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

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***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.

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