as *continuous development*, i.e. as a continuous process of improvement.
…G. as *creating knowledge* to develop new solutions, i.e. to do research.

Category A: Participation in CS/IT experienced as USING
This category describes experiences of *using* artefacts, e.g. applications or devices. Such experiences were commonly described as an entry point to the discipline.

> I was just fascinated by technological development in general. It may have begun with simple things, for instance that one played some computer games when one was younger. (Finley, IT)

Playing games and "being fascinated" relate to activities that include the whole person. Such experiences also have a social character, as the students usually share these interests with friends and/or family. Playing games could hence be seen as an experience of participation.

We also find examples of participation as *using* that refer to professional activities. Jaylin (CS) talks about using the terminal, which he seems to perceive as something computer scientists do:

> The introduction to Unix was good, to test using the command prompt It felt like one could have a few "cheat sheets" in the computer room. Just because I have done it one time does not mean that I will remember it later, so now I don't use the terminal. (Jaylin, CS)

However, Jaylin clearly experienced using the terminal as predominantly about memorising and using commands.

In summary, experiences of participation in CS/IT as *using* entail using artefacts, programs or devices. These experiences are predominantly focused on following and utilising existing rules and opportunities.

Category B: Participation in CS/IT experienced as INQUIRY
This category builds on exposure to and using technology which leads to questions such as "how does that work?" which then motivates further engagement in different activities to explore further, understand and learn:

> It may have begun with, that one has played a bit of computer games [...] that one has wondered about how things work, and also [...] the internet was developed, and all this about websites that has kind of pushed me. […] One has become curious and tried to learn and one has found information via internet, and to be able to read, things that not even friends nor parents were aware of. (Finley, IT)

This experience is about being wondering, learning, exploring, an interest sparked by experiences of *using*, exposure to technology and availability of information.

> Sometimes you see a homepage and think "God", that was really cool, how did they do that? (Finley, IT)

As a consequence, Finley explored the source code and eventually started manipulating and adapting websites.

Many educational experiences can be interpreted in terms of experiences of participation.

> I thought that the digital electronics part was much fun. Because there, we could test [to build digital circuits] and learn how things work, electronically. (Jaylin, DV, who took this part of the IT program)

Learning about the "smallest building blocks of a computer", as Jaylin describes it, is in focus here. Jaylin stated that the lab was especially important for his learning, because there he got to use his knowledge and really build and connect components. This supports our interpretation that this experience involves thinking, doing, and feeling (as Jaylin experienced it as fun).

One might argue that experiences of participation as *understanding* should be interpreted as learning experiences and not as experiences of participation in CS/IT. However, *learning* is experienced as an aspect of participating in CS/IT, for example by Quinn, who worked as a consultant prior to studying:

> After high school, I got a job as an IT consultant directly, because of my interest in hardware [...]. And there one had to learn more coding, which was essential for the job. But then, it was HP's specific programming languages for their hardware. (Quinn, IT)

Quinn needed to learn a specific programming language, that the company was using for working with HP hardware.

In summary, experience of CS/IT as *inquiry* involves a type of participation that entails learning, seeking to understand. The category also includes experiences of being exposed to, and using, artefacts or technology. Hence experiences of participation in CS/IT as *inquiry* are an extension of experiences of participation in CS/IT as *usage*.

Category C: Participation in CS/IT experienced as CREATING
The focus of this category is the experience of being able to create things that work and can be used. All examples of participation in CS/IT as *creating* relate to one or several of the following three aspects: the *outcome* of the creation, the *process* of creating, and *doing with others*.

The *outcome*-aspect is in focus in some experiences of *creating*. The students talked about creating things, they have used before, mostly games, apps and websites. Asking Emerson what he wants to do in the future, he says:

> Well, something I have also spent much time with is computer games, when I was small, which I thought was quite fun. And it would be fun to work as a computer

> game programmer. [...] To create something, a game, that one can have fun with. (Emerson, IT)

Jaylin's original objective was to become a fashion designer. He took a few courses in design, however then he decided that CS would be a better choice of study. He had tested a bit of HTML and Javascript, so CS was not a big step in Jaylin's view. He said that he was working on a website but...

> ... I never used it for anything, it was more for my own amusement. [...] I liked this aspect of designing the interface, or how the images are placed and how, which colours to use so that it becomes an attractive website. It is not about just taking any colour; it is quite difficult to get it right. (Jaylin, CS)

What made testing and creating the website fun for Jaylin was that he could be creative. Jaylin experienced the possibility to engage in creating when participating in CS. When starting to participate in creating websites, he explored using HTML and Javascript. Hence, the experience of creating included experiences of *inquiry*.

The *process of doing*-aspect is another student focus in the experience of *creating*. Here, the students focus on the process of doing, without reasoning about overcoming barriers or solving problems.

> [The programming course] was quite interesting, there was a lot to learn. [...] Overall, the thought behind how one creates a program, the overview like "If I will write a program, what do I need to do? Maybe, I need certain data structures?" That was something, I didn't see before. (Emerson, IT)

Emerson stated that he could imagine to write programs in his future work life.

> I: What makes it fun [to write a program] for you?
> S: It depends a bit on what this program is, one writes. But, [...] it is rather of a craft as well [...] It is a bit like, instead of having a car that one kind of cleans and polishes, one has a program which one programs and hones and builds and tries to get it as neat and optimal as possible, and everything should be so neat and perfect and it should work nicely, kind of. (Emerson, IT)

Emerson compares his engagement in creation with a craft. The goal, in his view, is to create highly polished, optimised, programs. Coding is reflected upon by quite a lot of students, mostly in the context of participation in CS/IT as *creating*.

The *doing with others*-aspect is another focus in students' expressions that can be interpreted as *creating*. These *others* are experienced as part of the process of *creating*. The following example illustrates this well. Jaylin talks about experiences during a previous IT-related study program:

> I thought that it was much fun when we were asked to develop those UML diagrams, with which one plans how information is handled in a system. [...] We would plan such a thing, and it was really good work in the group. I think that it is fun when one can discuss one's way to an answer (Jaylin, DV).

Emerson reflects on what he learnt during the programming course:

> [I learnt] a lot also [...] how do I write it [a program] so that someone else, who perhaps comes later and looks at the program, how he or she understands what I have done. That it is not only me that is sitting there, writing on my own, self-invented way, but instead that there is a standard way – this is how one writes a program. That was something quite valuable. (Emerson, IT)

Emerson experiences participation in CS/IT as *doing with others*, which one can learn how to do. Emerson gave two examples of standards he has learnt: writing specifications for functions and using a certain style to program.

In summary, our analysis of the experience of participation as *creating* reveals three different focuses, on the *outcome*, the *process* of creating, and *doing with others* when creating. The experience of *creating* is fundamentally different, richer, than the experience of participation as *inquiry*, as the students experience that this kind of participation in CS/IT leads to something that wasn't there before, something that works and can be used, and that one can show or give to others.

Category D: Participation in CS/IT experienced as (SYSTEMATIC) PROBLEM SOLVING

Here participation in CS/IT is experienced as about creating things, with an emphasis on approaching problems systematically through methods and strategies. Strategies are experienced as learnable and as a resource of the discipline.

Finley for exampled talks about his working experience prior to studying. He solved problems, however he lacked systematic methods and tools with which to do that, which gave him the motivation to study IT.

> I have solved things, a bit following my own head. [...] Something that made me feel that I need to study [was] that I didn't have so many tools to approach the problems. What I want to develop is some kind of methodology for how I approach a problem in a best way, as effective as possible. (Finley, IT)

Finley refers to methods for solving problems effectively, in less time. The students also talked about methods to solve problems in better ways as in the following example:

> S: That is something one strives for, that it [the program] becomes as optimal, best, as fast as possible should everything go. (laughs)
> I: That is something you find interesting?
> S: That is something applicable, measurable, how good something is. [...] That is something one thinks about more now, when one writes a program, how one should think kind of, so that the program runs as fast as possible. (Emerson, IT)

Many students refer to a "way of thinking" to solve problems, which they have acquired through education. Finley describes more specifically what it involves to systematically approach problems:

> In particular the programming course [...] I have gotten so many different ways of looking at the problem. For example working on the structure: [...] Before, one has perhaps many times solved problems by testing ones way to the solution. [...] It is better to decide in advance, let's say that you write a program with different functions, how will they communicate [...], what do you need to send in and what do you get out, you need to decide that in advance, how you will solve the problem. (Finley, IT)

The divide-and-conquer method was mentioned as an example of a method to systematically approach problems. Quinn for

example talks about the relevance of such methods based on his prior workplace experience:

> This way of thinking, many [students] have acquired, e.g. this divide-and-conquer-technique. [...] You never get away from that. It was applied clearly when we set up the system [at work]: There it was like, we want to have this, what do we need – we need hardware, [...] software, [...] network, [...] the client needs devices... (Quinn, IT)

What we left out in the quote was Quinn's explanation of how the different parts, hardware, software and, network, were set up, which refers to the *process of doing*. This quote furthermore refers to the *outcome* ("We want to have this"), and *doing with others* ("what do *we* need to do").

Some students also reflect on how working together can be done effectively. Jaylin, for example, reasons about "the way of working" within CS/IT that suits him, i.e. working together with others, collecting ideas and good ways of solving problems when creating. Jaylin experiences himself as a leader when working with others.

> I like to steer a bit, I think, I am quite good at deciding what should be done and when. Because when I work in groups, then it is often the role I take. It usually becomes that way quite naturally. (Jaylin, CS)

This example illustrates one example of reflecting about the students' role in the process of problem solving.

In summary, the examples given here refer to one or several of the three aspects, the *outcome*, the *process of doing* and *doing with others*. The students seem to integrate these aspects in their reasoning about how to approach problems. This is one argument why experiences of participation as *(systematic) problem solving* include experiences of participation as *creation*. Furthermore, the students focus on problems, as well as methods and tools to solve problems systematically. This is not the case in the previous category.

Category E: Participation in CS/IT experienced as CREATING FOR OTHERS

The students experience participation as *creating*, solving problems, and furthermore *creating* something *for others*.

Emerson, for example, sees the need to create programs that run efficiently. In his experience this is how one determines how good a program is:

> The user wants to always be able to do things, they expect the program to go as fast as possible. (Emerson, IT)

Jaylin, who enjoys the CS way of working, emphasising creating, and solving problems in groups, furthermore expresses that he wants to create something that is easy to use. Usability, Jaylin realises, can be different for different target groups:

> S: I am a bit interested in Human-Computer-Interaction. I want, well, I don't know exactly which program it would be [that I will develop] but it would be something that is easy to use for the user, because it is other humans that one programs for and not computer scientists (laughs), so that I think is very interesting. [...]
> I: Who would you like to develop something for?
> S: [...] I can imagine different things. It can be a very different to develop for a 20-year-old or for a 70-year old. (Jaylin, CS)

Here creating something for someone includes taking into account the user's perspective, needs or requirements. As such, it extends the previous category of experiencing participation as *(systematic) problem solving*.

Category F: Participation in CS/IT experienced as CONTINUOUS DEVELOPMENT

The focus is on a continuous process of developing and improving. The two students that have had IT-related jobs prior to studying have had experiences that can be interpreted in terms of participation in CS/IT as *continuous development*:

> As an IT consultant, I really saw that it is so much bigger. A computer at a family's house is an unbelievably small part in this whole picture of - well all networks that need to be fixed, base stations that need to be connected, it must be administrated, it must be secured, it never gets perfect, but it has to be improved all the time. (Quinn, IT)

Quinn states this as an experience that made him feel that IT would be the right choice of study. The experience is about participation as a continuous process of improving and technology in a bigger context.

Finley has been engaged in a bigger IT development project. He also experienced a richer context, more in the sense of working in a bigger group of people with different roles:

> The project runs continuously, but one also has new things all the time. 20 people were engaged that worked on different things, developer, consultants for testing and documentation, product owners as well as the people from the support. This, that one has so many different people working together, I thought, was a lot of fun. (Finley, IT)

In summary, this category adds complexity to the previous categories, as *creation for others* is now experienced as a continuous process. The experience also seems to be about complexity. However, we do not find many examples, so we cannot be sure about.

Category G: Participation in CS/IT experienced as CREATING KNOWLEDGE

A few students mention research as a possibility for future engagement. However, they mostly do not elaborate on that. Vincent talks about experiences prior to studying:

> S: I leafed through magazines and websites [...] They presented kind of research, recent trends, and what companies, that are developing these different things, think is going to happen in the next generation [...]. One becomes even more excited, and thinks "how cool!" (Finley, IT)

Quinn describes a more nuanced experience of research, in contrast to participation as *continuous development*:

> Either, it is a lot of fun to apply knowledge [...] and continue to educate oneself, also as an IT consultant. [...] But in that case, it is not to create something new, instead one applies what already exists, what companies have created. But, one does want to be a part of creating new knowledge and to do research. One has to make a trade-off, decide what one wants to do. (Quinn, IT)

In summary, we have a few examples in which students experience participation in CS/IT as *creating knowledge*. The students seem to experience this with respect to the *continuous development* of technology. Also, the experience of participation as *creating knowledge* entails the experience that the development of disciplinary knowledge is a continuous, ongoing process. This implies that the experience of participation

as *creating knowledge* includes experiences of participation as *continuous development*.

VIII. Discussion

The outcome space (table I) describes qualitatively different ways in which students experience participation in CS/IT. This result has implications for students' persistency in and learning of CS/IT.

Each way of experiencing participation constitutes a way of negotiating meaning, as we use Wenger's notion of participation which he describes as a process through which meaning is construed (see section II). All of the informants report experiences that can be interpreted in terms of participation as *creation* (category C in table I). This experience seems to be important to the students. The students experience empowerment to do things, things that have not been there before. The experience of the next category, participation as *systematic problem solving*, furthermore entails the experience that students can learn methods and tools that enable them to systematically approach the process of *creating*. This enhances the experience of empowerment as it is linked to students' experience of self-efficacy. The experience of *creating for others* furthermore enriches the experience as creation now is not experienced as an end in itself. As the more advanced experiences of participation include the less advanced experiences, they can be seen as richer ways of negotiating meaning.

The category of participation as *creation* alludes to what Schulte and Knobelsdorf call experiences of "design" (see section III). They also find this experience to be important as it rouses the students' interest in learning programming. Eckerdal and Berglund's [21] outcome space of students' understanding of what it means to learn to program is comparable to this outcome space, in particular the first four categories. They argue that in order to support students' learning of programming, they should experience programming as "a way of thinking, which enables problem solving". This previous work focuses on experiences and understanding related to computer and programming. The outcome space presented here includes a broader perspective on participatory experiences and also other aspects such as computer systems, innovation, society etc..

The notion of participation and our outcome space contribute to a better understanding of students' reasoning about previous experiences, envisioned future, and educational experience, which Ulriksen et al find central to address issues of retention [3], [2] (see section III). In some cases, the students' reasoning appears to be particularly coherent. For example, a few students state that they have enjoyed playing computer games and that they find it attractive to *create* computer games in their future working life. These students seemed to be mostly positive about their studies, having learnt about programming and how a computer works. Some informants report that the students have formed groups to work on *creating* smaller games or apps in their spare time.

Our results help to illuminate the experiences of an informant, Jamie, who struggled to integrate his educational experiences with his perception of who he is and wants to be, and who decided to leave the study program after seven months. Jamie entered the study program with a strong interest in technology, having built computers together with his partner. Despite his decision to leave the program, he was positive about his studies in the sense that it helped him to understand what CS is about:

> It is all about, it is entirely about software in computer science. [...] So, I rather study electronics where it is mostly, where I can almost only make use of it, to get different components to work together, more than what it is [in CS], well, to produce an app. (Jamie, CS)

Jamie's prior experiences can be interpreted as participation in IT/CS as *creating*, with a focus on hardware. During his studies, Jamie experienced CS to be about something else, about creating software, apps. The *outcome*-aspect of participation as *creation* seems to be in focus here. Jamie's decision to leave the study program seems to also be based on his experience of the *process of doing* creation in CS:

> I would probably never get tired of the actual creating itself. It is pretty cool to kind of feel that, I have done this. But on the other hand, what I could become tired of is to more kind of to only sit in front of a monitor for the rest of my life, hammering on the keyboard. (Jamie, CS)

Doing creation in CS, as Jamie has experienced it in his education, is limited to coding activities. His comparison "hammering on the keyboard" indicates that he does not think of challenging activities such as *problem solving* when reflecting on *creation*.

Jamie's decision to leave the study program appears mainly to be the result of a limited experience of participation in CS/IT. We wonder in what ways education has intended to facilitate diverse and advanced experiences of participation and how it was experienced by Jamie. The experience of CS being about "producing apps" appears to be a result of a collective negotiation of meaning of the student group. Björkman [18] states that the CS student community is very homogenous, consisting mainly of males with an interest in computers and programming. Nespor [13, p. 8] argues that all learning is contextualised. Could it be the case that the experience of participation in CS being about "creating apps", "coding" is the collective way of negotiating meaning that the individual student is challenged to integrate in his concept of who he is and wants to be, as education does not provide alternative ways of negotiating meaning?

The results contribute to new insights on how participation can be considered in education to address issues of retention and support personal and professional development. It seems important that education facilitates diverse experiences of participation. Many students experience participation in CS/IT as *creation*. The *outcome*, *process of doing*, and *doing with others* are aspects that are relevant in the students' experience. Education could facilitate different experiences that show what these aspects can mean for a professional computer scientist. Furthermore, education needs to support more advanced experiences of participation in order to support richer ways of negotiating meaning.

Negotiation of meaning and advanced experiences of participation is not only important for retention but also for learning CS/IT and professional development. All ways of experiencing participation in CS/IT represent ways of participating in the discipline that the students should be aware of and become competent in during their education. Participation in CS/IT as participation in a *continuous process of development* to address the need of society for example necessitates competencies that CS students should develop during their education. We wonder, to what extent higher education currently achieves that goal. We find that first year students' experience of participation and negotiation of meaning may be limited. This work motivates and provides a basis for further research and educational development to better support students' identity work and negotiation of meaning.

IX. Conclusion and Future Work

Previous research indicates that students are currently not well supported in negotiation of meaning and developing a (professional) identity. This study contributes to addressing this problem in three ways.

We have delimited a notion of participation and related it to theories of identity development. The phenomenographical results provide insights into students' participatory development in CS.

The outcome space describes students' qualitatively different ways of experiencing participation in CS/IT. This contributes to a better understanding of how students negotiate meaning and contextualise what they learn. It appears to be useful to understand students' identity work, how they integrate their educational experiences with their perception of who they are and want to be.

We have discussed implications for educational development. In order to support negotiation of meaning, education needs to address students' current experience of participation in CS/IT and also facilitate more advanced ways of experiencing participation in CS/IT. We argued that this is important to address issues of retention, and that all of these ways of experiencing participation constitute important goals for professional development and learning.

In the future, we will do further analysis of students' experiences of participation to get more nuanced insights. One could for example consider different focuses, e.g. on computers, systems, software, and hardware. Furthermore, it will be interesting to see how students develop as they progress through education, e.g. in respect to their descriptions of experiences of participation and the role of education.

Acknowledgment

We would like to thank Michael Thuné from our research group for many inspiring discussions, comments, and feedback since the beginning of this research project in August 2011.

References

[1] N. Entwistle, "Conceptions of Learning and the Experience of Understanding: Thresholds, Contextual Influences, and Knowledge Objects," in *Advances in learning and instruction*, S. Vosniadou, A. Baltas, and X. Vamvakoussi, Eds. Amsterdam, The Netherlands: Elsevier, 2007, ch. 11.

[2] H. T. Holmegaard, L. M. Ulriksen, and L. M. l. Madsen, "The Process of Choosing What to Study: A Longitudinal Study of Upper Secondary Students' Identity Work When Choosing Higher Education," *Scandinavian Journal of Educational Research*, no. October 2013, pp. 1–20, Jun. 2012.

[3] L. Ulriksen, L. M. l. Madsen, and H. T. Holmegaard, "What do we know about explanations for drop out/opt out among young people from STM higher education programmes?" *Studies in Science Education*, vol. 46, no. 2, pp. 209–244, Sep. 2010.

[4] B. r. F. Johannsen, "Attrition and Retention in University Physics. A longitudinal qualitative study of the interaction between first year students and the study of physics," Ph.D. dissertation, University of Copenhagen, 2012.

[5] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press, 1999.

[6] A.-K. Peters and A. Pears, "Engagement in Computer Science and IT - What! A Matter of Identity?" *Learning and Teaching in Computing and Engineering (LaTiCE)*, 2013.

[7] F. Marton and S. Booth, *Learning and Awareness*. Routledge, 1997.

[8] V. Burr, *Social Constructionism*, 2nd ed. Routledge, 2003.

[9] J. M. Charon, *Symbolic Interactionism: An Introduction, An Interpretation, An Integration*, 10th ed. Pearson, 2010.

[10] L. Ulriksen, H. T. Holmegaard, and L. M. l. Madsen, "Weaving a Bridge of Sense : students' narrative constructions as a lens for understanding students' coping with the gap between expectancies and experiences when entering higher education," *European Educational Research Journal*, vol. 12, no. 3, pp. 310–319, 2013.

[11] J. Lave and E. Wenger, *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press, 1991.

[12] A. T. Danielsson, "Doing Physics - Doing Gender: An Exploration of Physics Students' Identity Constitution in the Context of Laboratory Work," Ph.D. dissertation, Uppsala University, Department of Physics and Materials Science, 2009.

[13] J. Nespor, *Knowledge in Motion: Space, Time, and Curriculum in Undergraduate Physics and Management*, ser. Knowledge, identity, and school life series. Routledge Falmer, 1994.

[14] H. T. Holmegaard and L. Ulriksen, "Why students choose (not) to study engineering," *Proc. of the Joint International IGIP-SEFI Annual Conference*, 2010.

[15] C. Schulte and M. Knobelsdorf, "Attitudes towards Computer Science-Computing Experiences as a Starting Point and Barrier to Computer Science," in *Proceedings of the third international workshop on Computing education research - (ICER) '07*, Atlanta, Georgia, USA, 2007, p. 27.

[16] M. Knobelsdorf, "Biographische Lern- und Bildungsprozesse im Handlungskontext der Computernutzung," Ph.D. dissertation, Freie Universität Berlin, 2011.

[17] K. Yasuhara, "Viewpoints from the Doorstep : Pre-major Interest in and Perceptions of Computer Science," Ph.D. dissertation, University of Washington, 2008.

[18] C. Bjorkman, "Crossing Boundaries, Focusing Foundations , Trying Translations : Feminist Technoscience Strategies in Computer Science," Ph.D. dissertation, Blekinge Tekniska Högskola, 2005.

[19] M. Tedre, "The Development of Computer Science; A Sociocultural Perspective," Ph.D. dissertation, University of Joensuu, 2006.

[20] S. Kvale, *InterViews: An Introduction to Qualitative Research Interviewing*. SAGE Publications, 1996.

[21] A. Eckerdal and A. Berglund, "What does it take to learn 'programming thinking'?" in *Proceedings of The First International Computing Education Research Workshop*. ACM Press, 2005, pp. 135–143.

Recent licentiate theses from the Department of Information Technology

2014-003 Liang Dai: *On Several Sparsity Related Problems and the Randomized Kaczmarz Algorithm*

2014-002 Johannes Nygren: *Output Feedback Control - Some Methods and Applications*

2014-001 Daniel Jansson: *Mathematical Modeling of the Human Smooth Pursuit System*

2013-007 Hjalmar Wennerström: *Meteorological Impact and Transmission Errors in Outdoor Wireless Sensor Networks*

2013-006 Kristoffer Virta: *Difference Methods with Boundary and Interface Treatment for Wave Equations*

2013-005 Emil Kieri: *Numerical Quantum Dynamics*

2013-004 Johannes Åman Pohjola: *Bells and Whistles: Advanced Language Features in Psi-Calculi*

2013-003 Daniel Elfverson: *On Discontinuous Galerkin Multiscale Methods*

2013-002 Marcus Holm: *Scientific Computing on Hybrid Architectures*

2013-001 Olov Rosén: *Parallelization of Stochastic Estimation Algorithms on Multicore Computational Platforms*

2012-009 Andreas Sembrant: *Efficient Techniques for Detecting and Exploiting Runtime Phases*

2012-008 Palle Raabjerg: *Extending Psi-calculi and their Formal Proofs*

UPPSALA
UNIVERSITET

Department of Information Technology, Uppsala University, Sweden