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Crossing Boundaries,
Focusing Foundations,
Trying Translations:

Feminist Technoscience Strategies in Computer Science

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Feminism is not a dogma but a set of critical questions
Sara Heinämaa 2002

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Christina
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Till Mats

Abstract

In this thesis I explore feminist technoscience strategies in computer science, starting in "the gender question in computer science", and ending up in communication and translation between feminist technoscience research and computer science educational practice. Necessary parts in this work concern issues of boundary crossings between disciplines, and focusing on the foundations of computer science: what it means to "know computer science".

The point of departure is in computer science (CS), in particular CS education. There are at this starting point two intertwined issues: the gender question in computer science (often formulated as "what to do about the situation of women in computer science?") and the foundation question: "what does it mean to know computer science?". These are not primarily questions looking for answers; they are calls for action, for change and transformation. The main focus and goal of this thesis concerns how to broaden the meaning of "knowing computer science"; to accommodate epistemological pluralism and diversity within the practices and among the practitioners of CS.

I have identified *translation* as fundamental, to make feminist research and epistemological perspectives communicable into the community of computer science practitioners. In this, questions of knowledge and how knowledge is perceived and talked about are central. Communication and translation also depend on the ability and willingness to cross boundaries, to engage in "world-travelling" (Lugones). Additional issues of importance are asking questions open enough to invite to dialogues, and upholding critical (self) reflection.

An important goal for feminist research is transformation. Because of this, interventions have been part of my research, interventions in which I myself am implicated.

The work has been based in feminist epistemological thinking, where the concepts of *positioning* and *partial perspectives* (Haraway) have been of particular importance.

After an introduction, the thesis consists of three parts, each part relating to one of the three issues in the title, issues identified as important for feminist technoscience work in computer science.

In part A, I investigate and discuss what it means to be simultaneously an engineer/computer scientist and a feminist technoscience researcher. What boundary crossings, challenges, conflicts, negotiations and issues of being inside and outside are involved? This part also focuses on what the implications of these boundary crossings and different "mind-sets" are for transformatory work in science and engineering education, as well as a discussion of what feminist technoscience research can be and how it can be used for interventions and transformations.

Part B focuses on foundations of computer science. This part consists of studies of texts, which I critically read and query from a feminist technoscience perspective, in order to challenge existing approaches and concepts within computer science. The texts are about the gender question in computer science; foundational topics of "what is computer science", as well as epistemological questions concerning approaches to knowledge in computer science: "what does it mean to know computer science"?

Part C deals with a concrete intervention project aiming at establishing conversations with computer science faculty. In this project, the issues of communication and translation appear as central. The focus in this part is communication between computer science educational practice and feminist technoscience research, language as a carrier of epistemology, and a discussion of translation.

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But the road that has led to this thesis started earlier. I had very likely never come to this point had it not been for Annika Lundmark at Uppsala University, whom I like to think of as my mentor. Thank you Annika, for providing me with the opportunity to get away from teaching,

to work with the project that came to lead to this research. You and our co-operation through the years have been invaluable to me.

During these years, I have also worked with an educational project, the development of the Systems in Technology and Society engineering programme at Uppsala university. Apart from my research studies, this project has been the most inspiring, challenging and wonderful in my professional life (so far!). I owe the experiences and fun with this project to Jörgen Nissen. Jörgen: Thank you once more for giving me this opportunity, you know how much this has meant to me. I have enjoyed our co-operation through the years, what you called the "double command" of the STS programme. Thanks also for valuable research discussions.

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Prologue

Introduction

"Why are there so few women in computer science, and what can be done to increase numbers?" This is what I call, paraphrasing Sandra Harding (1986): "the gender question in computer science". This question was the starting point for my research, the question that initially led me to this work, albeit as more of a motive than a research question *per se*. There are no answers to this question in this thesis; rather the question itself is highlighted as being of considerably greater complexity than is often realised by people within computer science (CS) who honestly and sincerely want to change the current state of affairs. "The gender question" is part of the larger issue of diversity. Maria Klawe succinctly expresses my belief, motive, and wish:

> "The point here is that computer science also needs to attract students with broader interests and abilities than the traditional computer scientists—nerds. […] We need more computer scientists whose passions are art, language, literature, education, entertainment, psychology, biology, music, history, or political science. We need them because computers have an impact on all areas in our world. We need people with passion and vision from every area to drive the development of computer technology as well as the applications. […] We need non-nerds in computer science, so let's figure out the proper approaches to integrate their talents and perspectives into our field." (Klawe 2001, p. 67f.).

"The gender question in computer science" tends to focus on women (or possibly gender) rather than on the other half of the sentence: computer science. Noting that the way the question had conventionally been approached had not led to any significant changes in the proportion of women in CS, I turned my attention to the discipline of computer science itself. I focused on that which is often taken for granted and thus somehow becomes invisible in the common approaches to "the gender question": the discipline. This led to asking questions from feminist research perspectives[1], questions

[1] Feminist research can have two general focuses: sex/gender on the one hand, and science itself on the other. Feminist research within natural science and technology mainly concentrates on the second of these, focusing on science itself, its theories, methodologies and other knowledge processes (Trojer (ed), 2000). For a further discussion of feminist research, see the section on research communities below.

concerning the foundations for CS, and in particular about knowledge. I took the turn, the perspective, that Judy Wajcman demands:

> "Feminists have pointed to all sorts of barriers – in social attitudes, girls' education and the employment policies of firms – to account for the imbalance in the number of women in engineering. But rarely has the problem been identified as the way engineering has been conceived and taught." (Wajcman 1991, p. 19).

At the starting point for my research, there were thus two intertwined issues: the gender question in computer science, and what can be called the foundation question: "what does it mean to know computer science?". These are not primarily questions looking for answers; rather they are calls for action, for change and transformation.

A common denominator for all my research is the aim of contributing to change: change in recruitment to CS, change in the culture of CS (both the disciplinary and the social), change in the practices of CS – and in particular education. In short: to explore possibilities for change with the aim of making CS more inclusive, what I call feminist technoscience[2] strategies in computer science.

Transformation is at the heart of feminist research: "For feminists, research on technology is not just about adding to our academic knowledge, it is also an emancipatory project." (Grint and Gill 1995, p. 21). However, I do not want to stop at emancipation, if this means primarily emancipation for women. I see my project as transformative in a more profound sense, in that it discusses issues of disciplinary importance for computer science. One way of seeing it is as aiming at emancipation of the discipline of computer science itself.

The main focus and goal of my work concerns how to broaden the meaning of "knowing computer science". This includes accommodating diversity: diversity among students, diversity in ways of knowing and learning (what is called epistemological[3] pluralism), diversity among practitioners of CS, and diversity of practices and approaches to knowledge in the discipline.

I have borrowed the expression "knowing computer science" from the work of Leone Burton, whose work concerns "knowing mathematics". She has developed an epistemological model of what it means to know and come to know mathematics (Burton 1995). Her model has implications for the teaching of mathematics, and for attracting new groups (e.g. women) to the discipline. I use the expression to emphasise the activity of knowing rather than the passive concept of knowledge. In using this, I want to underline that knowledge does not exist independently of a knower.

In this thesis, I explore feminist technoscience strategies in computer science. This comprises several parts. The first issue concerns *boundary crossings* between disciplines, or what I, inspired by Maria Lugones, call "world-travelling" (Lugones 1990).

[2] Feminist technoscience is described and discussed in the section on research communities below. See also http://www.bth.se/tks/ teknovet.nsf/.

[3] Epistemology is the theory of knowledge, discussing issues such as "who can have knowledge?", "what counts as knowledge"? and "what can be known?" In Sandra Harding's words: the "concepts of knowers, the world to be known, and the process of knowing" (Harding 1986, p. 140).

The second point is to *ask questions* from feminist research perspectives: "Feminism is not a dogma but a set of critical questions". (Sara Heinämaa 2002). We have to ask perhaps unexpected, but crucially important questions that illuminate what is at stake, questions that are open enough to encourage dialogue – and critical (self) reflection. My questions have mainly focused on the foundations of computer science. This includes analysing approaches to knowledge and fundamental concepts within the discipline.

Since my aim is transformation, interventions have been an important part of my work, interventions in which I myself am implicated. I have worked on a concrete intervention project aimed at establishing dialogues with computer science teachers. From this work, I identified a third strategy, concerning *translations*. This is about communication between two very different communities: feminist technoscience research and computer science educational practice. How to make feminist research and epistemological perspectives communicable in the community of computer science practitioners? Here, questions of knowledge and how knowledge is perceived and talked about are central.

Inseparable from this research journey is my own development, from engineer and 'traditional' computer scientist to feminist technoscience researcher, and further to feminist computer scientist (by which I mean integration of the engineer/computer scientist and the feminist technoscience researcher). This journey includes constant work on my own epistemological thinking, a re-thinking of most of what I have been taught. Part of my work is about the conflicts and possibilities that these different positions give rise to, where I refuse to choose one single position. As I see it, the only possibility is to try to remain a computer scientist and not lose my 'old world', in order to be able to communicate within CS and thus work for change.

My aim has been to write this thesis as both a feminist technoscience researcher and a computer science lecturer. These two positions are not easily combined, as I also discuss. But to *write* for both communities is a very difficult, delicate and risky (even potentially impossible) task, as I also discuss in paper A1. It remains to the reader to decide on how far I have come towards this goal.

To summarise: in this thesis I explore feminist technoscience strategies in computer science, starting out with "the gender question in computer science", and ending up in communication and translation between feminist technoscience research and computer science educational practice.

Before introducing the papers that make up the body of the thesis, I present the work I have done in three sections, relating it to research questions, research communities, and research method(ology) respectively.

However, before doing this, two more issues need to be addressed in the introduction. First, I discuss how I have delimited the field of computer science in this work. Second, I introduce the concepts of "worlds" and "world-travelling" that I use.

Computer science: delimitations in this thesis

The meaning of computer science, as I use it in this thesis, needs some deliberation.

When I started out on my research, I did not problematise how I used and saw computer science (CS). Thus, I have taken CS as it was seen and practised in the environments where I have worked and the communities that I have been part of. This means a fairly traditional and Anglo–American definition of CS (see paper B3) as a discipline in the faculty of natural science and/or engineering. The area is mainly constituted by computer engineering and 'datalogi' (theoretical computer science). Apart from the departments where I have worked, I have also used the views prevalent within ACM[4], in particular the SIGCSE (Special Interest Group for Computer Science Education) community (which has a clear Anglo–American bias), and also documents defining or describing CS and education in CS produced within ACM (Denning et al. 1989, ACM Computing Curricula 2001). In these, and in the communities that I have been part of, CS is seen as stemming from mathematics, engineering and natural science. In the Swedish context, the stronger of these traditions within CS are probably the mathematical and the engineering parts, but there is a certain tension within the CS community concerning which one of these is the most important.

In Sweden, computer science is commonly separated from Information Systems ("systemvetenskap") , which at most universities is placed within the faculty of social sciences. This is different to the situation in many other European countries (e.g. Norway, Germany) where computer science is called Informatics, and is defined much more broadly and inclusively than in Sweden, and also includes Information Systems.

It is notable that at the departments of computer science where I worked until the late 1990's, I never once heard of Participatory Design, the Scandinavian school of systems design[5], or User Centred Design[6] (my guess is that they made their presence more felt within "systemvetenskap"). Human Computer Interaction (HCI) within these departments and at that time was considered to be mainly about ergonomics and cognitive psychology. At these departments, knowledge about different ways of seeing CS and different communities was poor, if it existed at all. It was not until I had spent some time

[4] ACM (Association of Computing Machinery) is one of the largest international professional organisations within CS. See www.acm.org. ACM has special interest groups for different areas, including one for computer science education (SIGCSE), www.sigcse.org.

[5] "The central issue in the Scandinavian tradition of systems development has been user involvement in computer-based system design. The location where most of the design experiments have been done is working life, in concrete work place settings such as industry and hospitals. The approach has had two trajectories: to participate and influence the democratisation of working life and also to democratise the design process. The traditional Scandinavian approach when travelling to other contexts partly changed its purpose and methods. Today especially in the North American context the approach is called Participatory Design (PD)." (Elovaara 2004, p. 165).

[6] Within User Centred Design, the role of the user is vague. It is more about "know thy user" and second-guessing the needs of users, than direct participation by the user (Inger Boivie, personal communication).

as a graduate student at Blekinge Institute of Technology (BTH) that I learnt about, for example, Participatory Design and its communities. No doubt, these approaches challenge the boundaries of what can be considered computer science.

Furthermore, it was not until very recently that I became aware of some other differing traditions and alternative voices within computer science. For example, Christiane Floyd discusses human questions in computer science (Floyd 1992), where she among other things points out that "[T]he computer science we know to a large extent still sees itself as a formal and engineering science *only*, and disregards the fundamental human questions […] it does not provide a sufficient basis for viable decisions on developing and using computer technology today." (Ibid p. 27, original italics). Peter Naur (who among other things contributed to the development of the ALGOL 60 programming language) emphasises computing, including programming, as a human activity (Naur 1992).

Obviously, the alternative voices and traditions I mentioned above were invisible to me in the Swedish 'mainstream' communities of computer science. Nowadays, I am well aware that I have only looked at parts of what can be called computer science, and that there are other communities than the ones that I have been in and which are the focus of my research.

I have come to realise that within, for example, the Scandinavian school of systems design, as well as in some of the other work mentioned above, many of the things that I talk about exist or are being advocated. Thus, one way to work for changes within CS would be to strive to integrate approaches advocated within these traditions into 'mainstream' CS education. I have not studied these traditions of CS (although I hope to in life after graduation), but I do not believe that integrating these into traditional CS will replace feminist analyses and critique, for example concerning epistemological pluralism.

In working on this thesis, I have confined myself to the CS environments that I believe are the most common in Sweden. Unfortunately, all my experience both before and during this research points to strong forces at work, wanting to draw boundaries around a narrow core considered to be 'pure' CS.

"Worlds" and "World-travelling"

During my work, I became more and more preoccupied with the experiences of dualistic "worlds": engineering/computer science and feminist research respectively.

In Maria Lugones' article "Playfulness, "World-travelling", and loving perception"[7], I found a concept that described my experiences perfectly. This concept makes it possible for me both to talk about my own "world-travelling", and to talk about the different "worlds" as I experienced them.

[7] Maria Lugones' article concerns different ethnic worlds, but as I understand her concepts they are not limited to this sphere. I use them in her sense, but for other social worlds.

By using the concept of "world", Maria Lugones wants to capture the experiences of 'outsiders' to the mainstream. She explains how she uses the concept: "In describing a 'world' I mean to be offering a description of experience, something that is true to experience even if it is ontologically problematic." (Lugones 1990 p. 396). If the description were ontologically unproblematic, it would not be true to these experiences. Furthermore, "a 'world' need not be a construction of a whole society. It may be a construction of a tiny portion of a particular society." (Ibid p. 395).

Two aspects are of particular interest in my work. Firstly, the idea of "being at ease in a 'world'" (ibid p. 397). Maria Lugones identifies four ways of being at ease in a "world". The first is to be a fluent speaker of the language in that "world": "I know all the norms that there are to be followed, I know all the words that there are to be spoken. I know all the moves, I am confident." (Ibid p. 397). The second way of being at ease is by "being normatively happy, I agree with all the norms" (ibid p. 397). Yet another way is by "being humanly bonded" (ibid p. 397). And finally, one can be at ease because one "has a shared history" (ibid p. 397). Maria Lugones points out that one may be at ease in one or several of these ways.

However, people who feel at ease in all four ways, tend not to be inclined to do "world-travelling". This is the second concept that I want to expound on. "One can 'travel' between … 'worlds' and one can inhabit more than one …at the very same time." (Ibid p. 396). And furthermore: "Those of us who are 'world-travellers' have the distinct experience of being different in different 'worlds'… the shift from being one person to being a different person is what I call 'travel'. This shift may not be wilful or even conscious" (ibid p. 396). But it is not a matter of acting, of consciously playing a role, rather "… one *is* someone who has that personality or character or uses space and language in that particular way." (Ibid p. 396). In particular I note that *language* is part of these worlds, what it means to be at ease in a "world", and what it means to travel between "worlds". This resonates with my experiences, where I have come to focus on language as a signifier of "world-view". I discuss this in particular in paper C2.

Research Interests, Motives and Questions

Background: Engineer and computer science lecturer

My undergraduate education is in engineering; I have an MSc in engineering physics. This training as an engineer, with its main focus on problem solving, is deeply rooted within me. After a couple of years as a hospital engineer, I worked for many years as a lecturer in computer science (more specifically computer systems). I taught classes mainly within programming, computer architecture and operating systems. I also have experience from other types of work, such as student counsellor, director of undergraduate studies and programme director for a computer science education programme. I was (and still am!) genuinely interested in education: creating good education, understanding and accommodating students' needs and interests, creating a good learning environment.

I pinpoint the middle of the 1990's as the starting point for the journey that has led to this thesis. At that time, as part of my duties as a lecturer, I also worked as a student counsellor. During this period, I started participating in international conferences organised by the ACM Special Interest Group for Computer Science Education. It was inspiring for me to discover that this community was much more gender balanced than the community of CS in general, at conferences I found myself surrounded by many other women, which was a great feeling. To begin with, my interest was not research oriented, but more that of the pedagogically interested practitioner. At the very start, my main interest concerned issues such as distance learning/teaching, and the teaching of core CS curricula.

It was also at this time that I started being interested in gender issues (or as I called it back then: women in CS). My interest concerned both the under-representation of women in CS, and the situation of the few women (both students and teachers) in the field. For a number of years, I was engaged in different projects targeting female students, working on both attracting and retaining women. I have described these projects and experiences in my licentiate thesis (Björkman 2002). During this period, I gradually started questioning the most common approaches to the "gender question in computer science", and developed an interest in exploring the complexity of these issues. I started to think about what I called 'paradigms' and knowledge within the discipline. Experiences from the projects I was engaged in led me to ask other questions and to an interest in the invisible and taken for granted: the discipline of computer science. These experiences (both my own and the female students') included a feeling of being an outsider, of being 'wrong'. This raised questions in me such as: why are only certain ways of being in and knowing CS accepted? Why is not everyone included? Why does it seem impossible to negotiate the discipline including all its aspects?

At the same time, I became a feminist, to begin with not as a researcher, but more in the political and activist sense of feminist. The reasons for my becoming a feminist were entirely due to experiences encountered in my professional life, experiences that

were deeply personal and painful. At this time, I also started reading literature, and participating in courses within what was then called "women's studies".

One way to describe and understand my journey from the "world" of computer science education to feminist technoscience research is to use Maria Lugones' concept of "world-travelling". Thinking of my first five to eight years in computer science, I believe I felt more or less fully at ease, in terms of the four ways of being at ease: I felt I was a fluent enough speaker, I agreed with the norms, I was humanly bonded (these were my friends, not only colleagues), and we started very quickly to have a shared history, due to some rather turbulent changes the department was going through. Then things happened, which are hard to account for, but I slowly ceased to feel at ease. I think one of the first things that occurred was that I stopped agreeing with all the norms (this probably coincided with my starting to work as a student counsellor and engaging in projects for female students.) This is where the process of separation from the community started. Following this, I realised that I was not really a fluent speaker, or at least I had the feeling that others did not see me as a fluent speaker, I was not quite 'right'. What probably still made me stay for a long time was the shared history and the strong human bonds. But the process of separation continued, and at one point, my sense of being at ease was so lost that I changed courses and started to travel to another world: that of feminist research. I think at that point I at least partly wanted to separate myself from computer science – the world that had been mine for so many years. I wanted to do that, because I had never been integrated into it, I had never *really* been part of it. Maria Lugones' words describe my experience perfectly:

> "I had a sense of not being quite integrated, my self was missing because I could not identify with [them]… [I was] a different sort of being, not quite of the same species. [I saw this] as a lack in myself" (Lugones 1990 p. 393).

The experiences I had are shared by many others (e.g. female students) who do not feel at home in the discipline, and, just as Maria Lugones writes, might see this as a lack in themselves. These experiences and feelings of 'outsiderness' are driving forces for making the discipline more inclusive, so that different ways of 'being' are accepted.

My first research exercises

At this point, the opportunity arose for me to become a PhD student in what was then called the "IT and gender research" (the name was later changed to "Technoscience Studies"[8]) group at Blekinge Institute of Technology. I came to gender research[9] with my knowledge and experiences from computer science, and from the projects I had participated in, as well as with my questions.

[8] See http://www.bth.se/tks/teknovet.nsf/.

[9] Gender research is the term most commonly used in a Swedish context. However, the term "feminist research", which is common in Anglo-Saxon countries, is becoming more widespread in Sweden. I prefer to use the term feminist research for my work. I write gender research in some places when that term was used in a specific context, e.g. it was in the name of the research group when I started my research.

When I started my research, my thinking was (implicitly) dominated by the idea of defining a problem and then finding a way to resolve it. This is fundamentally and deeply rooted within the engineer, although it is seldom articulated and made visible. I was trained to delimit a problem, make it as simple as possible, and then apply the most straightforward solution. This is an approach where logical and abstract thinking are emphasised. Within CS, I was further trained in the use of algorithmic approaches to problem solving. This tends to encourage linear thinking about problems. Thus, my education and professional life had trained me in a certain way of thinking and approaching problems. I discuss some aspects of this in paper A1[10].

I started out my PhD studies in the issues and questions I had been involved in earlier, concerning "the gender question in computer science". As a starting point I wanted to get a picture of research done within the area, in order to take things one step further. Paper B1 is written within this context.

As a kind of a continuation of paper B1, and at the same time as an exercise in and discussion of epistemological and methodological issues, I wrote paper B2.

Focusing on the foundations of computer science

My first real research question, and what would become the focus of my research, concerned what I called "the paradigmatic[11] basis of computer science". The goals for my research were formulated in a research application to the Swedish Research Council for Engineering Sciences[12]: "To develop new possible, broader understandings and interpretations of computer science and its practices, starting in analysis of existing paradigms and knowledge processes within computer science and how these interact in forming the activities within the discipline (education, research and development of applications). The project aims at contributing to the development of a supplementary force within the discipline that will have the potential to influence the renewal of recruitment, education and research, which is of vital importance for a sustainable increase of women's participation in computer science."

My argument for focusing on this 'paradigmatic basis' of computer science was that issues concerning CS itself and its knowledge processes were for the most part absent in research and discussions on gender and CS. In my licentiate thesis, I formulated this as turning the question around, from women to computer science. This meant the question was raised to a more general level, towards "the science question" (Harding 1986), discussing the discipline, its 'paradigms' and knowledge processes. My aim was to open up the 'black box' of computer science in order to be able to renegotiate what is going on inside.

[10] The papers are further described and commented on in the introduction to each part of the thesis.

[11] My use of the word 'paradigm' here is very loose and not very well considered. I do not use the term in this sense any more.

[12] This application was granted money. During the years 2001–2003 my research was supported by a grant from the Swedish Research Council for Engineering Sciences.

However, gender in CS is but one part of the larger issue of *diversity*. The overarching goal for my work is to strive for inclusion and accommodation of diversity in CS, both among its practices and among its practitioners. This idea is developed and discussed in paper B3, written together with professor Lena Trojer. This paper outlined what I saw as the important points for my research.

When I finished my licentiate thesis three years ago, I wrote: "In my future work, I will concentrate on "the science question", the paradigmatic basis and knowledge foundation within CS, how this is formed and mediated within education and research, and what it means to 'know CS'". To learn more about the foundations of CS, I studied some work within the area of the philosophy of computing. During this work, I wrote paper B4, in which I discuss how feminist research focusing on epistemological issues can be used within computer science.

Boundaries and "worlds"

During a journey like PhD studies, things happen along the way that can lead to new issues becoming more important to deal with and new research questions appearing. This happened during my last two years as a PhD student. It does not mean that I have abandoned the issues of knowledge in CS, but rather that these have raised other questions that needed attention.

In 2003, we started to discuss in the research group what our work was about, its main focuses, etc. We talked a lot about boundaries, boundary transgressions, transdisciplinarity, opening up and rearranging in the 'black box'[13] of information technology, interventions, transformations, experience-based research rather than discipline-based, etc. This led to joint work on paper A2, which became a sort of "manifesto", or policy statement, for the research done within the Technoscience Studies group.

During this period, I also became more and more preoccupied with issues concerning the different "worlds"[14], which I experienced in two different, but interconnected ways. The first way was within myself, with my 'identities' as an engineer/computer scientist and as a feminist researcher. Paper A1 is written as an investigation of these experiences of different "mind-sets" and what their implications are for doing feminist technoscience research in engineering and related areas.

Communication and translation

The second way I concretely experienced the different "worlds" was during a project in 2003–2004 with computer science faculty. The project was called "Knowledge and learning in computer science from gender research perspectives". It intersected three areas that are strongly related: integration of gender issues into computer science education,

[13] The process of blackboxing is equivalent to the process of naturalisation, in which something (an artefact, an idea, a concept, etc.) is stripped of its origins, context and consequences and is regarded as given, as self-evident.

[14] By "world" here I refer to Maria Lugones' concept discussed above.

feminist research about knowledge in computer science, and pedagogical development. The project is described and discussed in paper C1.

One of my initial aims was that this project should provide empirical material about how computer science teachers think and talk about issues of knowledge within their discipline. I wanted to start a reflective process concerning knowledge among practitioners of CS (including myself!), to reflect over our own understanding and basic assumptions of the subject – what do we mediate to students? This was connected to my goal of accommodating diversity within CS.

During the project, I instead came to focus on communication between feminist research and computer science practice. Issues of creating a language to communicate across boundaries that different disciplines, or rather 'world-views', create came to be the most important. As Lucy Suchman expresses it, there are "…discontinuities across our intellectual and professional traditions and associated practices" (Suchman 2002, p. 97). The final paper in the thesis, C2, discusses the encounters between these "worlds", and translation as a way of bridging the differences.

Thus, communication and translation came to be in focus during the last phase of my doctoral studies. This does not mean that the issues of knowledge are left behind; on the contrary these are completely intertwined with language and communication. It was my interest for and research questions concerning knowledge that led to issues of translation, and how to create prerequisites for and participate in (transformatory) dialogues.

Let me briefly summarise how my research questions have changed during the journey: initially, my overarching research question concerned what I called the 'fundamental paradigms' within CS. While knowledge issues in computer science were and still are my main focus and interest, the concrete questions have come to deal more with translation and communication between feminist technoscience research and computer science education. In these, the issues of knowledge and how knowledge is perceived and talked about are central.

In the epilogue at the end of this thesis, I look in the rear-view mirror on this journey and its entailing change in research questions, and discuss and summarise the thesis and its contributions.

Research Communities

Last year, an editor of a journal commented that my work did "not fit into an easily recognised research paradigm". I believe that my work *does* fit into a (probably not so easily recognised) research 'paradigm': that of feminist technoscience research. In this section I try to draw a map of the different research areas/research communities that I have visited during my journey, which have all influenced my work. In this thesis, some areas are more visible in some papers, though I believe that I draw from several areas in most of my work.

Computer science education

As described earlier, the ACM has a special interest group for computer science education (SIGCSE). A very brief description of this community as it appears at the SIGCSE conferences and in its publications[15] gives the impression that SIGCSE is an international forum, though it is dominated by an (Anglo)–American tradition. The main annual conference is always held in the USA, but since the mid 1990's a conference is also held in Europe each year: "Innovation and technology in computer science education". The view of CS as it appears within SIGCSE is the Anglo–American view, where CS is commonly located within science or engineering, and differentiated from Information Systems.

Initially, SIGCSE was not really a forum for research in CS education, but rather a forum where educators met to share experiences and present work along the lines of "this is what I did in my course last year and it worked great" – i.e. it provided inspiration, discussion and feedback. However, a group of people, active within SIGCSE, started to do research into pedagogics/didactics in CS education. This work grew, and there are now a number of journals dedicated to computer science education; as well as conferences (including the SIGCSE conferences), where computer science education (CSEd) research is an important topic. Furthermore, an international "informal alliance", CSERGI (Computer Science Education Research Groups International[16]) has been created, as "an initiative to enhance collaboration between the different computer science education research groups on a world-wide scale." (Berglund 2005, p. 24). This group works actively to advocate high-quality research in the area of CS education.

Anders Berglund provides an interesting and good overview and discussion of "What is computer science education research" in Berglund (2005).

> "The field of computer science education research has a cross-disciplinary structure, and encompasses computer science – of course – but also a wide range of other disciplines: pedagogy, psychology, cognitive science, learning technology, sociology to mention a few. What unifies this diversified field is the aim to improve learning and teaching within computer science, and thereby to contribute to computer science." (Ibid p. 23).

[15] www.sigcse.org/publications/.

[16] www.docs.uu.se/csergi.

On the basis of this description, my work can be placed within computer science education research, in the broadest sense, since my aim is to improve teaching in computer science and also to contribute to the discipline as such. However, my research is not an explicit project within CSEd. Anders Berglund refers to Sally Fincher[17] in her identification of four areas (or types of research projects) in computer science education research (Berglund 2005, p. 25):

1. Small scale investigations of a single aspect of discipline and practice.
2. Investigations motivated by the use of tools in computer science teaching and learning.
3. Investigations of specific mental and conceptual skills in the psychological traditions.
4. Research anchored within the educational traditions.

Using this definition, my research project does not fit into the identified areas of research in CSEd. So, one way for me to look at the relationship between my work and that of CS education research is that my research fits into a broad description of the aims of CSEd, but the research project *per se* does not fit into it.

A good example of recent research in CSEd, belonging under area four in the listing above, is the work of Anders Berglund (Berglund 2005). Using a phenomenographic[18] research approach, he has studied how students taking an internationally distributed project course in computer systems experience the topic of study and act in their learning situation.

Anders Berglund also discusses what he terms "the critical tradition in computer science education research" (ibid p. 32), where he for example writes: "The work of Björkman and Trojer (2002)[19] can illustrate feminist research within computer science" (ibid p. 32). Thus, he regards this type of research as being 'within' computer science education research[20]. But Anders Berglund also notes that there are some fundamental differences between what could be called 'mainstream' CSEd and research within the "critical tradition": "While computer science education research builds on traditional research approaches … the critical research questions values and the foundations of the research as well as the results." (Ibid p. 33).

I consider the CSEd community a potential 'audience' for my research: I have presented my work at workshops and also attempted to publish within it.

[17] Fincher, Sally (2001), in Clancy, M. et al (2001): "Models and areas for CS education research" *Computer Science Education*, Vol. 11 No. 4, pp. 323-341.

[18] See Marton, Ference and Booth, Shirley (1997) *Learning and Awareness.* Mahwah, NJ, USA: Lawrence Erlbaum Associates.

[19] Björkman, Christina and Trojer, Lena (2002) "Computer science and its paradigmatic basis – broadening understandings through gender research from within", in Björkman, Christina *Challenging Canon: The Gender Question in Computer Science*. Licentiate thesis. Karlskrona: Blekinge Institute of Technology.

[20] Which I am of course very happy about. I would like to thank Anders for this, as well as for providing me with the manuscript of his thesis.

The influence of on-going discussions as well as publications within the SIGCSE community is visible in my early work, in particular papers B1 and B3.

Research on gender and computer science: the liberal feminist approach

This is not actually a particular research community, rather an attitude towards the issue of gender and computer science, but I am treating it under a separate heading for the sake of clarity. The perspective in this work can be summarised as the "women into technology/computer science" approach. It is closely linked to gender-equality work: "Equality for women and men in IT is seen as coming about via increased access for women into IT jobs and careers" (Henwood 1993, p 35).

Projects with this approach are about finding and defining what hindrances exist for women in computer science (or technology in general), where the focus has mainly been the low number of female students in (traditional) technical education. Since computer science/engineering is one of the areas where the gender imbalance is very marked, there have been many projects, both research and interventions, targeting these issues.

I would characterise most of the work done and presented within the CSEd community (as it has been visible in SIGCSE) as belonging to the liberal feminist tradition. This work has focused on getting more women into computer science. It is notable that in the SIGCSE community, it is almost exclusively computer scientists who engage in and write about this topic. During the years I participated in and followed the discussions in this community closely, there were only minor influences from and knowledge about research done within social science, pedagogics, etc. Some other research has made its way in, mainly from 'traditional' gender studies within psychology, pedagogy, sociology. I have reviewed and criticised this work in paper B1.

Equality approaches take technology as given, they can be characterised as upholding technological determinism, where technology is seen as a force external to society. One problem with these approaches is that technology is never subjected to critical analysis (Grint and Gill 1995, p. 7). In many studies of gender and CS, the discipline is seen as firmly defined, and the underlying perceptions of development and knowledge are seldom brought into focus. Since technology is seen as neutral, this stance has not seldom led to seeing women as the problem: women should be informed / educated / adapted to technology: "Women shall be enticed into existing practice and adapt to it." (Trojer 1999, p. 13). With this view, it is mainly women who are expected to change. There is also a tendency within liberal feminism to treat men and women as homogeneous groups, ignoring differences between individuals, as well as for example ethnicity and class. In practice, liberal feminist projects have had very little impact on the gender balance within technology or computer science; in fact this approach can be seen as reproducing and reinforcing the status quo.

> "What remains crystal clear is that liberal campaigns to increase the participation of women in technology will amount to little unless they are linked to a radical vision and agenda for the transformation of technology – into a practice that is more democratic and respectful of diversity…" (Faulkner 2001, p. 92).

Science and technology studies and feminist technology studies

Science and technology studies (STS) is mainly an interdisciplinary field within social science and the humanities. I only give a very brief account of this large and diverse field here[21]. It provides a background for the discussion of feminist technology studies, and for me STS also served as an introduction to the latter area. I encountered STS for the first time during my work on the creation of an interdisciplinary engineering education[22] not long before I started my PhD studies, and it contributed to broadening my perspectives.

In my description here, I focus on research concerning technology. The approach taken can be described as recognising that there is no technology without a social context, the relation between technology and society is a densely interactive, seamless web (Faulkner 2001, p. 82). These approaches challenge both technological determinism and the presumed neutrality of technology.

My description of STS below is mainly taken from a presentation of the field written at the introduction of a research centre for STS at Uppsala University[23] (Widmalm and Nissen 2004).

According to Widmalm and Nissen, mainstream STS has grown out of the history, sociology and philosophy of science, with anthropology as an important source of methodological inspiration. Research within the STS field analyses the emergence of new knowledge and technology in a social and cultural context. Studies provide analyses of how research and development are shaped by social structures. Analyses have most often been founded on detailed case studies. On the one hand, they have focused on the production of new knowledge and technology, on the other hand on the growth of systems or networks for the spread and implementation of knowledge. One particular strand that is quite often discussed by feminist researchers is ANT (Actor-Network Theory, based on the work of sociologists John Law, Michel Callon, and Bruno Latour).

Widmalm and Nissen emphasise that it is of fundamental importance for STS researchers to deal with technical problems on a technical level. "In order to understand the social and intellectual realities of science and engineering the practices of research and development must be investigated in detail." (Widmalm and Nissen 2004, p. 13). These authors see the development in STS as calling for a much closer exchange between the humanities and social sciences on the one hand, and science and engineering on the other, something that mainstream STS has traditionally been lacking (ibid p. 12). "The challenge today is for STS scholars to collaborate more closely with scientists and engineers, thereby confronting their own work with the social and technical realities

[21] An extensive overview of the field can be found in Jasanoff (1995).

[22] The "Systems in technology and society" engineering programme at Uppsala university, http://www.utn.uu.se/sts/. This engineering programme integrates traditional engineering subjects with courses from social science and the humanities, where the overarching approach is that of science and technology studies.

[23] See http://www.sts.uu.se/.

that it purports to describe...." (ibid p. 12). I believe that such a development could also contribute to a much larger extent than is currently the case, to transformation within the practices of science and technology.

Feminist studies of technology can to a large extent be regarded as part of the STS tradition, in that the starting point and approach can be summarised as the social construction / shaping of technology. According to Vehviläinen (2001) this approach sees technology as a process consisting of three interrelated parts: artefacts, knowledge and social practices. As within the 'parent-field' of STS, the studies are mainly done from within social science or the humanities.

This is a large and quite diverse field of research. Here, I will briefly describe and discuss the research that I have studied as part of my own research. Good overviews of the field can be found in Grint and Gill (1995) and Vehviläinen (2000). Wajcman (1991) is a classic book.

According to Grint and Gill (1995), the area has grown out of STS and feminist critique of science (I discuss the latter below). However, as Wajcman (1991) notes, there are fundamental differences between (natural) science and technology: technology needs to be understood as more than applied science, since it is primarily about the creation of artefacts (ibid p.13). Håpnes and Sörensen (1995, p. 175), argue that feminist technology studies has not only grown out of STS research, but at least in Scandinavia also has ancestry in industrial sociology and labour process theory.

Many feminist researchers do however criticise much of the mainstream research within STS for making gender and power invisible (e.g. Wajcman 2000). Their argument is that the absence of certain groups in the making of technology may also be significant.

To begin with, feminist technology studies mostly consisted of empirical studies of particular types of technology (where reproductive technologies constituted one major area). Grint and Gill (1995) argue that in the mid 1990's, the field of gender and technology was under-theorised. Around this time, a shift towards understanding technology as culture became more apparent. According to this view, both gender and technology can be understood not as fixed and given, but as processes, which are constantly being formed and re-formed in ongoing negotiations in relation to each other. Flish Henwood's article "Establishing gender perspectives on information technology: problems, issues and opportunities" (Henwood 1993) marks out this shift in technology studies. Henwood provides a good historical overview of how computing changed from a woman's job to one occupied mainly by men, which she sees as linked to changing definitions of skill. She further argues that:

> "Technology meanings are not 'given', they are made. … We should be focused on that knowledge … we have to be involved at the level of definition, of making meanings and in creating technological culture." (Ibid p. 44).

One strand in this research can be called the "technology as masculine culture" approach (e g. Håpnes and Sörensen (1995) as well as Nissen (1996) discuss computing as

masculine culture). As pointed out by Grint and Gill (1995), the idea that technology and masculinity are intimately related seems to be accepted by most feminist writers within this tradition, who rather than challenging this idea try to understand why this is the case. These researchers claim that the definition of technology too readily defines technology in terms of male activities, and that the dominant (western) cultural ideal of masculinity[24] has an intimate bond with technology. Thus, technology has been defined to exclude technologies invented and used by women. This means that women's contributions to technical development are largely ignored, as is also pointed out by Judy Wajcman (Wajcman 1991). "Women's alienation from technology is a product of the historical and cultural construction of technology as masculine" (Grint and Gill 1995, p. 8). This has been taken further by some researchers (e.g. Wajcman 1991) to suggest that for women to enter into technical fields has implications for their feminine identities (where femininity is constructed as the opposite of masculinity, and hence as rejecting technology). According to this view, entering technology endangers women's sense of femininity.

Within some feminist analyses of technology, technical determinism as well as essentialism seems to persist (e.g. women lack technical skills, or certain technologies are not consistent with women's values). As pointed out by many researchers, working with the concepts of 'men' and 'women', and furthermore seeing these as binary oppositions, creates these risks of essentialism. One example of such a pervasive idea is that men are interested in technology *per se*, while women are interested in what it can be used for. Such ideas become prescriptive and are quickly naturalised into truths. This has been challenged by for example Catharina Landström (Landström 2004). She argues that some work in feminist technology studies has (however involuntarily!) reproduced gender as a stable dichotomy and confirmed traditional views about gender and technology. For example, she claims that many of these studies start with the assumption that women and men relate differently to technology. This does not account for all the varieties that exist, but reinforces stereotypes of gender and technology.

Feminist technology studies have been valuable for me as a more radical approach than the liberal feminist perspective, broadening the views and approaches to technology and computer science. It has also made me aware of the large risk of writing 'the other' into a text, of looking at engineers/computer scientists from the 'outside', and not meeting them in respect for their own practice. This is an issue that I have tried to address explicitly in my empirical work (in particular in paper C2).

This type of research provides possibilities to deconstruct the social bases of technology and technical artefacts. However, what is often left untouched is the epistemological basis. This can of course be seen as part of the social basis, but what I want to say is that epistemology is seldom included in these social analyses, which often stop at levels of cultural inscriptions.

[24] Note that masculinity and femininity are defined as socially and culturally constructed, historically changing notions, which are, however, often confused with (biological and physical) men and women.

Feminist science-critical research and epistemology – a brief introduction

This research is important as constituting a background both for feminist technology studies as discussed above, but even more for the area of feminist research within science and technology, which I discuss below.

Some 30 years ago, feminist researchers started to address science as both knowledge and institution. The starting point was in the claim that science is andro-centric and has to be changed so that it better serves women, in all their diversity (Rose 1994). It was thus perceived inadequacies and imbalances in established research that motivated a growing feminist critique of science. This feminist science critique evolved from issues about women, to realising and focusing on problems concerning how science is constructed and practiced. This was formulated by Sandra Harding in her groundbreaking book "The Science Question in Feminism" (Harding 1986). Harding argued for a shift of focus, away from "the woman question in science", by which she meant "What is to be done about the situation of women in science?" (Harding 1986, p. 9) and towards "the science question in feminism". A new focus for research came to be science itself, its theories, methods and other knowledge processes.

An important feminist science critic is Evelyn Fox Keller. Having herself been an active scientist (within physics and later mathematical biology) she has long and deep experience of the inner workings of science. This makes for a perspective from within *both* science and feminist science studies, making her analyses particularly pertinent. She has contributed to the understanding of gendering of metaphors, for example she has discussed in depth issues of what she calls "gender *in* science" (Fox Keller 1995, p. 86, original italics). Here, she draws attention to how gender metaphors work in two directions, or rather in a vicious circle: social expectations influence how representations of nature are chosen. These representations will then reproduce cultural beliefs and practices.

Feminist science critics commonly prefer scientific models that are interactionist and contextual, over those which are linear, hierarchical, causal or "master" theories (Fox Keller 1995). This is in opposition to the dualisms of mind and body, culture and nature, as well as projects of domination. An example of this is that hierarchical structures, e.g. in biology, can be used to support existing social hierarchies and structures, as well as for domination and control.

I have been greatly influenced by the essays in Evelyn Fox Keller's book from 1992: "Secrets of life, Secrets of Death", and in particular the essay "Critical silences in scientific discourse". Here, she discusses how science could be transformed. She also discusses how representation and the form of scientific knowledge and not only content is important. Representations will in themselves carry understandings. She argues that we need a more complex understanding of *how* science works and *for whom* it works.

Evelyn Fox Keller has also, together with other researchers, in particular within post-structuralism[25], pointed to the importance of language in the making of science.

[25] For a good description and discussion of poststructuralism, see Dorthe Gert Simonsen (1996).

I want to emphasise that feminist research has always had transformation as a prime goal:

> "Feminist critique of science […] is a politically engaged discourse committed to changing both the present organisation of the production of scientific knowledge and the knowledge it produces." (Rose 1994 p. 20)

The feminist epistemologies I build my work on do not accept the (still strongly prevalent) ideas of science and the scientist as neutral and objective. This is eloquently expressed by Sandra Harding:

> "Observations are theory-laden, theories are paradigm-laden, and paradigms are culture-laden: hence there are and can be no such things as value-neutral, objective facts." (Harding 1986, p.102).

Feminist epistemologies are critical of paradigms of objectivity, and of the neutral and objective observer, what Donna Haraway terms "the God-trick of seeing everything from nowhere" (Haraway 1991, p. 189). Instead, she develops the concept of *situated knowledge*:

> "I am arguing for politics and epistemologies of location, positioning, and situating, where partiality and not universality is the condition of being heard to make rational knowledge claims. These are claims on people's lives; the view from a body, always a complex, contradictory, structuring and structured body, versus the view from above, from nowhere, from simplicity." (Haraway 1991, p. 195).

Situated knowledge is a far-reaching concept, which I understand and use as implying an epistemological standpoint. Thus, *situatedness* refers to conscious epistemological positioning. It is not simply a matter of an individual place or state, it is part of practice and knowledge production, and it means actively taking a stand. And there is no such thing as an innocent position.

Feminist epistemology contributes by expanding the notions of knowing, accepting other and different ways of knowing than the dominant propositional view of knowing ("knowing that", e.g. Adam 1998). An important notion is *epistemological pluralism* (e.g. Wagner 1994). Furthermore, feminist epistemology acknowledges (embodied) experience as a valid basis for knowledge.

These feminist epistemologies attempt to refuse the choice and dichotomy between on the one hand universalism and on the other relativism. Donna Haraway's alternative to both is partial, locatable, situated knowledge.

I discuss this epistemological basis and how I use for example the concepts of *position* and *partial perspectives* (Haraway 1991) in several of the papers in this thesis, e.g. papers B2 and C2.

Feminist research in science and technology

Feminist research can have two general focuses: sex/gender on the one hand and feminist frameworks for science itself on the other. Feminist research within natural science and technology mainly concentrates on the second of these, focusing on science itself, its theories, methodologies and other knowledge processes. Feminist research studies the

basis of the discipline and develops new ways of approaching the core of knowledge production.

In studying and discussing the foundations of the disciplines, this kind of feminist research makes visible the kinds of understandings that are represented in the knowledge production. In addition, it aims at formulating other kinds of understandings. This research is thus not limited to simply drawing attention to the perspectives, experiences and needs of women. It is important to note that feminist research in technology does not develop 'female' technologies as distinguished from dominating 'male' technologies. "On the contrary… a gender dichotomous thinking reproduces a stereotypical thinking and risks reproducing a far too narrow understanding of technology." (Trojer 2002. p. 62).

Knowledge and knowledge processes within science and technology are of particular interest for feminist research. A number of questions beg to be asked, such as: what knowledge is valid and why? Who can have knowledge? Who has the preferential right of interpretation and why? And "Whose science? Whose knowledge?" (Harding 1991). Last, but not least: how could it be different? Such questions can throw light on implicit scientific practices.

Interdisciplinarity is one of the fundamental prerequisites for feminist research in technology (Trojer 1998). Furthermore, it is important to stress once again *transformation* as an important goal for feminist research. Feminist research in technology aims to participate in development of processes of change within technology.

For a thorough account of feminist research within science and technology, see the work of Lena Trojer (2002). Christina Mörtberg has also discussed these issues, e.g. Mörtberg (1999).

Within computer science, the body of feminist research is still small, but growing. I see myself as belonging to this community of researchers. In my opinion, using and developing feminist research within CS opens up possibilities for new approaches. Theories and methodologies developed in feminist research offer new opportunities to explore issues around knowledge in CS. In particular, I believe that feminist epistemological thinking has the potential to enrich computer science, especially by focusing on epistemological pluralism. In this way, feminist research could become an active participant, in particular within CS education, and work for broadening the meaning of "knowing CS", to accommodate diversity both among practitioners and practices.

To take a few examples, feminist research in computer science has challenged the 'paradigms' or fundamental metaphors of the discipline (e.g. Grundy 2000, 2001), made visible the underlying epistemological foundations for object orientation (Crutzen and Gerrissen 2000) and argued for integration of use and practice into the core of computer science (e.g. Bratteteig and Verne 1997).

Feminist research in computer science is surveyed and discussed in papers B3 and B4.

Feminist technoscience research

> "Feminist inquiry is about understanding how things work, who is in the action, what might be possible, and how worldly actors might somehow be accountable to and love each other less violently." (Haraway 2003, p. 6f.).

I belong to the research group Technoscience Studies at Blekinge Institute of Technology (BTH) and see myself as a feminist technoscience researcher. But what does this mean? It is important to point out that this research, as it is practised in our research group, has grown out of (and belongs within) feminist research in technology (described above).

The main academic aim of the Technoscience Studies research group is to develop complex understandings of information and communication technology as reality-producing technologies from the perspective of feminist research in technology. A prerequisite for this work is our own participation in processes of knowledge and change in technology. Internationally, feminist technoscience research provides an epistemological foundation for a variety of choices and decisions in a society that is increasingly dependent on research and technology[26].

I understand the concept of 'technoscience', as implying that the boundaries between science, technology, politics and society are blurred, not sharp and firm. Donna Haraway is the main source of inspiration for my use and understanding of 'technoscience'. Her view implies attention also to hybridisation processes between humans and non-humans (cyborg theories).

I want to quote at some length from the interview with Donna Haraway in Haraway (2000), pp. 156–158. The interviewer (Thyrza Nichols Goodeve) asks Donna Haraway to describe her model of feminist technoscience.

> DH: "Understanding technoscience is a way of understanding how natures and cultures have become one word. So the analysis of technoscience, the understanding of what kind of world we are living in, is what we call technoscience studies. Feminist technoscience studies … involves technoscientific liberty, technoscientific democracy, understanding that democracy is about the empowering of people who are involved in putting worlds together and taking them apart, that technoscience processes are dealing with some worlds rather than others, that democracy requires people to be substantively involved and know themselves to be involved and are empowered to be accountable and collectively responsible to each other. And feminist technoscience studies keeps looping through the permanent and painful contradictions of gender… Feminist technoscience really means going beyond the kinds of institutions we have now. It's filled with different kinds of work processes and knowledge-practices, including reshaping time and space."
>
> Interviewer: "What is your modest technoscientist then?"
>
> DH: "I never used that phrase exactly, but if I did it would have to do with a kind of willingness, and ability; a honing of skills, of being alert to and opening up your work to kinds of accountability you might have resisted before."

Pirjo Elovaara points out important features of feminist technoscience research:

[26] See http://www.bth.se/tks/teknovet.nsf/ for a further description of Technoscience Studies at BTH.

> "Feminist technoscience research is not keen to be labelled under one specific school or frame, but as I understand it, it challenges much of the present understandings, interpretations and even experiences of technology and demands re-thinking." (Elovaara 2004, p. 27).

Much of feminist technoscience research has revolved around exploring the epistemological foundations of knowledge understandings and practices, where above all Donna Haraway's figurations of situatedness and partiality have been central for this work (Haraway 1991). To a large extent this research has been about deconstructions, opening up concepts and definitions. However, feminist technoscience research does not want to stop at opening up the 'black box'of technology; it also wants to ask questions such as: could and should things in the black box be otherwise?, "… there is nothing necessary or inevitable about the presence of such franchises." (Star 1991 p. 38). And if so, how could things be different? It is about finding new approaches, ideas, understandings, and possibilities for intervention and change, in my case with a focus on computer science, in particular CS education.

In working from a feminist technoscience perspective, it is important to ask in what ways we can connect research with our other practices, such as education and working together with people with different perspectives and knowledge productions, in order to contribute to intervention and change.

Paper A2 in the thesis further presents and discusses feminist technoscience as practiced in the research group Technoscience Studies at BTH.

Method(ology)

The topics of method and methodology are tightly entwined with that of epistemology. Sandra Harding (Harding 1987) points out that methodology and epistemology are intertwined with what we do and how we do it. She argues that there is no one feminist method. For my research, methodology and epistemology are the most important, providing the different approaches I have used.

Sandra Harding defines a methodology as "a theory and analysis of how research does or should proceed" and also as concerning how theory is used in different disciplines (Harding 1987 p. 3). Thus, the epistemological position of the researcher has implications for how theory is chosen and applied.

From my perspective, the idea of methodology is formulated even more clearly and explicitly by Liz Stanley and Sue Wise: "A 'methodology' is a 'perspective' or very broad theoretically informed framework …" (Stanley and Wise 1990, p. 26).

An example of a methodology is, in my opinion, the importance stressed within feminist research of placing the researcher in the same plane as the researched, which puts the entire research process (not only the research object) under scrutiny (Harding 1987). The researcher is not a neutral, invisible, anonymous person, but a visible, situated person with specific interests and behaviour who becomes part of the whole process. This approach can be called *reflexivity*, and I will discuss it in more detail below. This kind of methodology also follows explicitly from the epistemological positioning.

Seeing emotions as a research experience (Stanley and Wise 1990 p. 23), and thus something to be taken seriously, can also be said to constitute a methodology, or comprehensive approach. Taking feelings seriously makes a useful contribution to research. I found that by analysing and applying analytical and critical reflection to what could be dismissed as 'mere feelings', I have gained valuable insights (as was very clear in the project discussed in papers C1 and C2). Emotions can, if properly investigated, say something about the situation in hand; they can be a part of the learning process.

In this section, I outline the ways I have worked, which could be called my 'methods'. The methods are also described and discussed in the papers.

Gathering material

In Sandra Harding's words, "a research *method* is a technique for (or way of proceeding in) gathering evidence." (Harding 1987, p. 2). In this sense, the research methods I have used largely fall into two categories: what Sandra Harding terms "examining historical traces and records" (ibid p. 2) and "listening to (or interrogating) informants" (ibid p. 2).

If the first method can be extended to reading/examining articles, this is the method I have mainly used in papers B1–B4. I have discussed how the texts were selected in the individual papers. As for the analysis, see below.

The second method, "listening to and interrogating informants", is the method used in paper C2. The empirical material consists mainly of taped project meetings, to

which I have applied what I call 'reflective listening' (see paper C2). I also transcribed the conversations and coded them according to various themes. Taped and transcribed interviews with the project participants supplemented this material. I would say that this is also the method used in paper A1, although in a slightly unusual way, in that the 'informant' is the engineer in me, i.e. it can be seen as the technoscience researcher 'interrogating' and interpreting an engineer.

However, my use of these familiar methods is done from the perspective of, and is entwined with, epistemological and methodological positionings.

Analysing material

In my analyses, I have used an analytical and epistemologically positioned attitude or approach, rather than any particular method. "At bottom, feminism is a mode of analysis" (Hartsock 1998, p. 35). I here outline and describe the ways I have worked in analysing my material.

Reading texts – asking questions

> "Questions are a way of opening up the world. Answers without questions do not yield any knowledge. By contrast, questions without answers can open up the world, for example, by revealing voids. Voids can lead to other questions and action. We can even ask questions without answers." (Molander 1996, p. 176).

The papers in part B all focus on texts: texts concerning gender and CS (B1 and B2), texts on the foundations of CS (B3) and texts from the philosophy of computing (B4). The 'method' I have used here is a critical reading and interrogation of these texts, pointing to issues that from my feminist technoscience research perspective are particularly interesting.

In papers B1 and B2, the questions concern how the issue of gender and CS is constructed. In paper B2, my method is to interpret and ask questions from different perspectives on a specifically chosen text.

In papers B3 and B4, the questions target views of knowledge and what CS is considered to be. The questions here are asked from an explicitly feminist technoscience perspective, where I have for example been sensitive to words that signal approaches to knowledge in the texts I read.

I ask questions in order to highlight important issues. These are generally not questions that need immediate answers; they should rather be seen as comments from a feminist technoscience position. Asking questions is a way of starting a reflective process (both within myself as the researcher implied in my work, and among computer scientists) as well as being a way to communicate. These questions are meant as starting points for respectful, shared conversations between feminist research and computer science practice.

I have found that asking questions sometimes gives rise to astonishment, when the questions are unexpected (e.g. this is visible in paper C2). For this reason, I am very fond

of Sara Heinämaa's 'definition' of feminism, which I use to set the tone for this thesis:

"Feminism is not a dogma but a set of critical questions"[27].

Including myself

As Lena Trojer and Elisabeth Gulbrandsen point out, "as partakers in the modern research complex, [we need] to develop a readiness to think and feel ourselves as part of the problem, and learn how to use our implicatedness as a resource for transformatory projects." (Trojer and Guldbrandsen 1996, p. 131). To be included, both in the material and in the analysis, is a method I have used explicitly, in particular in papers A1 and C2, where I also discuss this method.

Including oneself is related to the methodological approaches I discussed above: putting the researcher on the same plane as the researched, and seeing emotions as constituting part of the research experience and material. The latter is also pointed out by Mats Alfvesson and Kaj Sköldberg (Alfvesson and Sköldberg 1994), who write about the position of the researcher in qualitative research: "Self-reflection and critical self-analysis of feelings is an important part of the research process" (ibid p. 295). They also note that within "women's studies" there are several examples of how the researcher uses his/her own experiences and feelings as a systematic part of method (ibid p. 296). I have made use of this in particular in papers A1 and C2.

The issue of including oneself is closely related to the next issues:

Positioning and critical reflection

In several of the papers in this thesis I have consciously and deliberately used my different knowledges and experiences. To do this, I use the concepts of *position* and *positionings* (e.g. papers B2 and C2). I take the concepts mainly from Donna Haraway (Haraway 1991). *Positioned* implies the use of power or strategy and a subject (and sometimes also an object). A position can either be forced upon me by others, in which case my subjectivity is limited, or I can choose it, take it strategically and use it as a conscious subject. Thus, I can either be *positioned* or I can *position* myself. In these papers I use conscious and explicit positioning. This 'method' enables me to see several different stories. I can let different positions confront each other, ask questions, interpret, analyse and listen to each other, while I move between them.

Closely related to positioning is the issue of *reflection*. By this I mean *critical reflection* (e.g. Harding 1991, Gulbrandsen 1995). Included in this is critical *self-reflexivity*. It is vital for me to subject both myself as a feminist researcher and feminist research to a critical gaze. I use this in paper C2 in particular, where I am also inspired by the method of "reflexive interpretation" (Alfvesson and Sköldberg 1994).

[27] Sara Heinämaa in an interview with Tuva Korsström (my translation). Korsström, Tuva (2002) *Kan kvinnor tänka? En undersökning av det kvinnliga tänkandets villkor* [Can women think? A study of the conditions for women's thinking], Stockholm/Stehag: Brutus Östlings Bokförlag Symposion.

Donna Haraway recognises this critical or *strong reflexivity* as being close to her figuration of *diffraction* (Haraway 1996, p. 439). I have come to realise that what I have done could be described by this figuration[28].

Diffraction

Diffraction is an optical phenomenon that occurs when light passes through a narrow slit. The light rays at the edges of the slit will be bent and also to a certain degree reflected at the edges, causing a spread of the light after the slit. The narrower the slit, the greater the angle that the light is spread by. This means that the image produced on a screen opposite the slit is not sharply demarcated. Instead, a *diffraction pattern* appears on the screen, which is seen as a broadened and somewhat diffuse centre image, and on either side of the centre image there is a pattern of weaker secondary images separated by dark areas. This pattern results from the wave-like behaviour of light.

If instead we have a grating with a large number of slits in, and let light (of only one wave-length) pass through it, the result will be a sharp central line opposite the grating, surrounded by less intense, but nevertheless sharp lines at particular intervals. If, on the other hand, the grating is illuminated with white light, it will be split into a spectrum, with all the colours visible.

Donna Haraway describes diffraction in the following way:

> "When light passes through slits, the light rays that pass through are broken up. And if you have a screen at one end to register what happens, what you get is a record of the passage of the light rays onto the screen. This "record" shows the history of their passage through the slits. So what you get is not a reflection; it's the record of a passage." (Haraway 2000, p. 103).

She sees diffraction as carrying "more dynamism and potency" (ibid p. 101) than reflection: "Reflection displaces the same elsewhere; diffraction patterns record the passage of difference, interaction and interference." (Haraway 1996, p. 429f.). It is about difference, and about making a difference: "Diffraction is a metaphor for another kind of critical consciousness … one committed to making a difference […] So I use it to talk about making a difference in the world, as opposed to just being endlessly self-reflective." (Haraway 2000, pp. 101f., 104).

Physicist and feminist researcher Karen Barad finds this metaphor or figuration a useful way to avoid the "representationalist trap of geometrical optics" embedded in reflection (Barad 2003, p. 803). For her, diffraction is a way of "thinking about differences that matter" (ibid p. 803), as well as thinking about boundaries: "The diffraction patterns illuminating the indefinite nature of boundaries – displaying shadows in 'light' regions and bright spots in 'dark' regions" (ibid p. 803).

Christina Mörtberg interprets the figuration in the following way: "Haraway uses […] diffraction to shed light on various meanings or stories that exist at the same time. The beams illustrate different positions or contexts…" (Mörtberg 2003, p. 65).

[28] My colleagues know that for a long time I was sceptical about this concept, not really knowing how to make sense of it from my engineering physics background.

I fully agree with Donna Haraway's aim of critical consciousness, of making a difference, and that is how I have used the concept of self-reflexivity. The reason I have been sceptical about diffraction is that I have not been able to make sense of the part about the passage through the slit(s). What does it mean that the diffraction pattern shows the record of the passage through the slits? Where in my own work do I find the slit(s) creating the passage(s) for texts, empirical material, experiences, etc.?

However, I think I can look at it like this: if I am the grating, where my different positions and perspectives are the slits through which the material I study, as well as my experiences, pass, this will create many images on the 'screen', i.e. the stories that I tell. This is thus a diffraction pattern, where some stories are stronger than others, some stories disappear, but many stories exist. The broad light beam (the initial story, the source) is diffracted into several stories. The slits make it possible to see parallel and different, diffracted, stories. This is perhaps a particularly relevant way to look at the situated readings I have done in paper B2, which could also be called "diffracted readings".

One of my ambitions with this thesis is to tell several different stories, to show how things can appear to the computer scientist, the feminist (technoscience) researcher and from the position that I am aiming at: the feminist computer scientist.

Interventions – conversations and dialogues

As pointed out earlier, *transformation* is a prime goal for feminist technoscience research. Since I am aiming at transformation in computer science education, *interventions* have been an important part of my research (interventions are methods used in papers C1 and C2). The issue is how feminist researchers and (in my case) computer science educational practitioners can make things happen together.

The questions I ask in my readings are meant to be brought into shared conversations, into dialogues where feminist researchers and computer scientists together look for potential answers. What is needed is to get involved in respectful conversations without losing sight of my own goals, fundamental ideas and epistemological positioning.

For the material from this project, used in papers C1 and C2, this means that I do not have the traditional role of the researcher who listens to the informants, but I am an active participant, thus contributing to what happens. I discuss this further in the papers.

Brief Outline of the Thesis

I have chosen to organise the articles under three themes, not chronologically. Each part relates to one of the three issues in the title of the thesis – issues I have identified as feminist technoscience strategies in computer science. Here, I will introduce the three parts briefly. Each part then has its own introduction, where I describe and comment on the papers and put them into context.

I believe the order of the papers and the road through them is important when reading and understanding the research I have done. At the end of the thesis, I have included an epilogue, where I look back and summarise the work done and discuss the contributions of the thesis.

Part A, "Crossing Boundaries"

This part can be seen as constituting and discussing important points of departure for my research, but also some 'end-points'. It deals with what it means to do the kind of research that I do, as well as the work we do in the research group Technoscience Studies. It contains discussions of inter/transdisciplinary work on and across boundaries and what is needed in order to communicate between "worlds" and thus contribute to transformation. I also investigate and discuss what it means to be simultaneously an engineer/computer scientist and a feminist technoscience researcher, to live on boundaries.

Part B, "Focusing Foundations"

This part consists of studies of texts, which I critically read and query from a feminist technoscience perspective, in order to challenge existing approaches and concepts within computer science. The texts are about the gender question in computer science, foundational topics of "what is computer science", as well as epistemological questions concerning approaches to knowledge in computer science: "what does it mean to know computer science"? These papers also illustrate the journey I have done in my research: from using feminist technoscience research as 'tools' and towards communication and translation.

Part C, "Trying Translations"

This part is about a concrete intervention project aiming at establishing conversations with computer science faculty. In this project, the issues of communication and translation appeared as central. The focus in this part is communication between computer science educational practice and feminist technoscience research, language as a carrier of epistemology, and a discussion of translation.

Epilogue

I finish this thesis with a brief epilogue, or postscript. Here, I look back on the research journey. I discuss and summarise the thesis and its contributions, and what I see as feminist technoscience strategies in computer science.

The presence of two "worlds" in the thesis

The two "worlds" of engineering/computer science and feminist research are both present in the thesis. There are mainly two voices[29]: the engineer/computer scientist, and the feminist technoscience researcher, occasionally uniting to form a third: the feminist computer scientist. These voices can be recognised through their language and style of writing. I believe both are strongly present throughout the entire thesis, even though there is a chronological factor, where the engineer/computer scientist is likely to be more dominating in the early texts (in particular paper B1). This is visible in language and expressions, such as the use of categorisations and categorical statements. However, the engineer and computer scientist is also deliberately brought out in papers A1 and C2. A reader from within feminist research might see a 'development' in thinking and writing in the thesis. By contrast, a reader from computer science might find the earliest papers the most readable and comprehensible (and possibly most interesting). This reader might find interesting questions and issues in the thesis, but no answers, and might therefore be disappointed. These potentially differing views illustrate once again the different "worlds".

My belief is that both voices are necessary. If I want to make myself understandable to and communicate with computer scientists, I need to keep the computer scientist voice alive in my texts. The conflicts need to be there, their presence is about not striving for unity and smooth texts, but instead revealing the complexity. I believe it is important to let the different voices, experiences and perspectives be visible, even if this means potential inconsistencies.

[29] By two voices, I do not mean that these two are consistent, nor always exactly two, but I want to stress the existence of two quite different, sometimes opposing voices.

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Introduction to Part A: Crossing Boundaries

This part can be seen as constituting and discussing important points of departure for my research, but also some 'end-points'. I have chosen to include these articles in a separate section, since aspects discussed in these are important for the other papers in the thesis. Chronologically, these papers are originally written/presented soon after the middle of my PhD studies, both of them originating in 2003.

I investigate and discuss what it means to be simultaneously engineer/computer scientist and feminist technoscience researcher, to live on boundaries. What boundary crossings, challenges, conflicts, negotiations and issues of being inside and outside are involved? This part also focuses on what the implications of boundary crossings and multiple identities and "mind-sets" are for transformatory work in science and engineering, as well as a discussion of what feminist technoscience research can be and how it can be used for interventions and transformations.

Paper A1 came out of the experiences I had of different "worlds" or "mind-sets" within myself. In the article I use some experimental writing such as a "narrative of the self", and a dialogue between the engineer and the feminist technoscience researcher. It is in a way similar to a feminist researcher doing close interviews with an engineer/computer scientist, the difference here is that I take both positions and let them participate in a dialogue, i.e. I use my own experience. One way of seeing the article is as a reflexive discussion concerning engineering and feminist research. The article introduces the problem of differing "mind-sets", epistemologies and methodologies between different "worlds", which in turn have implications for doing feminist technoscience research in engineering and related areas (e. g. the work forming the basis for part C in the thesis). These "mind-sets" are important for several functions: they are in this article mainly the subject of investigation, in other articles (e. g. B2 and C2) they are a method used in the analysis, and it is suggested that by developing knowledge about these they can provide tools for change and communication between "worlds". The experiences and knowledge in this paper, and the last paper in the thesis, C2, are connected, making up a sort of spiral movement.

Paper A2 is a joint paper with Lena Trojer and Pirjo Elovaara. For my research, this paper outlines the position of "feminist technoscience researcher" which is the explicit starting point for my work, in particular the work with the project that is the topic of part C. Furthermore, this article can be seen as a 'manifesto' or policy statement for the research done within the Technoscience Studies group at BTH. An important issue here is that feminist technoscience research does not want to stop at deconstructing and criticising technology and its knowledge processes, but has a transformatory goal. In this paper we discuss how feminist technoscience research, in particular in the area of information technology, can be used for interventions and transformations. This is illustrated by the respective author's own story about the interventions we create and/or participate in. The stories illuminate and discuss the kind of research taking place in meetings and co-operation with other knowledge producers within or outside of academia. We conclude the article with a discussion about the possibilities and potentials we see for feminist technoscience research.

Contribution: I see the contribution from this part in the in-depth discussions of inter/transdisciplinary work on and across boundaries and by illuminating the differences between "worlds" and what is needed in order to communicate across them and thus contribute to transformation.

Paper A1

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The Engineer and the Feminist Researcher - A Story of (Im?)Possibilities

> "The reasons for the divergence in perception between feminist critics and women scientists are deep and complex. Though undoubtedly fuelled by political concerns, they rest finally neither on vocabulary, nor on logic, nor even on empirical evidence. Rather, they reflect a fundamental difference in mind-set between feminist critics and working scientists – a difference so radical that a "feminist scientist" appears today as much a contradiction in terms as a "woman scientist" once did". (Fox Keller 1992, p. 21).

Introduction

I am an engineer. I am a feminist researcher. These 'labels' can be thought of as kinds of multiple identities, belonging to in several senses separate worlds. I think of them as identities when it comes to epistemology, approaches to knowledge, modes of thinking, of working, of doing research, of talking and writing, of language.

In this article I investigate and discuss what it for me means to be simultaneously engineer and feminist researcher. The point of departure are my experiences of what Evelyn Fox Keller calls different "mind-sets" or as I call them: "thinking modes". I use these experiences as a starting point for discussing feminist research and transformatory work in engineering and related areas.

About the title

My undergraduate education is in engineering; I have an MSc in engineering physics. After that, I have worked as a lecturer in computer science (CS) for many years. To be more correct the title should have said "the engineer/computer scientist… (but that was a bit long). I see the training as engineer as the primary basis for one of the "mind-sets" I will discuss, and since education tends to make strong and lasting imprints, this 'identity' continues to live on strongly within me. My work in computer science has in no way upset this engineering "mind-set", rather it has been strengthened. There are no major obstacles or conflicts between the thinking of an engineer and a computer

scientist, their foundation, not the least within epistemology, are in all important matters the same. In fact, engineering is seen as one of the roots of computer science (e.g. Denning et al. 1989). I see computer science (as it is practised in Sweden today) as very close to engineering, not only because of language and ways of working, but simply because computer science is concerned with construction of artefacts, be they computers, models of computation, or computer programs.

The second part of the first line of the title should be expanded to "feminist technoscience PhD student"[1], in order to situate myself more specifically within the large family of feminist research, as well as to signal that I am in the process of becoming a researcher.

The last part of the title indicates problems. I write about what I have from time to time experienced as impossibilities, but that is by no means the end of the story…

Content

I take my starting point in emotions, thoughts and experiences that have kept me preoccupied. These experiences, which have been present during my whole time as PhD student, gradually grew somewhere in the middle of the studies, and became an almost on-going discussion or close to conflict within me. They have mostly appeared during conferences, seminars and the like, i.e. those are times when I have not been able to avoid them.

From these experiences grew a need to deal with the conflict. By speaking up, formulating and articulating these experiences, feelings and thoughts, and by analysing them, I want to deal with these 'identities' in me. As Mats Alfvesson and Kaj Sköldberg (Alfvesson and Sköldberg 1994) point out: "Self-reflection and critical self-analysis of feelings is an important part of the research process" in qualitative research (ibid p. 295).

My aim is to investigate and analyse these experiences and see how they can be useful for my concern and goal: the feminist technoscience project in engineering and computer science.

In this article I discuss what it can mean to be both engineer/computer scientist and feminist researcher (which is not to say that everyone sharing the same background and concerns as I do have had the same experiences).

I write this paper from the position of feminist technoscience PhD student. It is the feminist researcher looking at and interpreting the engineer, not from the 'outside', but from the 'inside', which requires that I can bring reflexivity from the feminist researcher to the engineer. I would not be able to reflect on the engineer in this way had I not been trained in reflexivity as feminist researcher. As engineer, this type of critical reflexivity

[1] See http://www.bth.se/tks/teknovet.nsf/. For a discussion of feminist technoscience as practiced in the research group Technoscience Studies at Blekinge Institute of Technology, see Björkman, Elovaara, Trojer (2005).

is not part of my repertoire, something that Evelyn Fox Keller, with her long history as practising scientist, helped me understand: [2]

> "The reality is that the "doing" of science is, at its best, a gripping and fully absorbing activity.… The net result is that scientists are probably less reflective of the "tacit assumptions" that guide their reasoning than any other intellectuals of the modern age. […] Indeed, the success of their enterprise does not, at least in the short run, seem to require reflexivity. Some would even argue that very success demands abstaining from reflection upon matters that do not lend themselves to "clear and distinct" answers". (Fox Keller 1992, p. 27).

One reason for this lack of reflexivity is that as scientist or engineer, you most of the time work on a very detailed level, a small part of a large system for example, with a solution to a small problem, and thus very seldom see the "big picture". You are entirely occupied by intricate details and very seldom at the "higher" level where reflection becomes necessary. The reality of engineering work today is a fragmented process, "in which most engineers occupy specialist roles, where reductionism is acceptable, while only a few ever occupy heterogeneous roles, where holism is necessary" (Faulkner 2001, p. 87).

I deliberately use dichotomies and simplifications in my story. Using simplifications, dichotomies and categorisations is sometimes necessary, in order to be able to talk about things. But it is at the same time crucial to remember that these are simplifications, and not a general description of "how things are". However, the issues I discuss are important for the general discussion of feminist research communication with, and interventions into, technology and science.

From the starting point in my experiences, I go on to discuss more general issues of different "mind-sets" and practices of knowing, and their implications for doing feminist technoscience research in engineering and related areas.

Form

In writing this article, I have been inspired by Laurel Richardson's article about writing as "a method of inquiry" (Richardson 1994). She demonstrates how "…science writing, like all forms of writing, is a sociohistorical construction and, therefore, mutable." (Ibid, p. 518). Donna Haraway further helps to see the historical construction of the traditional science writing, in her discussion about the "modest witness" [3], and how this witnessing was transferred to the written scientific report: "…the rhetoric of the modest witness, the 'naked way of writing', unadorned, factual, compelling, was crafted. Only through such naked writing could the facts shine through, unclouded by the flourishes of any human author." (Haraway 1996, p. 432).

Richardson argues that as researchers in the postmodern era, we should liberate ourselves from the restrictions and prescriptions of this 'traditional' kind of science

[2] Engineering in principle shares the same epistemological basis and scientific traditions as natural science.

[3] The term "modest witness" refers to the men who witnessed Robert Boyle's experiments with the air-pump in the 17th century.

writing. She argues that postmodernism, and in particular poststructuralism, by its insistence, indeed requirement, of recognising the knower as situated, actually frees the writer to explore new ways of knowing. Writing, according to Richardson, is not only the common academic form of reporting on one's findings, but also a method of inquiry, as well as a method of knowing. She recommends and gives examples of many forms of research writing, including experimental ones such as "narrative of the self", in which the writer can write in a personalised way, telling stories about her or his lived experiences (Richardson 1994, p. 521). This form of writing can be used to "say what might be unsayable in other circumstances" (ibid, p. 521).

I start out this article as a "narrative of the self", and in that I use the form of a dialogue, which I see as useful for illuminating the issue of different "mind-sets". Writing dialogues is one form suggested by Richardson, but it also has a long tradition within science, think for example of how Galileo presented his ideas and results in the form of dialogues.

Dialogue

The scene is a seminar room somewhere in Europe. In this room, a distinguished group of researchers, some very well known within their field, are gathered for a workshop. A tension has been building up during the whole seminar, and suddenly it bursts into the open, during a talk about research using Actor Network Theory in a hospital environment. The two voices in the dialogue are the Engineer/Computer Scientist and the Feminist Technoscience Researcher.

E: This is nonsense! I can't stand it – how can this be called research, he doesn't DO anything, it's just rubbish! He only uses some kind of in-comprehensible words for ordinary things and persons, and describing their relations!! What good does that do??

F: Ssssh! It's interesting. It's very good and advanced research!

E: But what good does his work do for patients or people working in the hospital??

F: Well, …these kinds of analyses can be very fruitful to understand and deconstruct some network relations, actors, translations, points of passage…and…

E: (interrupts): What "understand?" Does that **do** or **construct** anything?? Just describe things for fellow researchers in a little club for mutual admiration? I can't understand how this can be SCIENCE. And why can't you people use ordinary words? Or maybe that would not be "fine" enough – you have to be incomprehensible in order to hide that you don't do anything useful! Why am I here, I don't belong here and never will. I should go out and do some real work, write a computer program or something like that!

F: You engineers! You are always obsessed with defining and solving problems! You want to explain everything, to put neat little labels onto everyone and everything. Where is your self-reflection? Where is your understanding of the importance of language and discursive practices?? Where are your questions? You are just so pompous and think you know and can do everything! You are completely un-reflected and hasty!

As we can see, a real quarrel has now broken out, both sides strongly detesting the other and what it stands for. Why is this conflict here? Where is it? What does it mean?

The situation described above did take place (almost) as I described it, but it went un-noticed. It took place inside me. For a short time, I became what I call "the completely stubborn engineer", who does not give a "rotten lingonberry for"[4] ANT or similar research. This happens to me from time to time, something provokes a clear conflict within me, and I can feel it almost physically, as a physical sensation located in my head.

"Mind-sets" or "Thinking Modes"

In formulating and thinking around these experiences, I use the notion of "thinking mode", as this is how it feels: like I switch between different modes of thinking. These two modes can be felt as totally separate, but they are not, it is more of a continuum, there are overlaps and commonalities. Furthermore, the modes are not stable; they are constantly negotiating each other as well as other influences and ideas.

Evelyn Fox Keller (1992) sees the concept of "mind-set" as representing a key difficulty in the meeting of feminism and science. Her concept can be useful in throwing light on and understanding some of the problems involved in this meeting. I read her concept as essentially indicating the same idea as I intend with "thinking modes".

I describe how I experience these "thinking modes" by doing a very "engineering" thing: a table of opposites!

"Thinking modes"

The engineer	*The feminist researcher*
HOW	WHY
"Physical"	"Mental" (attentive to language)
Solving, explaining	Understanding
Answering	Questioning
Constructing	Deconstructing
Sharpness, clarity, logic,	"Wooliness", diversity, richness
rationality, linearity	freedom, reflexivity, associativity
Enclosing, "zooming in"	Expanding, "zooming out"
Homogeneity	Heterogeneity
Simplicity/simplification	Complexity

I feel these "thinking modes" almost physically in my head. It is as if I put my brain into different states. Feeling and labelling these from the position of the engineer, they represent 'common sense' vs 'gush'.

[4] In English, one would say: "does not give a dime for".

The first pair in the comparison above is an attempt to summarise the main question/perspective from the engineer's/feminist researcher's positions. The second pair is an attempt to describe where focus is *felt* to be: as the engineer I feel as if I focus the very concrete, physical 'real' world, whereas as the feminist researcher my attention feels more geared towards mental or linguistic dimensions. But these are not mutually exclusive of course I focus on the concrete world also as a feminist researcher. The words above are meant to describe the *feeling*, which in turn probably says something about how an engineer experiences what it means to learn new and very different ways of thinking and working: those of the feminist researcher.

Furthermore, the "thinking mode" of the engineer can be described as a feeling of sharpness and clarity in the head, while the feminist researcher's "thinking mode" feels "woolly" (or even fluffy), but also as richness and freedom. The engineers thinking and reasoning is logical, rational, linear, enclosing and simplifying, while the feminist researcher's is expanding, reflexive, associative and complex. Two quite different ways of thinking.

As for the dichotomy of homogeneous/heterogeneous, Vicky Singleton has discussed this topic in relation to her work as feminist science studies researcher:

> "Should I accept the ambivalence and contradictions inherent in my multiple identity, and celebrate my inability to explain and solve?" (Singleton 1996, p. 450).

For the engineer, whose job is to explain and solve problems, it might be essential with some kind of stable identity, some type of homogeneity. This identity is created during education, and it leads to and supports a strong ability within problem solving, but in my experience also a reduced ability to understand, question and reflect, and inflexibility towards differing ideas. This becomes clear in meeting beginner engineering students, who have not yet been shaped by education, vs. meeting teachers who in many cases have so completely internalised their own shaping that they cannot see it, nor see things differently.

Recognising that "we are all heterogeneous and internally inconsistent" (Singleton 1996 p. 462), could render the work of the engineer impossible, *in the way that engineering is commonly defined today.* Of course, there are constant negotiations within engineering work, but these seem not to be extended to recognition of ambivalences and contradictions (other than when it comes to tangible, measurable, issues). Many simplifications tend to go un-noticed, the road is made invisible, it is naturalised. Engineering is clearly prescriptive, it is a 'should' discourse:

> "There is no room in a 'should' discourse for ambivalence, negotiation of identity and multiple identities." (Singleton 1996, p. 462).

The table above is meant to describe how the "mind-set" of the feminist researcher is in many ways very different from that of the engineer and computer scientist. These differences originate to a large extent in the different epistemologies and scientific traditions, which I see as linked to issues such as education and culture. As engineer, I focus on solving problems and answering questions. I try to simplify problems and I use a foundation of knowledge that I rarely question or even think about. The

(unacknowledged) epistemological standpoint is that which most social scientists call positivism, or simply the historically traditional epistemology of natural science, building on realism and objectivism. As feminist researcher, I ask questions, formulate and attempt to understand problems. I acknowledge complexity, richness, diversity, multiplicity. I reflect on knowledge and knowledge production, and I ask questions concerning foundations: why are things the way they are and how could they be different? The epistemological standpoint can be summarised as that of "situated knowledge" (Haraway 1991).

Lastly, I want to focus on the pair of constructing vs. deconstructing. These are not, as I see them, dichotomies, rather they are mutually dependent on each other. If nothing is constructed there is nothing to deconstruct, and from a feminist technoscience point of view, the main objective for deconstructing is as grounds for re-constructing. Feminist research has contributed to important deconstructions, but how about re-constructions?

> "Feminist research has visualized science and technology as discourse, but has on the other hand been less good an agent for changing science/technology. Deconstructions have been made, but re-formulations have been less tangible." (Mörtberg 2003, p. 60).

There is an urge, a longing, within feminist technoscience to contribute to re-constructions and re-formulations within science and technology. Thus, *constructing* is obviously one skill where the feminist researcher could learn from the engineer. And this is one point where my engineering background shows up: in the wish for (re)-constructing, for contributing to change.

The feminist researcher, on her part, believes the engineer needs to apprehend quite a lot of qualities from the feminist researcher. Here is a risk for imbalance: the engineer needs to learn much from the feminist researcher but the need for learning is not as big the other way round. This means a risk for claiming one position as 'better' than the other, a risk that needs to be handled with respect for all the valuable qualities engineering does have. However, I believe these qualities could be much evolved with influences from feminist research in engineering education and work.

Traversing and Living with Differences

> "I need only to recall my own trajectory from practicing scientist to feminist critic to appreciate the magnitude of difference between these two mind-sets, as well as the effort required to traverse that difference." (Fox Keller 1992, p. 21).

Both engineering and feminist research entail 'world-views'. This is rendered visible in everything from the view of knowledge and the goals of knowledge production, to traditions of writing and language and what is seen as acceptable and 'good science'. The two produce different knowledges and in different ways (even if the engineer might say that the feminist does not 'really' produce knowledge, in the very concrete sense as the engineer is used to; an engineer typically demands clear 'answers' to 'problems').

Lucy Suchman, who has a background from anthropology, describes the uncertainty and even pain that the journey from one professional practice to another involves:

> "For those who have spent many years building up competence and identity within a domain of specialised professional practice, placing oneself again onto unknown ground is a difficult thing to do, particularly insofar as it may lead to painful reflections on one's own life and positioning." (Suchman 2002, p. 94).

One of my first experiences that really meant a shaking of my former rather 'safe' world was when I read an article by Cecile M. Crutzen and Jack F. Gerrissen: "Doubting the OBJECT World" (Crutzen and Gerrissen 2000). The authors analyse the ontology and epistemology of the object oriented paradigm[5], and present feminist critique of these. This article was indeed upsetting for me at the time, since I could no longer pretend to neatly separate the 'identities' within me. I felt feminist research dangerous, as a subversive force that threatened my professional grounds, it even extended beyond that and shook my world.

One thing is traversing the differences between the "mind-sets". But why do these give me feelings of 'right' and 'wrong'? Why does it feel "good and right" to be a feminist critic in technical contexts, but "wrong and bad" to be engineer in feminist contexts? Why do I feel that it is fine to break certain conventions but not other ones? It feels courageous and exciting to break engineering / computer science conventions, but not really the other way round. I suspect this is because feminist research has become a 'home' for me, and in a home, one wants to feel accepted, but it also takes some time to know what is accepted, to learn the norms.

Then another question follows: *Why* do I think/feel so strongly in dichotomies? Dichotomous thinking is one way that the engineering 'identity' influences my thinking. Wendy Faulkner, in her work within feminist technology studies, has noted the abundance of dualisms in engineering, and she wonders "why dichotomous or dualistic thinking appears so endemic to technology" (Faulkner 2001, p. 88). But for the engineer this is a 'natural' way of thinking, part and parcel of being an engineer, stemming to a great deal from the focus on problem solving. Thinking in dualisms makes it easier to solve problems, by thinking in terms of wrong and right approaches (i.e. what works or what does not work).

Having access to the "thinking mode" and language of the engineer is thus definitely valuable, but it is nevertheless tough to live with these feelings of 'right' and 'wrong'. The obvious risk is that I leave engineering /computer science, try to forget it, thinking of it as 'wrong', in order to become more 'whole', not having to live with the perpetual conflict. Some selves or identities can "cause great anguish and the felt need for unification, especially those that claim sovereignty over the entire self" (Star 1991, p. 50). Although I am perfectly aware that feminism does not claim sovereignty over me, I can still feel it that way. Why is that so? Even in feminist research, where discourses concerning plurality and diversity are celebrated, there seems to be gatekeepers, in practice quite strong discourses about 'right' and 'wrong' ways of 'being', indicating a tendency towards homogeneity.

[5] Object orientation is currently a popular 'paradigm' within computer science for the whole process of software production: analysis, design and program implementation.

It is fairly common that people leave their science / engineering background when becoming feminist scholars. Evelyn Fox Keller talks also about this phenomenon:

> "Indeed, a striking number of those feminist critics who began as working scientists have either changed fields altogether or have felt obliged to at least temporarily interrupt their work as laboratory or "desk" scientists." (Fox Keller 1992, p. 21).

Why? One part of this is likely to be the difficulties within academia to be part of several very different communities. But is that all? Or is adaptation to a certain extent and in some sense a prerequisite for being a feminist researcher? In that case, what does this adaptation include? What is permitted among feminist researchers (such as ideas, opinions, writing style, language etc)? If adaptation (to what is accepted within feminist research) is necessary, what happens to the possibilities of affecting science? This can be viewed as being part of the larger issue and discussion (at least in Sweden) of integrating feminist/gender[6] research into other disciplines vs. being accepted as a discipline it its own right. Gender/feminist research has strived to attain a position and become accepted within the academic system, for example getting the authority to award academic degrees in gender research. At the same time, many researchers argue the need for integration of feminist / gender research into 'traditional' disciplines, in which case the aim might be more explicitly transformatory. My belief is that both strategies are in fact necessary, and the mistake we might be doing is to somehow put these in opposition to each other, when in fact they are dependent on one another. However, as I will come back to in the last section, these two types of research have different prerequisites and need to be evaluated according to somewhat different criteria.

Communication Conditions

I want to be a feminist researcher *within* engineering / computer science. Given the differences between the "mind-sets" discussed above, is communication between these different scientific traditions possible? For feminist researchers who want to have an impact *in* technology (be it education, technology production etc), then communication and co-operation across "mind-sets" is necessary. No matter how illuminating and valuable the feminist deconstructions and suggestions for re-constructions might be, if they are not possible to communicate to engineering or other communities they are unlikely to make any difference. We cannot wait for and assume that the engineer / scientist will suddenly realise the need for the insights and approaches that feminist research contributes – we have to get our message across. It is left to the one who wants change to convince those who might be fairly content with the state of affairs that change is necessary, and for doing this, communication is required.

How can communication be possible? Which are the prerequisites? It is hard work to keep together different and potentially reluctant part(ie)s, it takes engagement, care, interest, respect and openness.

[6] Gender research has been the most common concept in a Swedish context, an earlier name was "women's studies".

My experiences within research relate to a project in interdisciplinary university engineering education[7] in which I have been involved. I participated in this project in my capacity as engineer and computer scientist during the years 1998-2004, i.e both before and in parallel with my PhD studies. Participating in this educational project simultaneously with doing research gave me rich opportunities for synergetic experiences. I was initially unwilling to believe in the chasm between the in-famous "two cultures", because of my own interest and enthusiasm as well as lack of experience from interdisciplinary work. However, I gradually had to accept a distressing experience of lack of communication, as well as of sharable world-view and language across disciplines / faculties, and the existence of indeed a chasm. I noticed that few people realised the differences, for instance in epistemology and other traditions, between disciplines, and thus happily stayed in their own 'world', and interpreted the 'worlds' of others solely from their own perspective.

Lucy Suchman has described this, in the context of technology production. She observes that disciplinary distinctions "all orient not only to different problems but more significantly to different, sometimes incommensurate conceptions of the social / technical world." (Suchman 2002, p. 97). What hinders our communication and co-operation are "discontinuities across our intellectual and professional traditions and associated practices" (ibid p. 97). This resonates with my experience, and I agree with what Lucy Suchman sees as the only possibility to bridge these discontinuities: "mutual learning and partial translations" (ibid p. 97). However, this is not an easy task, and in my experience it has to start with engaged individuals, sharing a joint interest, communicating and translating between each other's 'worlds'.

The different "thinking modes" cause conflicts within me, but I do not want to lose them. Keeping them alive might be what makes it possible to remember and thus connect 'back' from feminist research to engineering / computer science. If I forget "the effort to traverse that difference" as Evelyn Fox Keller talks about, such as how difficult some concepts can be to relate to, or understand (take for instance 'discourse', a terribly difficult notion to understand if you come from engineering), then translation will not be possible. It is necessary to understand a language in order to be able to translate into it. This is the same type of risk as I have to keep in mind when I teach beginner programming: if I forget the difficulties in learning to program, I am a poor teacher. But to remember the difficulties, in both cases, takes effort and work. It is very easy to forget what was difficult once something has become self-evident and 'natural'. Being an engineer gives me access to knowledge and insights that might be hard to gain otherwise, but on the other hand, I would not be able to formulate and discuss this 'inside' knowledge, had I not been trained in asking questions and reflexive thinking during my PhD studies.

[7] I participated in the development of the "Systems in technology and society" engineering programme at Uppsala University, see http://www.utn.uu.se/sts/ This engineering programme integrates traditional engineering subjects with courses from social science and the humanities, where the overarching approach is that of Science and Technology Studies (STS).

This doubleness is a resource, however difficult it can be to live with it. It provides possibilities for reflexivity in the collisions that occur between the "thinking modes". Exposing ambivalences and tensions between different positions can cast light on potentials and possibilities:

> "We shall try to keep ambivalences, contradictions and tensions… It is in the ambivalences and contradictions that the potentials for a steady radicalisation – a steady transgressing – lies." (Gulbrandsen 1993, p. 22).

Bringing up issues of two worlds that seem incompatible, not to say incommensurate, do I enlarge, even exaggerate, the difficulties? My answer to this is firmly "no". The difficulties involved in crossing boundaries and trying to work and live across them, must be made visible, in order to deal with and even be able to use them in transformatory work. If the difficulties are swept under the rug, this will result in maintaining boundaries, even if involuntarily, and thus difficulties to communicate and work across these boundaries.

Awareness of these different "mind-sets" is important if we want to engage in translation work. I recommend the engineer to be curious to learn from the feminist researcher and the feminist researcher to be curious to learn from the engineer. We might be able to expand our thinking if we learn from each other. So I highly recommend engineers / computer scientists to visit the world of feminist research and vice versa, to do "world-travelling", as a "wilful exercise" (Lugones 1990): to visit a world where you do not feel quite at home.

Doing Feminist Technoscience Research in Engineering / Computer Science – Living on Several Peripherals?

I am a hybrid, which for me is a necessity. I insist on the space for trans-disciplinary approaches, the possibility to create my own rules and move between domains and modes, to be allowed the joy and right not to adapt to either 'world'. To be multiple, be in several 'worlds'. But is it possible to live simultaneously on two peripherals? Doing feminist technoscience research means living with the risk of being marginalized in two 'mainstream' scientific discourses: engineering / computer science as well as (mainstream) feminist / gender research.

What is new, strange, difficult, or merely a non-issue within computer science can at the same time potentially be regarded as old and uninteresting within mainstream feminist research.

> "Will what one does ever become "good enough" within feminist research, and at the same time sufficiently understandable and graspable for computer scientists?" (Inger Boivie, personal communication, January 2005, my translation).

Amy Bug, with experiences from feminist research in physics talks about "culture clashes", and furthermore "culture lags" within natural science, and she has no illusions about the harsh reality for hybrids:

> "…scholars who hope for acceptance in both feminist and science communities are sometimes caught in a no (wo)mans land. People are rarely able to engage in both scientific and feminist

> research […] When they do, their energies may be placed in areas that are outmoded from the point of view of mainstream feminist scholars yet radical from the point of view of mainstream scientists." (Bug 2003, p. 886).

I hope and argue that feminist research to a greater extent than Amy Bug suggests is the case, accepts potentially hybrid forms of research, acknowledging the value and importance of the work done by those who try to take feminist research issues and perspectives into science and technology. Feminist research already holds the values necessary not only to accept this type of research but also to realise that it can not fulfil the standards for 'traditional', mainstream feminist research, and that it needs to be evaluated on its own terms, according to other, transdisciplinary, criteria.

Let me make a comparison with mathematics here. Mathematics is on the one hand an academic discipline in its own right, with advanced theoretical research. On the other hand it is also used in many areas, it is *applied*. There is research in what can be called applied mathematics, using mathematical theories and methods in many areas (and this kind of research is often, but not always, done within the discipline of application, e.g. biology, computer science, physics). Research done within 'pure' mathematics is thus different from that done within 'applied' mathematics. The requirements of the research are not the same, although the fundamental ideas and 'thinking' of mathematics is the same. Though application has a connotation of linearity, which I want to avoid in this context, the analogy can be used for feminist research. Both the more theoretically oriented research and the 'applied' are necessary, and both are ground-breaking in their own ways. We need those wonderful feminist theorists who contribute with for example developing and extending our epistemological understandings, but we also need those who are willing and able to 'translate' this into other 'worlds'. Furthermore, in contrast with the linearity of 'applied' science, the relation of these two types of feminist research are more that of a spiral. Theoretical thinking is a necessary prerequisite for intervention practices, but practices in turn nurture the theoretical thinking (Björkman, Elovaara and Trojer 2005).

We cannot expect to readily be accepted within science / engineering. Trying to bring feminist epistemologies into science and engineering is a really challenging undertaking, as Amy Bug concludes in the case of physics:

> "Yet mainstream physicists are deeply troubled by feminist epistemologies of science … a reconceptualization [of objectivity] is a move that mainstream physicists are loath to make." (Bug 2003, p. 888).

However, I believe that the prospects for feminist epistemology within computer science could be brighter than within physics. Computer science is constantly debated as to what it 'is' and 'should be', and there are already voices advocating feminist as well as other 'radical' and alternative perspectives within CS.

Feminist Technoscience Possibilities

Feminists have written extensively about the need for celebrating plurality, diversity, mulitiplicity and splitting:

> "The split and contradictory self is the one who can interrogate positionings and be accountable, the one who can construct and join rational conversations and fantastic imaginings that change history. Splitting, not being, is the privileged image for feminist epistemologies of scientific knowledge. 'Splitting' in this context should be about heterogeneous multiplicities that are simultaneously necessary and incapable of being squashed into isomorphic slots or cumulative lists." (Haraway 1991, p. 193).
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> "One of the great lessons of feminism has been about the power of collective multiplicity.…In the end, it is the simultaneity that has emerged as the most powerful aspect of feminism, rather than the outsiderness." (Star 1991, p. 50).
>
> "…the possibility and complexity of a pluralistic feminism, a feminism that affirms the plurality in each of us and among us as richness and as central to feminist ontology and epistemology." (Lugones 1990, p. 390).

Talking about plurality, diversity and mulitiplicitly more often and in un-complicated ways, could open up what seems closed. Maybe many people, both within feminist research and traditional disciplines, feel the lack of identification with the presumed unity? Why is unity seen as a necessity? For fear, uncertainty, disciplinary 'purity' or issues of power and privileges? If we realise that we are all members of several 'worlds' that are in themselves fluid and changing, what great fun we could have together, and just imagine all that we might be able to accomplish, once being ridden of the fear for being 'wrong'.

To wrap up, I want to return to the title of this paper. What could feel as impossibilities or at least big difficulties, are, I argue, full of possibilities. It is not the same possibilities as I would have as either mainstream computer scientist or mainstream gender / feminist researcher, but it opens up other potentials. It is time to acknowledge the possibilities of practising and theorising transdisciplinarity.

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Paper A2

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Living in the "Belly of the Beast"[1] – Doing Feminist Technoscience Research

> "Dozens of feminist writers have refused both relativism and universalism. Subjects, objects, kinds, races, species, genres, and genders are products of their relating. None of this work is about finding sweet and nice – "feminine" – worlds and knowledges free of the ravages and productivities of power. Rather, feminist inquiry is about understanding how things work, who is in the action, what might be possible, and how worldly actors might somehow be accountable to and love each other less violently." (Haraway 2003 p. 6f).

Introduction

What kind of focus will feminist research develop at a technical faculty of a technical university, where information technology (IT)[2] constitutes the overarching research field? With this article we want to illustrate this process with the core complex of problems that we identify, as well as to animate these with included stories of the authors, and also to propose a short agenda of action for future feminist technoscience research.

The first starting point for our article is feminist technoscience as it is currently defined by for instance Donna Haraway. This implies attention to issues related to boundaries and boundary crossings between science, technology, politics and society as well as hybridization processes between humans and non-humans (cyborg theories). To a large extent, the feminist technoscience approach has revolved around exploring the epistemological foundations of knowledge understandings and practices. Much of the work has been about deconstructions, opening up concepts and definitions. "Feminist research has visualized science and technology as discourse, but has on the other hand been less

[1] We send our thanks to Donna Haraway.

[2] We have chosen to use the term Information Technology and its abbreviation IT, since in the Swedish context these are the prevailing concepts, rather than the term Information and Communication Technology (ICT).

good an agent for changing science/technology. Deconstructions have been made, but re-formulations have been less tangible." (Mörtberg 2003, p.60). In our research group, Technoscience Studies, established in 1998 at Blekinge Institute of Technology (BTH), Sweden, we engage in research which from feminist technoscience research perspectives develops complex understandings and practices of IT. For us, the crucial challenge is to move beyond the layers of deconstructions, and the core question becomes: how can feminist technoscience research be used for intervention and transformation?

We take our second starting point from the definition of IT, which has often been "blackboxed"[3]. Thus, technology and the underlying perceptions of technology development and knowledge, are seldom brought into focus. One important issue that we see for feminist technoscience research with a focus on IT, is to open up and rearrange in this black box, in order to create new approaches, ideas and understandings as well as new possibilities for change. Paraphrasing Sandra Harding's concept of "the science question in feminism" (Harding 1986), we see feminist technoscience research as constituting a turn towards "the technoscience question in feminism." Feminist research here should not only be on information technology as something defined and ready-made, but also an active participation in research in information technology.

The article takes its third starting point from the authors´ lived realities, practices, experiences and reflections. This for us privileged position provides an opportunity not only to investigate IT from an outside perspective, but as Lucy Suchman writes: "…really to understand these processes of exclusion and resistance, feminist scholars need to get inside the 'black box' of technology production: that there is room for an effective politics around gaining access to technological work and institutions, and that there are, as she puts it, 'opportunities for disruption in the engine rooms of technological production" (Suchman 2002, p. 101).

This text is about realities where smoothness and roughness are co-existing and creating tensions that both tear and inspire. We indicate the core complex of problems by discussing boundaries, challenges, prerequisites for transformations as well as interventions and disruptions both explicitly and more implicitly in our stories. What happens when feminist technoscience research meets knowledge production and producers in 'the engine rooms', including the public and private sectors, development projects, education, academia, and local practices?

After discussing issues concerning boundaries related to university structure and our situation at a technical faculty, each of us will tell a story about the interventions we create and/or participate in. Interventions that are meant to contribute to re-arranging in the black box of IT and knowledge production. Interventions where we, in different ways, start from and use our being "in the belly of the beast." We conclude the article with a discussion about the possibilities we see for feminist technoscience research.

[3] "A subject to blackboxing, a process that makes the joint production of actors and artefacts (and activities) entirely opaque…Can we open the labyrinth and count what is inside?" (Latour 1999, p. 183).

Problematic Boundaries in the "Engine Rooms of Technological Production"

> "My experience of the working relations of technology production and use has led among other things to a preoccupation with boundaries, including efforts to recognize them, problematize them, at times maintain them, and at other times to work across them." (Suchman 2002, p. 93).

Lucy Suchman´s words have inspired us to identify categories surrounded by numerous boundaries and to analyze whether the boundaries limit our working and transformation space. Suchman invites us to explore what it would mean to transgress the problematic boundaries.

Boundaries create classifications and categories, spaces to live in and act from. Bowker and Star describe the phenomena and practice of classification: "A classification is a spatial, temporal and spatio-temporal segmentation of the world. A 'classification system' is a set of boxes (metaphorical or literal) into which things [we would like to add: people] can be put to then do some kind of work – bureaucratic or knowledge production…Classifications are consistent and unique, mutually exclusive and complete." (Bowker and Star 1999, p 10f).

A university is an arrangement based on categories and classifications, that fits well into Bowker's and Star's description. In our cartographical work when identifying the boundaries and categories inside the technical university the following four boundary based categories seem to be the most troublesome and powerful:

a. The university structure is based on disciplinary boundaries – difficult and challenging when developing inter- and trans-disciplinary research
b. The university definition and understanding of IT as a hardcore technical category – difficult and challenging when working for broadening the understanding of IT
c. The university category of knowledge often connected only to theoretical knowledge produced at academies – difficult to recognize distributed knowledge processes and challenging to respect and co-operate with other knowledge producers outside the university
d. The university as part of the academic world is a closed classification system based on mutually exclusive categories – little if any space for change.

Categories and classifications are named, listed and articulated as disciplines, departments, academic titles, professional positions, research areas etc. These categories provide a repertoire of labels which help to describe oneself and also finding others belonging to the same categories. Smooth orderings and stabilizations. These categories, and boundaries between them, are a living reality, not just constructions, and most tangibly present in attempts at inter/transdisciplinary work. Lucy Suchman concludes that disciplinary distinctions "all orient not only to different problems but more significantly to different, sometimes incommensurate conceptions of the social/technical world." What hinders us, she says, are "discontinuities across our intellectual and professional traditions and associated practices." (Suchman 2002, p. 96f).

This is related to difficulties and challenges encountered in broadening the understanding of information technology, where the issue of knowing within categories is raised: "A crucial assumption underwriting these persistent boundaries is the premise that technical expertise is not only a *necessary*, but is the *sufficient* form of knowledge for the production of new technologies." (Suchman 2002, p. 93, original italics). Categories are mutually exclusive. If you are placed inside a technological discipline you cannot at the same time be categorized as a social scientist, and vice versa. Being inside one specific category means that you firmly and definitely are outside another category. This leads to an attempt to understand who is outside and who is inside when the borders are drawn, and what it means to be outside and inside, when talking about power to define and power to act.

When knowing of and living with(in) boundaries one also starts wondering how powerful, well protected and stable these boundaries are. Or are they transgressable? Donna Haraway says, contrary to Bowker and Star, in an interview: "Categories are not frozen…The world is more lively than that, including us, and there are always more things going on than you thought, maybe less than there should be, but more than you thought!" (Lykke et al 2000, p. 55).

Challenging Boundaries

> "…crossing boundaries as a project of mutual learning and partial translation…" (Suchman 2002, p. 93).

Our inter/transdisciplinary research group Technoscience Studies fulfils the need for a 'home', a space for creating change. The members of the group all have backgrounds from a number of academic disciplines, spanning all the 'traditional' faculties: engineering, humanities, natural science and social sciences, as well as different professional experiences both from within and outside of academia. We all share and try to develop a common theoretical foundation in feminist epistemologies, such as it is suggested by for example Donna Haraway and her notions of situated knowledge and partial perspective[4], as well as her figurations of the cyborg[5] and diffraction[6]. We express it as building an epistemological infrastructure for our research, that is both broader and more explicit compared to the positivist traditions dominating at our technical university. This epistemological infrastructure combines theoretical thinking and intervention practices. Theoretical thinking is a necessary prerequisite for these intervention practices, but these practices in turn nurture the theoretical thinking. In this way, we work in spiral-like movements: epistemological theories give a foundation for interventions, which in turn enrich the epistemological theorizing. We see this work as our epistemological exercises.

[4] Haraway 1991

[5] Ibid

[6] Haraway 2000

What boundaries do we challenge? The group, by its very existence within technical faculty, challenges boundaries of what is considered to be technology. IT as a field of knowledge and competence crosses disciplines, as we see it. However, our experience/interpretation is that there are forces within the technical domains of IT (such as for example computer science and similar disciplines), striving towards disciplinary "purity," and a narrow, technical definition, where inclusions and exclusions are created and maintained. In contrast to this, our understanding of IT within the group challenges this strive towards a technical view. By asking questions and studying issues such as "What is IT?," "Who draws the boundaries for what IT is considered to be?" "Why are the boundaries drawn where they are?," "Who is excluded and who is included and why?," and not least "How could it be different?" we provoke the understandings of IT also within the technical faculty, aiming at opening up and rearranging in the black box(es) of IT.

Another boundary transgression comes from what we call experience-based research. Here, research perspectives as well as research questions differ from "traditional" academic discipline-based research, thereby challenging boundaries for what is considered (academic) research and knowledge production. Our research interests and questions spring from professional experiences, either from within academia or from outside of academia, meaning that we do not start our research from an a priori academic disciplinary interest. We acknowledge the understanding that contemporary knowledge and technology is increasingly produced in distributed systems, where the boundaries between universities, industry and government are flexible (Gibbons et al 1994, Nowotny et al 2001). The definition of knowledge, imperative at western universities, has considered theoretical knowledge as the only form of knowledge. This narrowness excludes above all knowledge understood as "practical intelligence" which is developed and used in concrete situations (see e g Göranzon 1991). For us, including not only our own but others´ experience based practical knowledge in our conceptual and practical understanding, is one of our epistemological foundations.

Interventions

In this section, each of the authors describes and discusses her own projects, and the experiences and questions they raise. The stories are about interventions, our epistemological exercises, which we create and/or participate in, interventions that are meant to contribute to opening up and rearranging in the black box(es) of IT and knowledge production. Interventions where we, in different ways, start from and use our being "in the belly of the beast."

[Pirjo´s Story]
When remembering my own nomadic personal history of crossing boundaries: geographical, language and professional ones, many of my research questions actually are my personal questions. I moved to a university when searching for a space for reflection and also believing that it is in the academia knowledge is produced. At the

same moment as I crossed the boundary between different practices I also reproduced and accepted the boundary dividing the world into two categories: research producing knowledge and practical work producing services and products. I had moved inside and by doing that I had created an outside I could observe and write about. At the best moments I could interpret and understand the world outside.

It was my research interviews with librarians that forced me to re-think the dividing lines between research and practical work, knowledge production, users and designers of IT. To take a serious thought about my epistemological position, about situatedness and about research. I changed my perspective away from boundaries as dividing the world into two separate spaces, to consider a possibility to live and act beyond the boundaries and looking for a space in between. And also considering what kind of research I could do in this 'third space' yearning "to move beyond simple dichotomies" (Suchman 2002, p. 94).

During the year 2003 I could take my thoughts, dreams, hopes and questions concerning the possibility of the 'third space' research with me into a municipal R&D-project defined as an e-democracy project focusing on spatial planning and concentrating on communication and interaction between the municipality and the citizens. The aim of the project was to create a web site, where the new municipal comprehensive spatial plan could be presented and where the citizens could comment the plan and discuss the spatial planning of the future.

The first phase of 'third space' intervention research was connected to transgressing boundaries. In this specific project transgressing worked in and through multi-perspective intertwined layers. First of all, the actors came both from the public and the private sector. Second, the project was both a research and development project combining a variety of competences. And finally, for the research part the project was a multidisciplinary[7] project. To transgress in order to meet and talk, as easy and uncomplicated activities they seem to be, can at the same time uncover the complexity of the transgression. Transgressing is necessary as a start but not a guarantee for a sustainable change if we do not take into account "the ability partially to translate knowledges among very different – and power-differentiated – communities…" (Haraway 1991, p. 87).

The second phase of 'third space' intervention research dealt with the 'noise' caused by the researchers. As a researcher you always interrupt people, you take their time. You take place. Intervention can be a negative disturbance, even from the researcher's point of view. During this project the research group actively participated in the project process. We arranged workshops and mock-ups[8]. We attended project meetings, not only as passive observers. To create space and time for the project participants to think concretely about the project and to work with the design. To blur the boundary between technology development and use. The project was thus a modest contribution to the larger intervention plan, namely to "…begin to replace the designer/user opposition – an opposition that closes off our possibilities for recognizing the subtle and profound

[7] The notion of multi-disciplinarity indicates the maintenance of the disciplinary boundaries.

differences that actually do divide us – with a rich, densely structured landscape of identities and working relations within which we might begin to move with some awareness and clarity regarding our own position" (Suchman 2002, p. 92).

Members of the research group talked with other members of the project. Taking time and disturbing the normal order of the working hours. The project leader expressed that talking with the researchers "costs time. So maybe you cannot say that you directly during the project get anything back to the operative results." [9] In discussions we raised issues concerning the notions of democracy and citizenship. The conversations revealed that the project participants did not have similar harmonious ways to talk and interpret democracy and citizenship. The dialogue was open and seeking not a final universal definition of the notions of democracy and citizenship, but local and located interpretations open for problematizations and frictions. The negotiations that also could be interpreted as taking a lot of time and giving no direct results, and being provocative but which also could be understood as ways to localize and situate the essentially contested concepts in a place and time. Or as Lucy Suchman puts it "The problems that interest us include the practicalities and politics involved in attempting to reconceptualize and restructure the ways in which work and technology design are done." (Suchman et al 1999, p. 399). What reconceptualizing in the project context meant was that during and through the huge amount of discussions the goal was to come closer to committed concepts of communication, interaction, democracy and citizenship. The concepts have to be situated and accountable as well as other members of the project.[10]

Working towards committed concepts takes time and effort. But if the aim of our work was to situate IT and make it sustainable and accountable, one of the goals of the feminist technoscience research is to intervene by de-and re-conceptualising our language and experiences. The other option, "this stance of design from nowhere is closely tied to the goal of constructing technical systems as commodities that can be stabilized and cut loose from the sites of their production long enough to be exported en masse to the sites of their use." (Suchman 2002, p. 95) does not work if the aim is committed, situated and "artfully integrated" (Suchman et al 1999, p. 99) design. I would claim that discussions about democracy, citizenship and technology in the long run were part of the positive stabilisation, which aimed to situate the often so rhetoric notion of e-democracy in this specific municipality.

Much of the experience gained from the actual project reinforces the need of co-operation, co-involvement, and trustful alliances. Alliances that include both people and technology. Alliances that tolerate discussions, tensions and slowness. Things do not often come quickly and easily. Interventions do not necessarily come in a shape of overwhelming and sudden change. Intervention might come in frictions, cracks, provocations and in small interferences as in the actual project.

[8] Working workshops to inspire and assist in this specific case the design of the project website.

[9] Interview with the project leader the 22th of April 2003.

[10] This discussion has been developed in a co-operation with my colleague Annelie Ekelin at Blekinge Institute of Technology.

It is not especially difficult to choose a sceptical approach to the numerous IT projects going on. To choose to read the project descriptions as hollow rhetoric and to consider the popular project form structuring the everyday change work as time-consuming, time-pressing and never-ending isolated islands, would have been a possible road to follow. I could have chosen a gender equality approach to investigate if/how women are excluded in IT-projects. But I chose to change the exclusion perspective to the perspective of inclusion: co-operation with heterogeneous actors, participation in the blurring of the boundaries of IT developers and users, working with differences, daring to work slowly and interfering in the "belly of the beast."

[Christina's Story]
My story is about attempts to open up and rearrange within one of the black boxes of IT: computer science (CS). So, I am in "the belly of the beast" of computer science, more specifically CS education at university level. This story is about boundaries, challenges and interventions into CS and its knowledge production, with a focus on education.

My research takes its starting point within engineering and CS, since my undergraduate education is in engineering, after which I have worked more than 15 years as a lecturer in CS at university level. Before I started my doctoral studies, I had some experience of interventions concerning women in CS: During the late 1990's I worked with a number of projects targeting the situation for the (very few) female students in CS. My approach then, with very little, if any, knowledge of feminist theory, was unarguably mainly that of liberal feminism (or the "women-into-technology" approach). The projects I worked with were no doubt attempts at interventions. Interventions into the male dominated culture of computing, interventions in order to support female students, and interventions into teaching (an experiment with gender segregated teaching). I would characterize these projects, these interventions, as targeting equality issues, and in fact, creating exclusions, instead of inclusions (singling out female students in the gender segregated teaching project for instance).

During my work with these projects, I gradually started questioning these "women-into-technology"-oriented approaches, realising that the equality project is not enough. I began to think around issues of knowledge within CS. My experiences lead to asking other questions, to an interest for the invisible and taken for granted: the discipline of computer science. This is the point where I crossed some supposed boundaries, into feminist/gender research.

What are the challenging boundaries involved in my work? One of them concerns epistemologies, where the feminist epistemologies that are foundational for me, such as situated knowledge and partial perspectives, and thus also the world-view, is completely different from most of the epistemological foundations of CS. There are also questions of definitions: such as what is considered to be CS, which in turn create inclusions and exclusions: who is considered to have valid CS knowledge?

In my intervention I target questions of integrating feminist research issues into computer science education. What happens when feminist research meets computer

science educational practice? I work in a project with CS faculty, where the participants get possibilities to deepen their knowledge around teaching situations and learning within computer science. This is accomplished through conversations about knowledge situated in the participants' context, and reflection over their own experience as teachers, with contributions from feminist research. A special focus has been the teaching of programming, and the 'paradigms' implicit in this teaching. Putting it another way: we try to bring the participant's practices together with feminist theory and research, in order to see if the latter can shed new and unexpected light on the former. A goal is to try to make hidden views and expectations visible, and to work for accommodation of greater diversity in the practices of CS as well as among its practitioners. My hope is that, in the long run, these types of changes can contribute to transformation of CS into a discipline that is more attractive to a broader range of students, for example women.

In this intervention project, as well as in my research as a whole, I find it important to ask questions. Questions that are unexpected, surprising, maybe even provocative. Asking questions is a way of starting a reflective process as well as it can be a way to communicate.

I have chosen to do feminist research, but hoping to stay a lecturer in CS at the same time. Remaining a computer scientist is for me vital if I want to be able to communicate and work for change within CS. I want to do what could be called feminist computer science research. What is this, does it exist, is it even possible? Is it possible to refuse categories and boundaries? I have the (impossible?) intention of being both a computer scientist and a feminist researcher. Norwegian informaticians[11] Tone Bratteteig and Guri Verne challenge the existing dichotomies: "We think it is of vital importance to stay an informatician, but with an interest in feminist research, refusing to resolve this dilemma by choosing one of these areas of research. By doing this, we do not accept the dichotomy between feminism and technology. The challenge is to learn to live with, and possibly harvest from, the contradictions and alleged paradoxes that arise." (Bratteteig and Verne 1997, p. 70).

However, I do not only make interventions into CS as a feminist researcher, I also make interventions as a computer scientist in feminist research. What is permitted among feminist researchers (such as ideas, opinions, writing style, language etc)? The attempt to be both computer scientist and feminist researcher leads to conflicts, not least internal, within myself. To cope with this, I think that the research environment is crucial, that it is acceptable to be both computer scientist and feminist technoscience researcher, and not to have to choose or to force one part to adapt to the other, but to enter into conversations. Thus, I find 'impurity' and inter/trans-disciplinarity very important. The research within technoscience studies gives me space for experimenting and exploring, and opens possibilities for new approaches, making it possible for me to move between

[11] "Informatics is the term for computer science departments in universities in Norway, indicating that the discipline is defined more broadly than in traditional computer science departments." (Bratteteig and Verne 1997, p. 59).

positions and see many different images and stories, thus approaching more complex understandings, as well as possibilities for translations and transformations.

[Lena's Story]

I want to illustrate why our feminist technosicence research has identified research transformation as the core issue and why I emphasize the transformation 'project' to be directed towards and located within our own knowledge producing body - that is the technical university itself. One of the necessary prerequisites to go from why to how is the development of a broader epistemological infrastructure in the places where we conduct academic research and where many have difficulties even to spell the word epistemology. I do not want to be ironic here, but to recognize the dominant norms of my own academic education within faculties of natural science and technology. Becoming an active partner in knowledge production, whether you are a feminist technoscience researcher or not, demands skills also in epistemological reflection and positioning. That means, the way you understand knowledge and how it is produced within the technical spheres is vital for functional and relevant IT development in its specific context.

Feminist technoscience with emphasis on IT is motivated by transformation goals. The reasons for transformation are not only seen in the ongoing difficulties of achieving appropriate IT system solutions especially in low-income countries, but also in the way we face contemporary processes of knowledge and technology development (Gibbons et al. 1994; Nowotny et al. 2001). The prerequisites for the latter are still to be met, and urge for transformation not the least within academy and technical faculties (Etzkowitz and Leydesdorff 1997). Feminist technoscience within technical faculties is a driving force for the transformation processes needed. (Björkman 2002; Trojer 2002; Elovaara 2004).

With a background in natural science, technology and non-formal adult education my professional life has been characterized by developing complex understandings about knowledge and research processes within technoscience and later with a special focus on IT. Low-income countries and the postcolonial context are important for my work, which also includes techno- and research- political studies.

My own experiences concerning the motives for transformation are co-evolving with the identification also made by others[12]. Developing appropriate and relevant technology (system) solutions is a complex and context-dependent issue and worked out in many technology fields (see e g Rydhagen 2002). As an illustration from the field of wireless telecommunication, almost a technical revolution is experienced in a low-income country like Tanzania by the implementation and use of mobile phones with prepay function. This kind of technology for direct communication between people seems to be appreciated as appropriate, relevant and affordable by a larger group of people than by the income-strong elite. The technology of cellular phones with

[12] The most recent reference I want to give is the numerous documents published within the WSIS (World Summit on Information Society) process, see www.genderwsis.org, www.itu.int/wsis.

prepay function has trickled out to more income-weak masses. This implies a further elaboration of situated use and socio-technical development. A 55 year old Tanzanian woman living in the poorer surroundings of Dar es Salaam told (Trojer 2004) that she and her family could not afford a fixed-line telephone. However, having a second hand cellular phone for prepay charging makes it possible for her to develop her businesses, necessary besides her low paid teacher job, as well as to communicate for the safety of her children, grandchildren and extended family members. Two motives for using this technology are brought out in her story. The possibility to reach the person you need to reach is higher with a mobile phone, in a country where the number of mobile-phone connections are three times that of fixed-line connections. This woman also emphasized the possibility to have control over the costs herself by the prepay function instead of a "salted" bill for the fixed-line telephone use. The latter is a sign of very low trust in public (and private) institutions in Tanzania – an understandable attitude under earlier and present circumstances.

Another experience is the transformation challenges that have to be taken and solved within a project in an integrated regional developing process built on applied IT. The region in question is Blekinge situated in the southeast of Sweden, a region that has undergone tremendous structural changes during the 1990s from a dependence of heavy industry and military service to a focus on IT development in industry and the education system with a new technical university (BTH). This experience implies recognitions of technoscientific and research politics deeply rooted in understandings of knowledge and technology production as processes that occur in distributed systems. In other words, knowledge creation today takes place on the boundaries between universities, companies (private sector) and other regional, national and international actors (public sector). These processes are no less prominent when located in the Blekinge region and in the research and development carried out at BTH. The concept "technoscience" is connected to this view of knowledge and technology production.

Since the year 2000 a new university campus is developing at BTH. The university is an active, cooperating partner in a local innovation node[13] called NetPort.Karlshamn[14] with a vision to become a competence centre focusing technology development within new media, experience based learning and intelligent transport systems. The other two main partners are the local government and the industry. One model explored for the processes taking place, when the three mentioned actors are to co-operate, has been the triple helix model stating that the three institutional bodies university, industry and government are increasingly working together (Johansen and Uhlin 2001). The triple helix model focuses mainly on the outer frame of the processes. The actual knowledge and development processes are more explicitly discussed within the concept of mode 2 (Nowotny et al 2001). Researchers and teachers at technoscience studies have been deeply involved in the complex development process of a distributed knowledge and

[13] A local organisation / system, within which several active partners cooperate for creating innovations, economic and societal growth.

[14] www.netport.karlshamn.se.

technology producing system like NetPort. This kind of practicing intervention is an advanced mode 2 experience, also discussed with Michael Gibbons[15]. The daily life consists of many difficult frictions and we can ask ourselves why feminist technoscience research is a driving force in these processes? To be very straight forward the answer is to be found in the identified potentials of feminist technoscience research listed below. For more detailed information about concrete results of the distributed knowledge and technology producing system NetPort so far see Trojer and Henningsson (2004).

With the two empirical examples given I want to illustrate the need for attention to epistemological infrastructure in order to be able to work transformatively within the knowledge and technology producing body (BTH).

Discussion

Feminist research has during a long time made great efforts to understand and develop the ideas of otherness and difference. Our experiences tell us that this discussion is also extremely central and relevant when talking about feminist technoscience focusing on IT. What we have to do is to investigate how the questions concerning differences and otherness need to be reformulated and situated in the context of IT. We have experienced that the differences present in technoscience/IT practices often show up in tensions concerning issues of expertise, participation, knowledge production, implementation, as well as political and societal development. The world of information technology, as well as all other worlds, consists of power differentiated communities. This differentiation is at the same time an essential part of the different actors' collected dreams of "how things might be different" (Haraway 1991, p. 93). There is no room for innocence but at the same time there is no place for never-ending conflicts either. But there should be room for "an earthwide network of connections, including the ability partially to translate knowledges among very different…communities." (Haraway 1991, p. 187). What we by telling about our experiences want to show is that this translation work, where there are no readymade models and methods, is at the same time a possible and a very difficult task. And we have no idealistic hopes that the work can be done immediately, extensively and without collisions.

IT and other technoscience practices are so tightly interwoven within our lives that stepping outside, only analysing and criticizing is not a position available for feminist technoscience research. Quite contrary, dirtiness and impure places and actions are the only option because we have to participate in situated, concrete practices "…that cobbles together non-harmonious agencies and ways of living that are accountable both to their disparate inherited histories and to their barely possible but absolutely necessary joint futures." (Haraway, 2003: 7). We would like to end this article by suggesting a list of important potentials which we see in feminist technoscience research:

– to expand the knowledge frames and practices for technology development in increasingly complex realities

[15] Interview the 14th of May 2003.

– to indicate alternative directions of technology/IT applications
– to create explicit cultures within technology-related institutions at the universities (phase out 'the culture of no culture') and thereby make clear that no research positions are innocent
– to develop epistemological infrastructures relevant to a society heavily dependent on research and technology
– to establish new agoras for developing understandings of relations between research and politics
– to constitute a catalyst in negotiations between science and society
– to create driving forces for inter- and trans-disciplinary constellations
– to open up preferential rights of interpretation e.g. in selections of standards, which always are reality producing activities
– to contribute with competences for situating knowledge and for context dependence e.g. concerning resource allocation from high-income to low-income countries.

These potentials can be seen as conditions for trying transformations. But how to participate and initiate a movement that aims at trustworthy interventions and processes of change? As the list of potentials suggests, the work cannot and ought not to be done by feminist technoscience researchers alone. When one of the fundamental bases for change is to look for and build up alliances we have to learn to co-operate, also with people who do not always share our own epistemological and political concerns. We have to learn to ask new kinds of questions about alliances and collaboration, because the alliances and collaboration partners might be unexpected and strange in many ways. The questions are complicated but simultaneously absolutely necessary, as Donna Haraway, referring to the work of Helen Verran, writes: "How can people rooted in different knowledge practices 'get together', especially when all-too-easy cultural relativism is not an option, either politically, epistemologically, or morally? How can general knowledge be nurtured in postcolonial worlds [our addition: in other worlds too] committed to taking difference seriously?" (Haraway 2003, p. 7). Taking differences seriously means that there is a need to find a position to act, from which it is possible to respect differences but not to be satisfied with the relativist thinking, "anything goes." What is instead needed is a desire to get involved in respectful conversations without losing our own intervention goals based on feminist epistemologies.

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Introduction to Part B: Focusing Foundations

In this part I have collected texts that span over almost the whole period of my PhD studies. They illustrate the journey I have done in my research. This journey starts in an engineering approach, where my aim is to bring 'tools' from feminist research into computer science, in order to bring about change. The point where this part ends, with paper B4, is where focus has been moved from using feminist technoscience research as 'tools', and towards communication between feminist research and computer science. In the epilogue, I further elaborate, discuss and summarise this journey.

Common for the papers in this part is that the material consists of texts, which I critically read and query from a feminist technoscience perspective. I challenge existing approaches and concepts whithin (traditional) CS as I have delimited it in the introduction to the thesis.

The first two papers focus "the gender question in computer science", while the other two more directly address issues concerning the foundations of, and approaches to knowledge in, computer science. In that way, they also illustrate the path from "the gender question" to what I in the introduction called "the foundation question".

Paper B1 was originally written for and published in my licentiate thesis 2002, but was slightly updated in Winter 2003. It is a survey of (parts of) what has been written about women/gender and CS within different areas. Focus is on how the issue is perceived and discussed among computer scientists, social scientists, interdisciplinary groups, and gender researchers within computer science. I contrast the different approaches with each other and identify problems and limitations with most of the approaches used so far. This article is an attempt to move from my former rather uncomplicated understanding of "the gender question", to more complex issues concerning the discipline of CS.

I want to make a few comments on how I see this article now. It is clear that this is written by the 'engineer'. This is visible in the use of some categorisations and simplifications that I do, and in the unproblematising use of words such as 'paradigm'. I have

now also changed my view of what I call "the epistemological level" in the article, and see it as somewhat closer to "the structural level", than I did when I wrote the article. There is also a tension in the article between offering a general review of existing literature and arguing for what I believe is the (best?) way to increase women's participation in computer science.

Paper B2 : An earlier version of this paper is printed in my licentiate thesis. In this article I analyse an article about women and CS that received quite a lot of attention within the community of computer scientists. I combine my 'old' knowledge and experience from computer science, with knowledge and methodology from feminist research. The approach is to use partial perspectives (Donna Haraway) to read this article from different positions. I use my own experiences as providing the different 'lenses' to read through. The paper shows how different perspectives give very different images and understandings, and thus also different perceptions of the article read. In retrospective, there are clear connections with the theme of different mind-sets in paper A1 (which is written later). Positions and critical reflection are appearing, although not yet as explicitly formulated as in later papers.

Paper B3 is a joint paper with Lena Trojer. An earlier version of this is printed in my licentiate thesis. This paper outlines what I saw as the important points for my research at an early stage of my PhD studies. It is partly a 'state of the art' paper, where we discuss "what is computer science" and what feminist research can contribute to CS. In pointing to some concepts and fundamental 'paradigms' that exist within computer science, we argue the need for research that examines these 'paradigms' and the knowledge foundations of the discipline. Further, we raise the issue of how feminist research can be used to this end. We identify issues where we believe feminist research can contribute to in particular computer science education.

This article can be said to outline maps over the two "worlds" or landscapes I travel in: computer science and feminist research regarding computer science. Some notions central for CS are identified which are later developed and problematised in paper B4.

The approach in the article is the 'feminist engineer' wanting to change CS, but a close reading shows that some cracks towards communication open up.

In **Paper B4** I discuss how feminist research focusing on epistemological issues can be used within computer science. I approach and explore epistemological questions through a number of themes, which I believe are important to the issues of *what* knowledge is produced as well as *how* it is produced and how knowledge is perceived in computer science. In order to illustrate epistemological views in CS and how these can be questioned from the viewpoints of feminist epistemology, I also do a close reading of and comment on a recent book within the philosophy of computing.

This paper can be seen as (at least partly) a continuation of issues touched upon in B3. If B3 outlines a landscape, B4 looks at this landscape from the perspective of the feminist technoscience researcher, and asks what does it look like then?[1] However, the approach to feminist research in computer science has changed between the papers. In B3, feminist research is supposed to provide the *tools* for the engineer to bring about change, while B4 is an invitation to a dialogue between feminist research and computer science practice.

Contribution: I see the contribution from these articles in asking questions from feminist research perspectives, and doing readings with other 'spectacles' than the traditional computer scientist would have. These papers relate to parts A and C in the thesis. Firstly, because issues of interdisciplinarity and different perspectives are discussed. Secondly, since these papers show how different positions and starting points present different images, they can be useful in projects aiming at communication with computer scientists.

[1] There is some overlap between papers B3 and B4, since they are written for different audiences/ occasions.

Paper B1

An earlier version of this paper is printed in
Björkman, Christina (2002) *Challenging Canon: the Gender Question in Computer Science*.
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Women and Computer Science

Abstract

This article focuses on issues of women/gender and computer science[1], through the question of women's under-representation within the area. I present an overview and critical discussion of different approaches to the question, by using the two dimensions of how it is perceived and who perceives it. The article outlines research and discussion concerning women and CS during the last 10-15 years, how these follow different strands and have developed over time. Lately, research has started to approach questions around the discipline of CS itself, its development and role in how the issues of female under-representation are represented and discussed. Issues of knowledge and paradigms within the discipline thus enter the agenda.

Introduction

Women are severely under-represented within computer science (CS), and although significant effort has been put into different attempts and projects[2], as yet little progress has been made in changing the gender balance within the discipline. The issue of female under-representation has been widely recognised as a problem, in the community of

[1] I have chosen to use the term "computer science" (CS) instead of computing, in order to emphasise the discipline aspect. I use the term in a broad sense, as similar to the view of CS expressed in the Computing Curricula 20001 (ACM and IEEE-CS, 2001). In the works refereed in this paper, I have taken pains to identify what the authors mean when they use the word 'computing', and unless otherwise stated, it can be understood, in this context, as equivalent to my use of 'computer science' in all relevant matters.

[2] In Sweden, several initiatives to recruit women into CS have been evaluated in Wistedt 2001. For statistics on men and women studying computer science, see the Computing Research Association's Taulbee Survey: www.cra.org/statistics/ (USA) and www.scb.se (Sweden).

computer scientists as well as among other researchers and in society at large for the last 15 years and is the cause of much concern. The reason(s) why CS is so male-dominated, and what can be done to remedy the situation, has been the focus of much research and discussion.

This paper presents an overview and discussion of research and literature that focuses on the problem of low female participation within the field of computer science. I have chosen to use two dimensions in my study. The first dimension deals with *how* the problem is perceived; the second dimension concerns *who* perceives it. It is clear that these two dimensions are connected: the location of the researcher tends to influence how the problem is seen and what solutions are suggested.

The way a problem is represented and defined does in itself carry with it delimitations and assumptions. Thus, the problem definition strongly affects the solutions suggested and becomes a limiting factor on the potentials for change. This means that it is important to analyse the presuppositions implied or taken for granted, as well as what is left un-addressed, in the representation of the problem (Bacchi 1999, see also Mörtberg 2002).

I try to identify problems and limitations entailed by the approaches found in the reviewed literature; in other words, I am attempting to 'problemise' the views and suggestions. "If the interpretations of the nature and/or causes of the problem miss the mark, so to speak, we can expect little to change" (Bacchi 1999, p. 66).

I regard the issues of women in CS as a computer scientist and at the same time as a gender researcher. My experience is from a northern European context (Sweden). Some of the works reviewed here come from a Swedish context, especially when concerning intervention programmes. However, discussion on the issues of women and computing in the Nordic countries is not substantial, and furthermore is to a large extent influenced by writings and research done in USA and Great Britain.

Why is the Under-Representation of Women Seen as a Problem?

Before discussing the issues of *how* and *who* mentioned above, I will briefly discuss what the motives can be for why the issue of the lack of women in CS should be given attention, time and effort. These motives can be divided roughly into four categories[3]:

- Shortage of labour force. This argument is quite common, especially when a person is trying to advocate why changes are necessary. However, it can be seen as a rather cynical argument, suggesting that women are inferior: their importance is solely as a reserve labour force, when there is a shortage of (talented) men. An example of this argument is: "In short, there is a critical labor shortage in CS…" (Camp 1997 p. 104).

[3] See also Verne 1988, for a discussion about motives for recruiting women into CS.

- Missing women's contribution. This argument can actually have two distinctly different motives. Either, it means simply that we miss the contributions from a number of talented people who choose to do something else. This argument is non-controversial; for example: "It is one of our major follies that, whatever we say, we don't in reality regard women as suitable for scientific careers. We thus neatly divide our pool of potential talent by two" (C.P. Snow, Rede lectures, Cambridge, 1959, quoted in Pearl 1995 p. 26). The other motive, which has been rather commonly voiced in the Nordic debate, is the idea that women have special qualities simply by virtue of the fact that they are women. "Women may also contribute different ideas and interests in the development and use of computer technology" (Rasmussen and Hapnes 1991 p. 1007). This latter interpretation of the argument can be seen as supporting essentialism[4] in its view of women, and women are seen as a homogeneous group. Women are then burdened with the responsibility of being representatives of their gender and contributing "something new and extra".
- Gender equality motives. Women should have the same rights and opportunities as men to participate in and influence technology, as well as access to good career opportunities. "…the disturbing possibility that the field of computer science functions in ways that prevent or hinder women from becoming part of it. […Need] to ensure that fair and equal treatment is being provided to all potential and current computer scientists" (Pearl et al 1990 p. 48).
- With CS's dominant position as a field of knowledge and technology follows the need for a broad representation of developers within CS. This argument does not explicitly mention women, but broadening the representation implies diversity within gender, race, class, ethnicity, interests etc. "The more diverse our profession, the more creative and flexible we can be – and the more important our contribution to the world we live in" (Pfleeger 1990 p. 14).

How is the Problem Perceived?

Drawing on Sandra Harding's terminology (Harding 1986), I group the obstacles that women face within CS into three different levels:

– *individual* – for example, female students often have less experience with computers and programming than their male peers when they enter the academic education system

– *structural* – in the form of the structure, curriculum and pedagogic of the education programmes, as well as structures and hierarchies within academia and industry

– *symbolic* – the obvious and strongly male-dominated culture within the field as well as prevailing images of men, women and what it is to be a computer scientist.

[4] Essentialism means attributing to women (and men) inherited, specific qualities. Often, however, it is unclear what these specific qualities are. Usually, men and women are also seen as homogenous groups.

Many initiatives taken so far to increase the number of women in CS started by focusing on issues of information (trying to change the attitudes of women) and the individual level (often identifying women as the problem). "The low female representation in technical faculties is often seen as a quantitative problem, that is the problem is placed outside the own practice and the solution is to inform girls (preferably from day care and all through school) about the interesting content in technology. Women shall be enticed into existing practice and adapt to it" (Trojer 1999, p. 13). With this view, it is only the women who are expected to change.

On the individual level, psychological, social or biological sex differences have been suggested as possible causes for women's low participation, thus locating the problem with women. This could be seen as essentialism, since certain qualities and roles are attributed to women (as well as to men). There are countless studies and reports focusing on the individual level, many of which are connected to outreach programmes, mentoring, and role models. Another common topic is to discuss women's lack of computing experience and psychological issues such as self-confidence. The methods suggested can be called additional, or "add women and stir", i.e. they require a one-sided adaptation on the part of the women.

Recently, we have seen an increase in the work on and interest in questions regarding the structure and content of education as well as social and cultural issues surrounding CS. Many studies and projects treat both the structural and symbolic level. These studies are often attached to reform and intervention programmes addressing pedagogy and occasionally curricula, as well as climate, gender stereotyping and images of computer science and computer scientists[5]. Focus is turned away from individual gender and towards larger and more complex issues. However, essentialism can appear also here.

Joanne McGrathCohoon summarises the current status (McGrathCohoon 1999, p 198):

> "Low female participation has most frequently been attributed to female disadvantages that stem from gender differences in computer interest, motivation or experience, mathematical ability or academic preparation, self-efficacy, early socialization, […] culture of computers and its particularly male character, […] and environmental factors such as competition among students and pedagogical techniques. […] In spite of these efforts, no adequate explanation of CS's gender disparity has been agreed upon. Research results are varied and conflicting".

What seems to be lacking in many of these discussions are questions regarding *the discipline itself.* While all the issues mentioned above are of great importance, so far, however, these efforts have not led to a stable increase in the representation of women within the core areas of CS (e.g. Wistedt 2001). These results, and my own experiences from working with female students of CS (Bjorkman 2000 (in Swedish), 2001), noting their reactions to the discipline during their first year of study (which resulted in many

[5] In the Swedish context, we can note the D++ project at Chalmers Institute of Technology (Jansson 1998, in Swedish), the DTI project at Luleå University of Technology (Brandell et al 1998, Wistedt 2000 (in Swedish)). See also Wistedt (2001) and Salminen-Karlsson (1999).

of them dropping out), has led me to conclude that the problem goes deeper and is more complex. As a result, I want to suggest a fourth level of obstacles:

- *discipline* and *epistemological*[6] issues concerning computer science itself and its knowledge processes. By this I intend to highlight the importance of issues surrounding knowledge and how this is constructed, such as what is considered knowledge within CS, and who has knowledge, i.e. epistemological questions, as well as how paradigms are constructed and maintained.

Who Perceives the Problem?

For the sake of simplicity, I distinguish and discuss four different communities. These communities sometimes overlap, and their boundaries are not rigid. In my overview, I have not attempted to cover everything that has been written on the topic of women and CS, but rather to focus on the one hand on research that I have found to be influential from the CS point of view[7], and on the other hand on research that present different and new approaches. I have concentrated mainly on research done since the mid-1990's, with some exceptions to provide a background or point to earlier influential work.

Computer Scientists

I have studied how the issue has been discussed in articles in Communications of the ACM (CACM) during the period 1995 – 2001 (plus a thematic issue on Women and Computing from 1990) and within the SIGCSE group[8] (the SIGCSE Bulletin and the SIGCSE technical conferences) during the same period of time. I believe this selection of articles provides a good picture of the interest and knowledge that an 'ordinary' (though interested) computer scientist would have in the issue. With a few exceptions, these articles have been written by computer scientists. In some cases, the work has been done in collaboration with researchers from the disciplines of education and psychology, and two articles are written entirely by a sociologist. I have chosen to treat their research under this heading, since the articles are published within the community of CS and are intended to be read by people from this community.

How has the problem been perceived?

The approach adopted by most researchers within this group can be characterised as the "women into technology" approach (Adam 1995). This approach focuses on the low number of women and issues of recruitment, education, training and equity. The focus is clearly on women. Statistics, information and the individual level have been the most prevalent issues discussed. Below I give a few examples of general articles that

[6] Swedish National Encyclopaedia defines epistemology as the 'theory of knowledge'.

[7] My perspective here is both Swedish and international, mainly from within the area of Computer Science Education.

[8] The Special Interest Group of Computer Science Education, a group within ACM.

have received a great deal of attention within the community of computer scientists. The article by Tracy Camp on the "incredible shrinking pipeline" (Camp 1997[9]) focuses on the depressing statistics concerning female representation within CS. In the November 1990 issue of CACM, with the theme "Women and computing", the ACM Committee on the Status of Women in CS reported their findings (Pearl et al 1990). Five years later, in the January issue of CACM with the theme "Women in computing", Klawe and Leveson (1995) report on the current knowledge status. Both these latter articles cover a broad field of explanations and suggestions for solutions, addressing mainly the individual and to some extent the structural and symbolic levels.

Arguments calling for efforts on the individual level have been voiced in many articles, including discussions on role models (e.g. Childress Townsend 1996, Haller and Fossum 1998) and recruitment programmes (e.g. Rodger and Walker 1996). The problems facing women in introductory programming courses, often because they have far less experience with computers and programming than their male peers, is a recurring theme (e.g. Sackrowitz and Parker 1996). Psychological approaches can also be found, such as trying to explain the low number of women with psychological personality components (Haliburton et al 1998).

However, issues of education, culture within CS and perceptions of CS are also addressed, and these have been given increasing attention over the last years. In the November 1990 issue of CACM, Karen Frenkel acknowledges the importance of these factors, in her report from a workshop[10] (Frenkel 1990). Other topics include the glass-ceiling in industry (Hemenway 1995) and suggestions to introduce students to the culture of computing, such as acronyms, buzzwords, non-academic literature, advertisements, movies, magazines and so on (Bernstein 1997). The influence of ethnicity in combination with gender on how CS is viewed has also been addressed (Von Hellens and Nielsen 2001). Ellen Spertus made an early contribution to the discussion of women and CS. Her report "Why are there so few female computer scientists?" (Spertus 1991) stresses the importance of social and cultural causes for women's under-representation.

A never-ending debate is that of the role of mathematics in CS, where there seems to be a widespread belief in the idea that women are put off by mathematics, although no research actually supports this (Haliburton et al 1998, Scragg and Smith 1998). However, there are also advocators of the opposite opinion, that CS ought to be more like mathematics in order to improve female participation: "Could it be the ill-defined nature of computing is what drives them away?" (DePalma 2001 p. 27).

The reasons given for female under-representation in most articles are the same as those that were found in a study commissioned by the ministry of education in Australia. I quote this article to summarise and confirm how the problem is commonly viewed (Selby, Ryba and Young 1998):

[9] A follow-up of this article is available on the web: see Camp (2000).

[10] This workshop is discussed further under Cross- and Interdisciplinary Groups and Forums below.

(1) Lack of Knowledge about Career Prospects
(2) The Image of Computer Science and Information Technology
(3) A Perceived Lack of Confidence Amongst Women Students Despite Their Obvious Abilities and Successes
(4) A Lack of Women Lecturers
(5) Computing as a Male Domain
(6) The Learning Environment Is Often Not Informed by Contemporary Learning Theory
(7) The Importance of Prior Computing Experience.

In the overwhelming majority of the articles I have reviewed, basically the same issues are discussed, the same results from studies presented, and the same suggestions for improvement made. There is a general belief in rather clear and simple solutions and at the same time that changes are necessary in society. It seems there is a willingness to accept the need for revolutionary changes in society, culture and attitudes, but not when it comes to one's own discipline, where more surface-oriented solutions are suggested. The view of the discipline is thus characterised by the habit of taking CS as a given. This is confirmed by the results from an on-line survey done by Tracy Camp (Camp 1998) as a follow-up to her article "The incredible shrinking pipeline" (Camp 1997). 111 computer scientists responded to this survey where they among other things were asked to rank activities to increase the number of women in CS. The alternatives that were ranked highest by the respondents are all on what I call the individual level, and the only alternative that touched on the discipline: "modify curricula", was seen as important only by 16% of the respondents. However, it should be noted that the way the survey was formulated and the issues it focused on helped define the problem and the suggested solutions in certain ways.

Most of the studies mentioned above were carried out by computer scientists who seem to be unaware of other research, for example research done by social scientists. This can be seen in the lack of references to publications from other fields, and the lack of references to gender research publications is especially notable.

New approaches?

Despite the efforts made within the community, as yet no sustainable increase in the number of women within CS has been achieved, demonstrating that the way the problem has been delimited and treated by computer scientists thus far leads to a limited understanding. This has been recognised by some computer scientists: "The nature of the computing discipline itself needs to be addressed by its participants: what is computing science? This need is slowly being recognised but the variety of answers reflects the problem" (Stack 1997 p. IX).

During the last years, however, critique of the status quo and 'cracks' in existing views have become visible. One such sign is the publication of an article by sociologist Joanne McGrathCohoon in the CACM, focusing on departmental characteristics and practices as an important factor for the retention of female students (McGrathCohoon 2001). She also notes that another key factor is "discipline characteristics".

Issues of social relevance and responsibility surfaced at a conference that gathered together 50 senior and successful technical women from the computing field in industry. The topic of the conference was to explore the most important issues for computing to address in the next 10 years. "The group decided to turn the creative process on its head. As a field, computing has been driven by technical or scientific goals. […] Imagine the societal challenge driving the investigation…" (Borg 2001 p. 140), thus letting the needs of people drive research and creation of technology. Anita Borg also discusses how such a change in focus could affect recruitment (Borg 2001 p. 141):

> "We have educated thousands of developers, engineers, and researchers who see their roles as technology inventors, and only a few who start by understanding situations and people and let that drive the creation of technologies. By presenting the major challenges of computing as technical challenges, we have lost the interest of many brilliant technical minds – often female – because their interest is in using that brilliance to solve real problems rather than creating technology for technology's sake."

Maria Klawe, president of the ACM and Dean of Engineering and Applied Science, Princeton University, recognises the need for change within CS in her article "Refreshing the nerds" (Klawe 2001). Based on a survey among 7500 high school students in Vancouver, she concludes that the image of CS has to be changed, but "also the reality of how we teach computer science, and how we design computers and computer applications. […] We tend to value abstractions rather than examples, technology rather than applications" (Ibid p. 68). She points out that there is an urgent need to broaden recruitment into the discipline (Ibid p. 67):

> "The point here is that computer science also needs to attract students with broader interests and abilities than the traditional computer scientists—nerds. […] But nerds are not enough. We need more computer scientists whose passions are art, language, literature, education, entertainment, psychology, biology, music, history, or political science. We need them because computers have an impact on all areas in our world. We need people with passion and vision from every area to drive the development of computer technology as well as the applications"[11].

Maria Klawe acknowledges the insufficiency of the current approaches: "Most of the current experiments are Band-Aid solutions that address only a piece of the problem. We need to look at the whole picture. […] We need non-nerds in computer science, so let's figure out the proper approaches to integrate their talents and perspective into our field" (Ibid p. 68).

These examples, found within the last years, open up possibilities for new approaches to the "women and CS problem" that will hopefully also include giving attention to the discipline level I identified above.

Strengths and weaknesses

I find the real strength within the community of CS is the commitment to transformation. This desire is not only due to more abstract ideas of equality or broader representation, but also stems from lived experiences, from daily work and situations encountered.

[11] Compare with the quote from Sheri Pfleeger above.

Change is the focal point on the agenda, and although ideas and knowledge from other groups must not be ignored, change can, in my opinion, only be made from within. However, there is far too little communication with research and knowledge acquired within other disciplines, and there is also, as I pointed out above, an unwillingness to question the discipline itself and its practices. In short, I believe the current understanding of the problem of female under-representation is too shallow – the problem has been constructed in a way that limits the solutions. The focus is still strongly on women. This is easily visible in that the word 'women' is always used when the problem is discussed. There is very little, if any, focus on the second part of 'the problem': computer science. However, above I pointed out some promising openings towards a discipline-oriented focus, and an understanding of the role of CS in society.

Social Scientists

The issue of low female participation in computing has triggered research and studies mainly within the fields of education, psychology, sociology and the interdisciplinary field of Science and Technology Studies (STS). I have chosen to focus on research that is relatively visible from the CS point of view (most probably because the researcher is interested in transformation and thus trying to communicate results to computer scientists). The overview I present is not intended to cover the whole area of research within social science that is relevant for the issues of women and computer science, but rather to point to some trends and contrast these with the approaches found within the community of computer scientists.

How has the problem been perceived?

Within social science, the issue, and thus the problem, is usually discussed in terms of 'gender and CS' – or at least in more recent publications. This difference in terminology is more significant than it might appear at first glance. It signals a move away from a focus on women and towards a focus on issues of *gender*, i.e. both men and women are included, and socially constructed gender is emphasised over the biological sex.

For the most part, it is some early research that can be characterised as approaching the problem on the individual level. This research often expresses essentialist views of women, e.g. that changes within CS may offer women a unique opportunity because changes in the mental model of computing will make it more 'feminine', or that object-oriented programming would require a reconsideration of traditional concepts of masculinity and femininity (Perry and Greber 1990).

A well-known researcher who employs a psychological approach on the individual level is Sherry Turkle. She assumes that technology is gender neutral in itself, but that men and women have different "cognitive patterns", based on psychological sex differences. Her approach can thus be seen as essentialist. She develops the concepts of 'hard mastery' (manifested for example in control over the machine and competitive behaviour) and 'soft mastery' (a more interactive approach to the computer as a tool and co-operative behaviour). She argues that most men take the hard-mastery approach while women tend to be soft masters. Neither style is superior for programming, but computer expertise is

defined in terms of hard mastery as the rational, logical approach and the only correct way to program, while soft mastery is seen as inferior (Turkle 1984).

Research among social scientists seems to concentrate mainly on the structural level and, increasingly over the years, on the symbolic level (e.g. Sanders 1995). The approach adopted by most researchers within this group can be characterised as the "gendering of technology" approach (Adam 1995).

This is connected to the social constructivist approach, where the historical and cultural contexts are seen as dominant factors behind the under-representation of women in computing. Much work within this group has focused on the social construction of computing – both as a discipline and as computer-related activities – as masculine. Kramer and Lehman (1990) is an example of an early critique centring on the role of contexts and embedded social contents of computer learning.

In her book "Feminism confronts technology" (Wajcman 1991), Judy Wajcman argues against Sherry Turkle's view. Judy Wajcman claims "cognition can not be stripped of its social content to reveal pure logical reasoning" (Ibid p. 157). Psychological development cannot be understood disconnected from the social context. She brings up the history of computer programming: "It was because programming was initially viewed as tedious clerical work of low status that it was assigned to women. As the complex skills and value of programming were increasingly recognized, it came to be considered creative, intellectual and demanding 'men's work'. Thus, depending on the circumstances, different cognitive styles may be characterized as 'masculine' or 'feminine' according to the power and status that attaches" (Ibid p. 158).

Flis Henwood has criticised what she perceives as technological determinism and essentialism in existing research (including feminist research). "Continued existence of biological and technological determinism is seriously inhibiting the development of appropriate transformation strategies" (Henwood 1993 p. 31-32). Instead, she suggests that "A suitable framework for analysing gender and IT relationships then, is one which understands both technology and gender not as fixed and 'given', but as cultural processes which (like other cultural processes) are subject to negotiation, contestation and ultimately, transformation" (Henwood 1993 p. 44). The problem of determinism is observed in a 'traditional' CS course (on data structures): "both 'gender' and 'technology' are taken at face value and their cultural nature is not understood. This limits the space that exists within such courses for students (or staff) to examine the gendered relations of technology and the resistances to change in those relations" (Henwood et al 2000 p. 128).

Linked to this approach are studies of 'computer culture', or the 'culture of CS', which is described as a whole complex of processes forming the image of the discipline and activities connected to the discipline. Fundamental work here concerns hackers, and hacker culture (e.g. Turkle 1984, Håpnes and Rasmussen 1991, Rasmussen and Håpnes 1991, Nissen 1993, Håpnes and Sorensen 1995). This research argues for a

concentration of attention on ongoing cultural production. Female students are defined (also by themselves) as marginal, because they distance themselves from this culture. The male domination is created by sharing certain values such as machine fascination, playful attitude towards computers, and total absorption in them (Håpnes and Rasmussen 1991).

> "The culture and ideas of a small male minority of students, the computer hackers, come to dominate computer science in the eyes of the female students. This minority culture is reinforced by the values and interests of the most powerful (male) groups in computer science, the male professors and teachers, and their disciples, the dedicated students. In this way, a male-dominated and machine-fixated culture works to marginalize women" (Rasmussen and Hapnes 1991, p 1107).

Jörgen Nissen discusses different answers to the question of male dominance within computing[12] arguing that the reasons are not to be found in psychological differences or in the 'essence' of computer technology. He sees technology as made by men for men, as linked to activities seen as traditionally male, and the control of the machine as a masculine symbol (Nissen 1996).

Minna Salminen-Karlsson (Salminen-Karlsson 1999) has studied curriculum reform processes aimed at making a computer engineering education[13] more attractive to female students. Focus is on how "gender contracts", denoting engineering as a masculine sphere, are reproduced within the education. She shows that lack of knowledge in gender issues among faculty can be a strongly limiting factor on change. "Thus, while engineering faculty seem to be the only agents who really can enforce even such reforms that can break gender contracts in the education, at the same time they seem to be limited in their views of what is possible and thus are unable to make such radical reforms as would be needed to change the contracts" (Ibid p. 239).[14]

Along with the culture of computing comes the problem of inequalities within the discipline and the ensuing dilemma for women who do not want to be seen as 'other'. By claiming "we are not different", they emphasise similarity of abilities and so avoid being segregated and excluded from science (Wilson 1997).

Gerda Siann (1997) argues against this focus on culture. She points out that women have gone into other areas that are dominated by a strong masculine culture, but that women choose not to go into computing because it is seen as lacking social involvement and commitment.

New approaches?

There is some emerging research within this community that is calling for a focus on the paradigms of computer science or what I have called the discipline level. Sue Clegg

[12] By computing, Jorgen Nissen means the whole field of computer-related activities, but since this is strongly related to the culture within CS, I find it relevant here.

[13] In Sweden.

[14] Compare this result to the project at Carnegie-Mellon University under Cross-and Interdisciplinary Groups and Forums below.

(Clegg 2001) argues that we need to understand how the discipline of computing is constituted historically. Computing was institutionalised alongside other male-dominated disciplines, establishing itself as intellectually challenging, tough and abstract. She claims that computing is neither an extension of mathematical thinking nor an applied science. The reasons it came to be thought of as such are due to the historically contingent ways computing developed. Instead, computing is best characterised as a concrete rather than an abstract science, containing materiality and social practices. She points to the need for research into CS: We should "ask what is wrong with computing rather than what is wrong with women" (Clegg and Trayhurn 1999). Linda Stepulevage and Sarah Plumeridge (1998) discuss how certain dogmas of science, such as physics as the paradigm of science, and 'pure mathematics' as value-free, are relevant to computer science. Connected to this is the separation of abstraction, as the 'pure', from the applied:

> "Computer science as the pure focuses on understanding the world via a rationality based in the abstract; therefore, the concrete products resulting from the discovery and development of algorithms can exist outside the domain of computer science and there is no need for critical self-reflection" (Ibid p. 316-317).

Just as with the community of computer scientists, examples of fairly recent research open up possibilities for more complex and new approaches to the issue of women and CS, including asking questions on the discipline level.

Strengths and weaknesses

On the whole, the strength of this group of researchers comes from their being outsiders to the community of CS, in the sense that they have no pre-understanding of what computer science is or should be, and as we have seen above, they question technological determinism. They also bring more complex issues, such as social construction, on to the agenda. However, there are simplifying features in this research too, for example in the strong concentration on social aspects such as history and culture. In constructing the problem as solely social/cultural, other factors might be overlooked, thus limiting the suggestions for action. There can be a tendency to focus on questions of why, i.e. to explain, rather than to suggest what can be done about the problem. The position of outsiders looking in is also one reason for the weakness of the research in limiting its possibilities to contribute to the transformatory project. For one thing, even if on a political level these researchers are strongly committed, the issue of women in CS is generally not part of their everyday life and experience. We can also note the absence of references to work done within the CS community. Furthermore, there is the problem of communication between disciplines. In my experience 'the two cultures' do exist, with a deep chasm separating the different disciplines. This is rendered visible in everything from the view of knowledge and what the goals of knowledge production are to traditions of writing and language and what is seen as acceptable and 'good science'. It can be as difficult for a computer scientist to read a research publication within social science as for a social scientist to read a technical publication within computer science.

Cross- and Interdisciplinary Groups and Forums

In this section, I have chosen to present two types of research, both characterised by some level of cross- or interdisciplinarity. One is interdisciplinary research groups, the other is research done within the respective disciplines but published and communicated deliberately at what I call a 'meeting place' for researchers from different disciplines. By presenting this type of research (cross- and interdisciplinary) separately, I want to point to the fruitfulness of interdisciplinary work. "The challenge is to continue what has begun, both so that 'women into technology' research can be more theoretically informed, and social science/philosophical research can be more directly linked to social action, which is in the best tradition of feminist thinking" (Adam 1995 p. 43).

I have chosen to present some approaches and groups that are particularly interesting, either because they have attracted attention and/or brought about changes within CS education, or because they adopt approaches that I find new and promising.

How has the problem been perceived?

One early meeting place that brought together participants from many disciplines was the workshop *In search of gender free paradigms for computer science education*, held in 1990 (Martin and Murchie-Beyma 1992)[15]. The premise of the workshop was that "the decline in the number of young women selecting computer science majors was attributable to a male-oriented paradigm in computer science" (Ibid p. VII). The organiser (Dianne Martin, computer scientist and educational researcher) discussed the power of paradigms. It seems clear that she is referring to *educational* paradigms rather than paradigms within the discipline: "the decline in young women…can be attributed to the existing educational paradigm that separates studies of science, math, and computer science from studies of the humanities" (Ibid p. 1), and she advocates a more integrated approach. Thus, she focuses on the structural level combined with the symbolic level. Robin Kay, psychologist, advocates a shift towards greater focus on process, encompassing for example complex interactions, social construction and context. In another contribution, Danielle Bernstein (computer scientist), discussed how students are best introduced to CS, in order for them to gain confidence. She argued for a new approach in the introductory course, using application software packages instead of procedural programming. This would give students immediate success in doing something useful, while still illustrating and reinforcing CS concepts. This is an example of an intervention at the structural level.

An example of interdisciplinary work is the research undertaken by Sherry Turkle (psychologist) and Seymour Papert (mathematician and pioneer within artificial intelligence) (Turkle and Papert 1990[16]). In studies of programmers they have identified two distinctly different styles: the 'planning' approach (rational, structured, controlled) and the 'bricolage' approach[17] (concrete, negotiating). The 'bricolage' approach is related to closeness to the objects of work, while 'planning' is coupled with keeping a

[15] This has been given attention within the computer science community, for example in Frenkel 1990.

distance. There is no difference in the quality of the product obtained using the different approaches; the difference lies in the process. They have found that most men are planners, while most women prefer the 'bricolage' approach. This is explained in terms of psychoanalytical theories, and I would argue that there is a tendency towards essentialism. These different approaches are seen as different attitudes towards knowledge, as different epistemological standpoints. Turkle and Papert argue for an "epistemological pluralism", and a "revaluation of the concrete". The emerging object-oriented approach is seen as potentially revolutionary: "first, within the world of programming through legitimising alternative methods; second, in the larger intellectual culture, by supporting trends in cognitive theory that challenge the traditional canon"[18].

Another area of research and action concerns so-called 'gender inclusive teaching' within CS. This forms the basis of research undertaken by pedagogues and computer scientists (e.g. Nightingale et al 1997, Involve project 1997). Gender inclusive teaching targets teaching (and learning) practices in order to improve participation by women. It covers many aspects related to the individual, structural (especially pedagogical) and symbolic levels (e.g. classroom climate). A central goal is "to enable all students to feel ownership of, and competency in, the aims and outcomes of their courses" (Nightingale et al 1997). An important element is introducing awareness among teachers about gender issues and different learning styles.

New approaches?

I have chosen to discuss at some length one recent example of extensive interdisciplinary co-operation concerning the issue of women and CS. The reason for devoting so much space to this single project is that it has been very successful, and as a consequence has aroused a lot of attention among computer scientists.

At Carnegie-Mellon University (CMU) an interdisciplinary programme of research and action started in 1995, headed by computer scientist Allan Fisher and social scientist and expert in gender issues in education Jane Margolis. The programme is called: "Women in Computer Sciences: Closing the Gender Gap in Higher Education" (Fisher, Margolis: project homepage). As motives for their project, they cite: "The under-representation of women among the creators of information technology has serious consequences, not only for those women whose potential goes unrealised, but also for a society increasingly shaped by that technology" (Ibid). The aim has been "to understand male and female students' engagement - attachment, persistence, and detachment - with computer science, with a special focus on the gender imbalance in the field" (Ibid). Their

[16] This paper has been reprinted as an appendix to *In search of gender free paradigms for computer science education.*

[17] The term 'bricolage' is borrowed from Claude Levi-Strauss, who used the concept for the knowing within primitive societies, meaning "a science of the concrete". Levi-Strauss, Claude (1968), *The savage mind.* Chicago: University of Chicago Press.

[18] No such epistemological changes, as an effect of object-orientation, have been observed yet. Compare also with the ideas expressed by Perry and Greber above.

research question could be summarised as "do women approach the study of computer science differently from men?" (Margolis et al 1999). The goal of the action component has been to "devise and effect changes in curriculum, pedagogy and culture that will encourage the broadest possible participation in the computing[19] enterprise" (Fisher, Margolis: project homepage). The project covers the individual, structural and symbolic levels, but barely touches on the discipline level (see below).

The field of computing, as represented by expectations, culture and curriculum, is very much oriented towards a narrow slice of males, while women approach it at a different pace and with different forms of attachment. Moreover, curriculum and culture do not acknowledge an interdisciplinary, contextual orientation toward CS (Margolis and Fisher 2002). Students' understanding (both intellectual and social) of the nature of the field is a key concept, but women often find the area too narrow, they feel they have to be too narrowly focused (Fisher et al 1997). This is connected to the effect of "boy wonders", the perception that there is only one way (the male way) to come to computer science (Margolis et al 2000). When the world around the female students grants prestige to the "boy wonders," any departure from this path becomes "lesser than" (Margolis et al 1999), leading to erosion of women's confidence.

> "The computer science culture assumes that men will succeed. […] Hence it bolsters men's confidence and sense of belonging. This same culture does not assume (often accurately) that women conform; hence they enjoy no default expectation of success, and their interests and attachments to computing may be regarded as deviant from the norm, and less serious than those of the male students" (Margolis et al 2000).

The aim of the group has been to broaden the culture and curriculum, to show that there are multiple ways to be a computer scientist and to be interested in the subject, and to demonstrate that valuable contributions to the field come from people with different sets of attachment to computers (Margolis et al 2000). Among examples of the changes that they have implemented are: different entry points to the curriculum, depending on the level of experience, an "immigration course" to expose new students to a wide variety of CS issues and applications in order to counteract the "all programming" stereotype, and interdisciplinary courses. The project has been a success, with an increase in female enrolment in the computer science programme from 7% in 1995 to 42% in 2000 (Margolis, Fisher 2002).

In their recent book: *Unlocking the clubhouse Women in computing* (Margolis, Fisher 2002), they describe the whole project, and the results. The book (and thus the project) focuses on educational change, but also discusses issues such as early gender socialisation, schooling experience, culture etc. The main perspective has been the college level, and the experiences of female student's in college computer science.

The authors take a firm standpoint against changing and adapting women:

[19] The group uses both terms: computer science and computing, but they do not seem to differentiate explicitly between them, as a result of which I assume that they use them in the same sense that I have used them in this paper, i.e. as essentially synonymous.

> "…change computer science into a field that is engaging and interesting for a much larger and more diverse group of students. The goal is not to fit women into computer science as it is currently taught and conceived. Rather, a cultural and curricular revolution is required to change computer science so that the valuable contributions and perspective of women are respected within the discipline." (Margolis, Fisher 2002, p. 6).
>
> "The perspective that computer science can make itself stronger by incorporating the values typical of women in the field changes the question from "how can women change to fit into computer science" to "how can CS change to attract more women"." (ibid. p. 60).

But what are the perspectives and values of women? And do all women hold these? Even though the authors are aware of the risks of simplifying the categories men and women, I find reason to warn for the risk of essentialism that is apparent here. The project devotes a great deal of attention to women's experiences and perspectives. Such projects are important in that they result in new knowledge about women, making their experiences and knowledge visible. However, these projects can also have negative effects: for example it can lead to the categories men and women being oversimplified, meaning we end up in a dichotomic deadlock (Mörtberg 1999). We will not be able to gain anything by dichotomising men and women and thus putting them in opposition to each other.

What will happen in the long run with the female enrolment?[20] Jane Margolis and Allan Fisher are well aware of the "challenge for the future" (Margolis, Fisher 2002, p. 138). How can self-sustaining change be created? They conclude: "If the enrolment of women continues to depend on a small number of contributors making targeted efforts, the change cannot be considered permanent or complete." (Ibid p. 139). What is needed is some kind of institutionalisation and continuation of improvements.

This project sets a very good example, since it is thorough and consistent; it is not just an isolated intervention, but rather a whole complex of research and action. I regard it as an excellent initiative to bring gender expertise into computer science, and see the success of the project as highly dependent upon the acceptance of this expertise within the community of computer scientists.

However, I would like to problemise some underlying assumptions that in my opinion might lead to limitations in the long run. I noted above that the discipline level is barely touched upon. There are many places in the text that open up for potential discussions of the foundations of the discipline of computer science, even though the authors have stressed these issues as mainly cultural and curricular. Some examples:

In the quote on the preceding page, the authors talk about "a cultural and curricular revolution". Is this enough? What about a "scientific revolution", in the sense of going beyond culture and curricula to look at the discipline and how it is constructed? It is not only about how computer science is "taught and conceived", it is also about how it is thought, talked and understood as knowledge and discipline.

[20] The long-term results of some major intervention programmes in Sweden have been somewhat depressing. When the computer engineering programme at one of Sweden's largest universities was reformed, the number of women increased in the first few years, but then decreased again back to the same low level as before the interventions (Wistedt 2001).

In the epilogue, the authors discuss what they term "changing the conversation in computer science" (p. 143), and ask: "Will women computer scientists change the conversation in CS? What will it then sound like?" (Ibid p 143). They continue: "We hope that faculty and administrators will rethink the assumptions that underlie the design of their programs and courses." (Ibid p 144)

Why just rethink assumptions underlying the design of courses? What happens if we also rethink the knowledge foundations – what is important and why? As for the conversation, can it also target the discipline itself and its knowledge foundation? Why are things the way they are? Can they be different? How do we for example see programming? How far can we get if we do not reconsider our fairly stable idea of what programming is and should be, but merely the way we teach it?

My criticism thus targets the lack of questions concerning the discipline of CS as such. The attitude of the authors appears to be that they take the fundamentals of CS as given. As noted above, they explicitly concentrate on curriculum, pedagogy and culture. As I have argued above, this will lead to a limited understanding. I argue that by *exclusively* focusing on social and cultural factors, we limit ourselves and fail to see other deeply rooted influences (such as issues of knowledge).

Strengths and weaknesses

The strength of interdisciplinary groups and meeting places lies in their ability to bring together researchers from several communities, allowing them to share and use each other's knowledge and experience as resources, and thus possibly creating space for more radical approaches. Researchers from interdisciplinary groups are also well informed about work from different areas. There are however many difficult positions to be negotiated for these groups, including navigating the internal requirements from within the separate disciplines, as well as trying to bridge the many gaps that exist between disciplines[21]. In the best of cases, they manage to achieve this and can then open up 'cracks' in existing views and problem definitions. However, the problems of acceptance for a 'foreign' discipline within CS should not be underestimated and can necessitate compromises in order to be accepted and to be able to work towards transformation.

Feminist/Gender Researchers Within Computer Science

Above, we saw what gender research can bring to computer science, in the example of the project at CMU. However, there is another type of gender/feminist research that is a so far mostly unacknowledged resource for research into the issues of gender and computer science. This strand of research takes a more science theoretical/critical approach. It has developed from issues around women, to realising and focusing on problems concerning how science is constructed and practiced. Frustration over problems encountered in transformatory work, has led to focusing knowledge processes within science and asking questions such as "what knowledge is valid and why?" and "who has

[21] See also the discussion above concerning the strengths and weaknesses of work done by social scientists.

the preferential right of interpretation and why?" Feminist scholars such as for example Sandra Harding (e.g. Harding 1986, 1991) and Evelyn Fox Keller (e.g Keller 1985, 1992) have contributed to a foundation that gives the possibility of new approaches. They discuss questions such as "Whose science? Whose knowledge?" (Harding 1991) and what the role of gender ideologies and metaphors is within science (Keller 1992). The use of language has proved to be very important in our understanding of ideas and the images they call to mind. The presence of clearly gender-marked metaphors can be a factor in supporting the gender structure within the discipline. Metaphors create images that will be of importance in the knowledge process (Keller 1995).

I will end this survey by discussing research done by people who are both computer scientists and gender researchers, and who have been inspired by the above mentioned strand of research. We can see how these researchers approach the problem of female under-representation in new, often radical, ways arguing the need to discuss issues concerning the discipline itself and its knowledge processes. Many of them also discuss the importance of doing research from within computer science, since it is from within that transformation needs to be staged.

A discussion of what a feminist perspective could imply for computer science, and how it could be used as a resource for transformation, has been discussed by Norwegian informaticians[22] Tone Bratteteig and Guri Verne (Bratteteig and Verne 1997). They use Sandra Hardings work as a starting point, and discuss the potentials yielded by gender research for the establishment of alternative understandings of knowledge within CS. They see "epistemological enquiries" as the most challenging, with the greatest potential for contributing to change within the discipline. As a totally different example, they discuss the idea of getting girls interested in computing through games, but they find it difficult and questionable to design alternative games for girls: "The question we are left with is whether we change anything or rather conserve status quo by implementing the conditions and characteristics of some present female culture" (Ibid, p. 67).

In the context of Artificial Intelligence, Alison Adam has focused issues of epistemology. (Adam 1998). She discusses issues of knowledge, such as 'whose knowledge' and 'what knowledge' is represented in AI systems. Among other topics, she discusses the differences between propositional knowledge ('knowing that') and skills knowledge ('knowing how'), or mental vs. embodied knowledge, and how the former, which is usually associated with men, has been seen as superior to the latter (often seen as linked to women). Anne Moggridge discusses how an extended epistemology can begin to account for more practical and personalised aspects of knowing, situated in social and cultural contexts. She considers the connections between gender research and conceptions of knowledge (Moggridge, 1998). "Knowing is not necessarily a matter of saying and representing what is the case but can also be a kind of practical involvement with

[22] "Informatics is the term for computer science departments in universities in Norway, indicating that the discipline is defined more broadly than in traditional computer science departments" (Bratteteig and Verne 1997, p. 59).

the world" (Belenky et al.1997[23], quoted in Moggridge 1998, p. 34). She discusses how this can be used within computing, to transformatory ends. She further argues (Moggridge 1998, p. 35):

> "In seeking to understand and change the "under-representation" of women in computing we should be less concerned with traditional theorising than with understanding, sharing and developing our own knowledge of technology and work, knowledge which is grounded in our experiences of both."

What changes can be made to the discipline? Can we change what we do? Frances Grundy examines possible solutions to the problem of the lack of women in computing (Grundy 1996, 1997). She discusses what she sees as three levels of criticism and solution: "add-more-women", the "liberal level" (qualitative changes to the environment, including teaching), and the "radical level": "This is where we start looking for a really new science and encouraging a transformation not only of the way we do it, but also what it is that we do" (Grundy 1997, p. 9). Frances Grundy also offers an interesting view of role models. Contrary to most computer scientists, who emphasise the value of female faculty as role models, she argues that young women might see these women as bearers of traditional views of CS and society and as "reinforcing the idea that there is no room for questioning the basis on which the subject is founded" (Ibid, p. 7).

Another approach is to ask what might be lacking within the discipline. Ulrike Erb (Erb 1997) has studied the professional ways and experiences of female computer scientists within their discipline and concludes that many of these women feel there is a lack of needs-oriented and use-oriented questions and complain about the marginalisation of so-called "non-technical" skills. She discusses issues of what is excluded in CS, in terms of the missing accountability, the absence of subjectivity and the excluded views of the system users. She argues for changes and challenges to the discipline (Ibid, p. 207-208):

> "Integration of the excluded and a corresponding change of the image and the paradigms of computer science could open up new identification possibilities for women in this discipline, and it would also augment the possibilities for both women and men to realise their creative potentials in computer science."

The discussion of inside-outside perspectives and positions is seen as important by many researchers. Anne Moggridge points out that there is an increasing amount of relevant literature on gender and computing, but that most of it has been produced outside of the discipline:[24]

> "There is no shortage of literature that is in some way relevant to our construction and understanding of the "under-representation" of women in the computing profession. However, little of the "knowledge" that has been produced in the course of researching this situation is of practical use for women working "inside" but seeking to effect change in computing.… […] Most of this research is conducted from the "outside" using established theories to help interpret observations of attitudes and events "inside" (Moggridge 1998, p. 32).

[23] Belenky, Clinchy, Goldberger, Tarule, 1997: *Women's ways of knowing: The development of self, voice and mind.* New York, Basic Books.

[24] The project at CMU, however, combines knowledge from the inside and the outside.

Tone Bratteteig and Guri Verne (Bratteteig, Verne 1997) further argue that the perspective on something differs according to whether it is seen from the inside or from the outside, and that a critique of the discipline requires knowledge about it.

An interesting analysis of an all-women programme in computer science and computer engineering, "from the inside", and using feminist theory, has been made by Christina Mörtberg. (Mörtberg 2002). She examined the assumptions implied in the diagnosis of the problem of the under-representation of women in the field, and whether these assumptions actually limit the possibilities for change. "Given the way the problem is represented to be, special types of solutions are reasonable. Consequently, the equality programmes create both the problem and the solution of the problem" (Ibid, p. 3). For example, the founders of the all-women programme assumed that women would have special understandings and experience, but what these were was never made explicit. Moreover, women were treated as a homogeneous group. In the programme, the female students become constructed as 'others' compared to mainstream students. The female students are actors moving in certain circumstances and dealing with, often contradictory, discourses. By crossing boundaries, by being at the same time insiders and outsiders, these students can have an advantage in casting light on what is taken for granted within the discipline.

Strengths and weaknesses

Within this group, we find approaches towards the discipline level. Researchers here point to the importance of focusing research on issues concerning the discipline itself. These questions lead right into the heart and core of CS paradigms and understandings. I regard this group as promising, since they combine gender research with a position within the community of computer scientists. Their work can be seen as challenging the canon surrounding the 'gender question' in CS. However, gender research within computer science faces a particular problem: is it possible both to do gender research and to maintain the legitimacy as a computer scientist? "Movements towards doing feminist research might weaken our contact with and ability to do technological research" (Bratteteig and Verne 1997 p. 70).

Concluding Remarks

As I stated in the introduction, the way a problem is defined affects the solutions suggested, and becomes a limiting factor on the potentials for change.

This is clearly seen in some of the works discussed in this paper. If the problem is defined in terms of arguments such as: women have less experience with computers, women lack self-confidence, women have too few role models, then the approaches are rather straightforward: give women experience with computers, strengthen their self-confidence, provide role models. What happens then when the expected effect of the action fails to appear? Do we return to the definition of the problem or do we blame the women? Moreover, as I have discussed above, what implications do the problem

definitions have? At least the first two definitions above directly imply that something is wrong with women, i.e. women are compared to an existing 'male' norm of success, albeit most often implicitly.

My discussion above refers mostly to the individual level, but what about the problem definitions that exist on the structural and symbolic levels? It is likely an oversimplification to believe that changes in teaching and pedagogy can be the whole solution; they may well be necessary but they are unlikely to be sufficient. One part of the problem may certainly be that the under-representation of women depends on the social construction of computing. However, the risk is that this research stops at the level of explanation, instead of promoting change, and also that many other factors contributing to the problem might be overlooked.

The discipline level has so far not been the focus of much research or discussion. How the paradigms and knowledge processes within CS are formed, mediated and mirrored, e.g. in education, is a large, but so far mostly overlooked, part of the complex problem of low female participation in CS. However, during the last years voices have been raised, both within the community of computer scientists, and among social scientists, calling for research focusing the discipline of CS.

I believe in the need for looking critically at the discipline of CS. Thus, I argue for research focusing on CS and its paradigmatic basis. We have to "ask what is wrong with computing rather than what is wrong with women" (Clegg and Trayhurn 1999). By doing so, we can find new insights both into the construction of the discipline of computer science, and into the construction of gender in relation to computing.

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Paper B2

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Computer Science, Gender and Knowledge: Situated Readings

Introduction

A text is read, interpreted and comprehended in different ways, depending on for example the perspectives of the reader. As a reader I take an active part in the creation of meaning when I interact with the text and so also, indirectly, with the author(s). In this paper I explore what I call *situated readings*, using the concept of partial perspectives in reading a text.

I will read a text on women and computer science, an article from Communications of the ACM[2] 1997. This article has gained a lot of attention and is still frequently cited within the community of computer scientists.

This reading exercise reflects my own development, in that I explicitly try to make use of my background and experiences. I am a lecturer in computer science, and for a number of years I have been interested in questions and issues surrounding the under-representation of women within computer science and in the various different attempts to define, describe and suggest solutions to this 'problem'. I have gone from taking part in, and actively leading, projects targeting women within CS, to an interest in trying to gain a complex understanding of this issue and challenging existing frameworks and explanations. The reading will reflect how my questions mainly concerning the low number of women in CS have evolved, as a result of experience and later from feminist studies, into other questions, approaching "the science question" (Harding 1986).

I start by a description and discussion of how I use concepts related to partial perspectives, and describe my situated readings before going on to the actual readings of

[2] Association of Computing Machinery is one of the largest international professional organisations within CS.

the text.

Epistemology as Point of Departure: The Issue of Partial Perspectives

My reading makes explicit use of partial perspectives and of being *located*, *positioned* and *situated*, as Donna Haraway advocates (Haraway 1991, p. 195):

> "I am arguing for politics and epistemologies of location, positioning, and situating, where partiality and not universality is the condition of being heard to make rational knowledge claims. These are claims on people's lives; the view from a body, always a complex, contradictory, structuring and structured body, versus the view from above, from nowhere, from simplicity"

By *located* I mean here simply 'placed' in a geographical, describing, stating sense without any connections to purpose, 'cause', before or after, but still involving context.

Positioned implies the use of power or strategy and a subject (and sometimes also an object). A position can either be forced upon me by others, in which case my subjectivity is limited, or I can choose it, take it strategically and use it as a conscious subject. Thus, I can either be *positioned* or I can *position* myself.

Situated is the most far-reaching concept, especially when used in connection with knowledge, as in *situated knowledge*. Important for me is Donna Haraway's use of the term as she describes it in *Situated Knowledges, the science question in feminism and the privilege of partial perspective* (Haraway 1991) and later in *How like a leaf* (Haraway 2000).

I understand and use situated as implying an epistemological standpoint. Thus, *situatedness* refers to conscious epistemological positioning. It is not simply a matter of an individual place or state, it is part of practice and knowledge production, and it means actively taking a stand.

When reading and interpreting texts we are never objective observers, but actively participating in the creation of meaning. Thus, the 'meaning' of a text is created by the author(s) and by the reader(s) and by the locations, positions and/or situations that author(s) and reader(s) assume, as well as by the text itself.

How and where am I located, positioned and/or situated in relation to the text I read? There is no one location that I can claim to be in, nor are the positions I take in themselves clearly defined. I have tried to break down 'me' into different 'me's', with every 'me' or *partial identity* reflecting different experiences in my professional life:

Engineer
Lecturer in CS
Study counsellor within CS
Project leader on projects for women within CS
Woman in CS
Feminist researcher

By *identity* I do not mean unity, but rather partial identities, " 'identity' is in fact a sort of conglomerate resulting from a fusion of identities" (Munnik 1999, p.108) and

"Identities seem contradictory, partial, and strategic" (Haraway 1991, p. 155).

My partial identities are not clearly separated, nor are they defined. They are intertwined with one another and can never be seen as 'points' in a universe (in the mathematical sense), but ought rather to be thought of as vaguely shaped three-dimensional figures, as 'shapes' without clear boundaries between inside and outside. They are not static, but are alive and dynamic, changing size and form continuously. These shapes overlap, and they are also partly and sometimes in conflict with each other. To complicate things even further, each of these shapes contains conflicts within itself: "We move between positions, which we take or are placed in, that can be both conflict-filled and contradictory" (Mörtberg 1997, p. 36, my translation).

The shapes are not abstract, they are very physical, embodied and inhabited. They are places where I have been, and where part of me still is, places that I sometimes inhabit (more or less) unconsciously, and sometimes position myself deliberately in for strategic reasons. They are the identities that have provided me with the experiences that I can now use in my reading.

The partial identities of the shapes offer me the possibilities of *partial perspectives*. Recognising partiality is a rich resource in attempts at transformatory work: "We do not seek partiality for its own sake, but for the sake of the connections and unexpected openings situated knowledges make possible. The only way to find a larger vision is to be somewhere in particular" (Haraway 1991, p. 196).

Below, I describe these partial identities, in order to make an attempt at describing my locations/positions/situations when reading and interpreting the text.

I mostly regard these identities as 'positions', i.e. I have been placed and/or place myself strategically in them. However, some of them also imply epistemological standpoints, which I will try to make clear.

Engineer

I have an M.Sc. in Engineering Physics. I studied in the late 1970's and early 1980's, during a time when I would call the education I received extremely streamlined and directed by behaviourist ideas. I sometimes think of my training as depriving me of the ability to read, write and think/reflect. I never heard of anything remotely resembling a discussion of knowledge, philosophy of science or epistemology. The education was fundamentally built on positivism[3], but this was so implicit that I had no idea whatsoever that science could be anything else but what we were learning and doing. There was simply just Science, and I remember vividly that when I much later learnt a little bit about the history and philosophy of science, I felt I had been betrayed throughout my entire undergraduate education. Yet, the training as an engineer, with its positivism and main focus on problem solving, is deeply rooted within me, bringing with it a logical,

[3] I use a simple definition of positivism, borrowing the words of Elisabeth Gulbrandsen: "By 'positivism' is meant the idea of science as neutral and objective" (Gulbrandsen 1995, VI: p. 20).

linearly oriented way of thinking, or "mind-set".

My reading from the position of a 'traditional' engineer is problem-oriented with the focus firmly on defining, delimiting and solving a problem. I will acknowledge and look for simplicity instead of complexity. Also, this reading will look only at what is clearly and obviously present in the text. The (unacknowledged) underlying epistemology is that of objectivism (in the positivist sense) and a belief in something rather vague and undefined, which is believed to be the 'scientific method'.

Lecturer in CS[4]

In the mid 1980's in Sweden, university education within CS had just started, and teachers holding a degree in the discipline were not to be found. Thus, universities would hire people who had at least some background in computer science (which I had). I started out in this location as the positivist-trained engineer, but with a burning interest in students and pedagogical issues. As a lecturer, I regard myself as belonging to the community of computer scientists, thus I am (partly) 'insider'. At least for my first few years as a lecturer, the subject matter (and the community) had the highest priority. Later, however, cracks and conflicts started to appear as my focus gradually shifted more and more towards students, learning and pedagogy, and I started questioning the importance of concepts and contents. This meant that the position became a tricky one – balancing 'scientific rigour' with aspects of the learning process such as understanding and reflecting.

In this position, I can move between different 'sub-positions', being able to understand (if not agree with) different positions that computer scientists assume vis-à-vis education, students and the subject matter. This is a position that I can both claim to have taken up consciously and to have been placed in, but the emphasis varies depending on whether it is my strategic position or not. I try to use this position as 'insider' strategically, in that I know how the discussion goes within the community and sometimes also agree (at least partially) with many of the values and principles upheld within the community. The epistemological ground is basically the same as that of the engineer.

Study counsellor within CS[5]

I spent 4 years working part-time as a study counsellor, alongside lecturing. This position involved being placed by others, in fairly limiting ways, since being a study counsellor means having very little power and belonging to the lower ranks of the academic hierarchy. However, taking and using this position strategically involves the acquisition of much knowledge through experience. In this position, my focus shifted more and more towards students, assuming responsibility in different ways and beginning to see accountability differently. However, I could not fully take a stand for students, since I

[4] I am still employed and active as a lecturer in CS.

[5] I do not explicitly use this 'shape' in my reading, but I include a short description of it, since this position marked an important transition.

was hired as faculty and thus had to balance my loyalty towards the community and my colleagues. I started to see problems and structures within the academic institution as well as within the discipline, but had very limited opportunity to act for substantial changes.

Project leader on projects for women within CS

In this position, I could really take a stand for female students and did not have to negotiate loyalties. I was invited to share some of their experiences, and learn about the conflicts they lived in. The experience was eye opening and often deeply upsetting, my knowledge, thoughts and the way I perceived things were shaken and changed. This position thus involved identification and experiences, including the conflicting identities that some of the women talked about. Change and transformation became increasingly important, and my frustration over lack of change grew.

I see the value of this position mainly in terms of the strategic insights it offered, but it also started the process of questioning the epistemological grounds of my earlier positions. For example, I developed a belief in the bodily experience of women as a valid basis for knowledge. I started to think about the limited possibilities for acting that these women had, and how their subjectivity was constructed and confined (although at that time I did not explicitly think in terms of 'subjectivity'). I gradually grew into questioning the common approaches to the problems women face within computer science, and developed an interest for exploring the complexity of these issues. This lead to thoughts and questions around paradigms and knowledge within the discipline. The experiences lead to asking other questions, to an interest for the invisible and taken for granted: the discipline of computer science; how it is constructed, pictured and mirrored in education, and the cultures that exist around it.

Reading from this position, I look for change, transformation, 'revolution', for suggestions of what to do about the problems women face in CS. My perspective is thus clearly action-oriented. I still mostly believe in the possibility to 'solve' the 'problem', having a belief, stemming from the engineer, in fairly straightforward 'cause and effect' relations - the 'only' problem is to find these causes.

Woman in CS

This position interrelates with some of the other positions. This is clearly both a position that others have placed me in, attributing certain qualities to me and expecting certain behaviour from me, and a position that I realised could be used strategically. The strategic use of it comes mainly from generating experience and thus knowledge. This position is both very personal and shared by other women. It contains strong feelings and experiences that have been hard earned.

For many years, to be a woman in an almost totally male environment, did not bother me. After around 6-7 years as lecturer, however, I came to question my suitability for the profession I had chosen, getting an increased feeling of 'otherness', not being fully accepted within the community. Out of this, insights slowly grew about structures, and

my questions were subsequently turned towards the discipline and the structures and cultures within academia. The experience of being at the same time 'within' and 'outside' a community can be hard, but, as Susan Leigh Star discusses (Star 1991), it contributes strongly to the feminist project. From this double position grows questions as to why things are the way they are, questions that might not come to the mind of the person who feels completely as an 'insider'.

In my experience (from the position of 'woman in CS'), the dominant scientific discourse within natural science and technology disqualifies the position of 'woman in science' for being 'subjective' and very 'partial' (in the negative sense that the words are used within positivism), thus not rendering any kind of 'knowledge' or 'truth' (this becomes especially clear when we talk about questions concerning the under-representation of women). Thus, it is very easy to maintain the status quo and reject all critique as coming from a 'non-objective' position. However, what is seldom recognised, is that the one position holding the preferential right of interpretation is just as 'subjective' and 'partial' as the position of woman in science. This conflict can lead to interesting tensions. The conflict is not dissolvable, since the positions are opposites. In fact, there is no reason to want to dissolve it, since it can shed useful light on underlying, hidden views.

Reading from this position I am eager to find resonance with my own experiences, to feel that I am involved in something, belonging to a community of "women in CS". However, I also want serious discussions of the problems for women in CS. I look for a critical examination of the complex issues, including the discipline and its surrounding culture.

Feminist researcher

I am a doctoral student in the research group Technoscience Studies at Blekinge Institute of Technology. The group is placed within the Faculty of Technology. With a foundation in feminist research, the work done within the group aims at creating knowledge for development processes within IT-related scientific disciplines, as well as in IT-strategic contexts. Here, interdisciplinarity is considered very important (Trojer 1995a). Another important issue for the group is to work from within the technical disciplines (Ibid). For me, this implication within is of utmost importance – staying within the discipline of CS allows me greater possibilities to work for change and transformation, which is my primary concern.

Perhaps the most fundamental and important difference in this position compared to the previous ones, is in epistemology. This type of gender/feminist research problematises the positivist knowledge tradition, for example the objectivity paradigm (Mörtberg 1999, 2000, Trojer 2002). As a feminist researcher I see myself as situated and taking certain epistemological points of departure, in this paper especially those of *partial perspectives.*

Reading from this position, I will ask questions, rather than look for answers. I will examine discourses, how these are reproduced or challenged. In contrast to my reading

as the engineer, I will here also look for what is not in the text. "What is present by being absent?"[6]. Shulamit Reinharz calls this "the study of what is missing": "Thus feminist content analysis is a study both of texts that exist and texts that do not" (Reinharz p. 162). She points out that what is interesting for the feminist researcher is the question why things are missing and the implications of these gaps.

Sara Mills discusses the question of absence in terms of exclusion from discourses: "Whilst what it is possible to say seems self-evident and natural, this naturalness is a result of what has been excluded, that which is almost unsayable" (Mills, p. 12).

"What is present by being absent" in a text, can be understood and used in two ways: on the one hand, what Mills calls "the excluded" and Reinharz terms "what is missing", and on the other hand in the sense of the non-articulated, implicitly present, discourse(s). The absent, implicitly understood issues confirm the discourse, and this needs to be made visible and explicit. On the other hand the explicitly absent questions or issues raise questions as to *why* they are absent, and this can also point to possibilities of creating cracks in the dominant discourses.

A reflection on mind-sets and tensions

The "mind-set" of the feminist researcher is in many ways very different from that of the engineer and computer scientist. As engineer, I focus on solving problems, I try to simplify problems and I use a foundation of knowledge that I rarely question or even think about. As feminist researcher, I acknowledge complexity, richness and manifoldness, I reflect on knowledge and knowledge production, and I ask questions concerning the foundation: why are things the way they are and how could they be different? Evelyn Fox Keller describes these differences strikingly:

> "The reasons for the divergence in perception between feminist critics and women scientists are deep and complex. Though undoubtedly fuelled by political concerns, they rest finally neither on vocabulary, nor on logic, nor even on empirical evidence. Rather, they reflect a fundamental difference in mind-set between feminist critics and working scientists – a difference so radical that a "feminist scientist" appears today as much a contradiction in terms as a "woman scientist" once did". (Fox Keller 1992, p. 21).

In my situated readings, I want to expose ambivalences and tensions between different positions, in a hope to cast light on potentials and possibilities.

> "We shall try to keep ambivalences, contradictions and tensions… It is in the ambivalences and contradictions that the potentials for a steady radicalisation – a steady transgressing – lies" (Gulbrandsen 1995, VI: p. 22).

[6] This expression is inspired from Pirjo Elovaara in her discussion on ANT, see for example Elovaara 2001, p. 109.

Situated Readings of the Text

Camp, Tracy, 1997: "The incredible shrinking pipeline". *In Communications of the ACM*, vol 40 no 10, p. 103-110.

Background

The article was written by an assistant professor in computer science. The main theme is the decline in the number of women involved in CS during the years 1985 to 1995 in the USA. The article tries to establish this as an indisputable fact by analysing statistical data. These data show that the number of Bachelor's degrees awarded in CS to women decreased, while the corresponding percentages in other science and engineering disciplines increased. This adds to the effect commonly called "the pipeline shrinkage problem", which refers to the decrease in the number of women in the academic pipeline (the higher up in the academic ranks you go, the fewer women you find). This is also sometimes called "the leaky pipeline", which implies that women 'leak' out of the pipeline at every stage. Tracy Camp also investigates the relationship between degrees awarded to women and the location of the CS department in engineering colleges, finding that "CS departments in engineering colleges graduate proportionately fewer women on average than CS departments in non-engineering colleges" (p. 107). Towards the end of the paper, Camp invites the CS community to respond to an online survey to identify possible causes for female under-representation and asks them to suggest strategies that could be used to attract and retain women in CS[7].

Tracy Camp is alarmed over the decline in the number of women, and she wants the community to respond to the situation. Her intended audience is computer scientists within academia. This article is interesting in my context because it has been widely read and is frequently cited in the community of computer scientists.

Reading from the position of engineer/lecturer

What is most striking about the article is that it is full of strict *facts*. The larger part of it is taken up with data from statistical surveys, thus proving that there is indeed a decline in the number of women within CS. It is also argued that we should all be concerned, due to the shortage of computer scientists on the labour market (p. 104):

> "There are a number of reasons why we need to improve the percentage of degrees awarded in CS to women. In short, there is a critical labor shortage in CS and, although women are more than half the population, they are a significantly underrepresented percentage of the population earning CS degrees."

This argument is reasonable and hard to contradict.

The paper is easy to read for an engineer/computer scientist, it is very well written, with a good foundation in statistics and a good presentation. It is clear, coherent and adheres strictly to existing norms within science/technology for how to write scientific articles. It thus conforms to what is well-known, accepted and seen as 'good practice'

[7] The results are available on the Internet (Camp 1998). See also conclusions below.

within the community. It gives the impression of sound research, thus it can be regarded as trustworthy, and it is still eye opening, because the statistics cannot be denied.

Tracy Camp never discusses possible causes for the under-representation of women, nor are solutions suggested, except that the community of computer scientists as a whole should become involved in ascertaining reasons for the female under-representation and implement the necessary changes (p. 110):

> "We hope the CS community will become involved in exploring the options and steering those changes. […] We urge the CS community to consider the posed questions and respond to the survey. […] If we work together, perhaps we can identify and implement the changes that are necessary to reverse the alarming decline of women's participation in CS."

This approach is unproblematic, since it does not try to 'blame' the community of computer scientists for the problem. Instead, the community is seen as being able to solve the problem, which makes me feel engaged and involved (in a positive sense).

A comment can be made on Camp's use of 'we', i.e. avoiding first person singular. This is the common scientific tradition, using 'I' is seen as boasting, claiming to be important. Thus, if it is not possible to use third person singular passive form, 'we' is commonly used even when there is only one author, in order not to draw attention to the author her/himself (Trojer 1995b).

Reading from the position of project leader

The article made a great impact on me, since it showed that the issue at hand is very important, and furthermore it is very impressive with the statistics. Most importantly, Tracy Camp talks about the need for change, and gives hope that change is possible, that the problem can be solved.

Using statistics can be a natural way for a person trained in science and engineering to approach a problem, but it can also be used as a strategy within the community of scientists and engineers. My experience, from presenting results from my own projects (this experience is also shared by others), is that starting out in a 'safe place', using 'data', 'facts' and statistics, serves several purposes. For one thing, it legitimates the project and is a way of gaining authority within the community. It also seems to make the listeners/readers feel secure – they feel at home, they can identify with the methods used and the issues become recognisable. In this way, starting in a quantitative analysis can pave the way for more qualitative, critical issues and discussions. Tracy Camp might thus use statistics as a way of reaching the community. This strategy is completely understandable and 'correct' to me.

The passage below made me especially happy (p.109f). I have used this quote myself many times in presentations on the topic of "women in CS".

"In a paper on women in science and engineering, John White, Dean of Engineering at Georgia Tech Institute of Technology, said: "If we want a different outcome, we're going to have to do things differently. We're making too little progress doing more of the same thing. The time for evolution is passed; it's time for revolution". White requests a revolution to improve on the small amount of progress in attracting and

retaining more women in science and engineering over the last decade."…In order to eventually make progress, computer scientists and educators seem to need dramatic change in direction."

Since Tracy Camp uses this quote, I assume that she agrees with the opinion voiced in it: a need for revolution. It is common within academia to reinforce one's own opinion by quoting someone else, preferably someone who is seen as an authority, and thus it does not bother me that she does not really directly express her own opinion, but uses the voice of another person.

I am also very happy about the conclusions, and in particular the invitation to the community (see quote above "we hope the CS community…"), I truly believe this could come to mark a breakthrough. It seems to me that finally something is being done, now we can make change happen!

Reading from the position of woman in computer science

Reading from this position clearly to a large extent is the same as reading from the position of project leader, since these positions strengthen and use each other. The woman in CS is very engaged in being project leader, and the project leader is to a large extent the woman in CS.

Most important is a feeling of recognition, and of someone giving voice to my own, not clearly expressed, thoughts. This is most obvious in the quote about the need for revolution. I am not alone, there are other people (even important men!) looking for change. The feeling of recognition makes me feel strengthened, and the invitation extended to the community feels empowering – I am able to do something.

However, I can also feel somewhat disappointed. How about issues other than equal representation? How about the problems women within CS face? None of these are mentioned in the article. I am not content with just working to get more women into CS, I also want more radical approaches, such as e.g. discussions of the culture within CS. Moreover, the labour force argument does not seem good enough, since I see this most of all as a question of justice, that is, of men and women having the same possibilities.

Reading from the position of feminist researcher

The readings above have acknowledged the approach in the article as completely reasonable, even "right" and "good". However, when reading this as a feminist researcher, many questions come to mind. I treat some of these below.

Why all these statistics? One possible explanation can be that a hypotheses has to be proved to be of value within the community. In order to be taken seriously, it is necessary to be able to produce evidence to back your claim. It is not unlikely that this is even more important when it comes to a sensitive issue such as women in computing, where there are likely to be many ideas and feelings involved. This prevalent use of statistics can be regarded as saying something about how knowledge is seen within the community, thus stating implicitly that (only) measurable quantities represent knowl-

edge. The article is clearly written within the dominating scientific discourse concerning what is considered as knowledge.

Why does Tracy Camp use the argument of labour shortage? This argument implies that women are regarded as a reserve labour force. In itself, this is not a neutral argument: are women a concern *only* in their capacity as a 'reserve', i.e. when there are not enough (talented) men? It then becomes a cynical argument, even though it is presented as a completely reasonable one, that points to a (perhaps subconscious) view of women as inferior to men, as 'second best'. However, I also want to point out that this type of argument does not necessarily reflect Camp's 'real' views. For example, she writes: "there are a number of reasons…". The argument of labour shortage is sometimes used in the belief that this is politically acceptable or neutral. By using this argument, it is possible to avoid discussions concerning equality and gender issues, which are often considered more or less irrelevant by the community (Egeland 2001). It thus becomes a means to obtain changes that might actually be wanted for other reasons (e.g. gender equality). So the motive of a critical labour shortage might in this context be used strategically. "We need to keep open the possibility that a particular representation has been selected for purely instrumental reasons, to achieve a particular goal, and has nothing to do with the values of the one making the representation" (Bacchi 1999, p. 9). However, a person invoking the labour force argument must ask her/himself: in what way do I reproduce dominant discourses of 'non-gendered' science by using this argument? Can it even reproduce the idea of women as inferior to men?

However, Tracy Camp opens up for other motives, without mentioning what these could be: "There are a number of reasons why we need to improve the percentage of degrees awarded in CS to women." (p.104). What are her own motives for being engaged in these issues?

Why are women under-represented within CS? The problem of female under-representation is discussed solely in terms of numbers, i.e. quantitatively. There is no tendency in the article to see women as the problem. In fact, Camp does not attempt to locate the problem anywhere at all. It is not possible to identify any construction of a possible cause of women's under-representation in the article, except possibly some traces in the sentence: "There are, however, other factors [than the location of the CS department within an engineering college] that may affect the percentage of degrees awarded in CS to women as well" (p. 108). Why does Tracy Camp never mention what these "other factors" might be? Why has she not included any thoughts at all about the 'why' issues? One possible explanation can be that it is very hard to prove a hypothesis about *why* women are under-represented. Even formulating such a hypothesis within the dominating scientific discourse in CS might be very difficult. Abstaining from 'speculations' is then the safest choice (compare the discussion on statistics above).

How can the problem be solved? No solutions are suggested in the article, except that the community as a whole should become involved in ascertaining reasons for the female under-representation and implement the necessary changes. "If we work together, perhaps we can identify and implement the changes that are necessary to

reverse the alarming decline of women's participation in CS" (p. 110). It seems that Camp believes that it is possible to find solutions, but there is a hint of caution, in her use of the word *perhaps*.

Tracy Camp does not directly express her own thoughts on the issue of female under-representation. Instead she uses the voice of another person (the quote of the Dean, see above). No doubt, the male dean she quotes has more power than she has, therefore his words weigh more heavily than hers. Does it matter that he is a man? Does this improve her chances of being heard? Is she using an authority in the area of science and engineering in order to justify her own opinion, although not wanting to state her own opinion explicitly? Is it about who has most power, and the preferential right of interpretation (she uses the voice of a man in a high position). When she speaks with her own voice in the quote above, she is more careful: …*seem to need*… [my italics]. Why is she being so cautious?

This can also be seen as an example of how Tracy Camp stays strictly within the dominating scientific discourse. In this case the discourse determines who has authority (which includes gender aspects).

Within one fairly strong discourse in CS more women are wanted, and the under-representation of women is seen as something 'bad'. [8] However, this is seen as a fact, the reasons given as to *why* more women would be 'good' can vary greatly. The article is written within this discourse, pointing to the "alarming decline" in the number of women. By presenting this simply as a problem that needs to be fixed (thus implying that the community can fix it), and not discussing the issues of *why* or *how*, the discourse is also strengthened. There is nothing that could be interpreted as questioning or criticising either the community or the discipline. This may be one reason why computer scientists have so positively received this article.

As discussed above, Camp never uses the first person singular: 'I'. Instead, she uses 'we' in many places. Her use of 'we' instead of 'I' in this way also confirms existing discourse of science. She is herself largely invisible in the article. This is yet another sign of the epistemology: the invisible researcher confirms the objectivity paradigm, "the god-trick of seeing everything from nowhere" (Haraway 1991, p. 189).

The engineer/lecturer (see above) interprets this 'invisible author' in another way, as the 'proper' way of writing in science. This explanation can be seen both as influenced by cultural values, and as a means of reproducing discourse.

There are however some very small cracks in this invisibility, in the few places where Camp becomes visible and (albeit indirectly) expresses her own opinion. This can be seen for example in the discussion of motives: "there are a number of reasons" and "there are other factors that may affect the percentage of degrees awarded in CS to women as well".

[8] There is another, competing, discourse concerning women in CS. Within this discourse, gender issues are seen as totally irrelevant.

The traditional positivist epistemology of science is obviously maintained and taken for granted. There are no signs of any kind of questioning of the discipline of CS, with the possible exception of establishing that CS departments located within a college of engineering graduate even fewer women than those located within other types of colleges. The foundation is invisible, but still very much present since the article makes no attempt to challenge existing discourses on science in general or CS. Instead, it conforms to the perception of statistics and measurable quantities as indicators of a problem and as important carriers of information.

Conclusions

I have reflected above that the whole article is clearly written within dominating scientific discourse. From that aspect, it is easy to understand why this article was so successful in gaining attention within the community of computer scientists. So, in order to gain interest, it seems to be necessary to conform to and confirm dominating discourses, as doing this makes the community feel at home and thus listen. This article does in fact, by its invitation and belief that computer scientists can help solve the problem, strengthen and bolster the community. However, then the problem remains unsolved – if it is necessary to stay within the dominating discourse in order to make the community react, then it is also more than likely that the solutions presented will be located firmly within existing discourses, thus not providing much hope for change.

The value of the article is doubtless: it has gained much attention, thus bringing the issue on to the agenda. But it has not brought on any real changes.

It seems to me that Tracy Camp has really made a strong effort to 'play by the rules' in this article, in everything from the impressing statistical evidence to the use of a voice of authority. This raises an interesting question: is this a conscious and strategic choice? Does she herself find it important to write the article according to dominating scientific discourse? Or is it simply the natural and obvious way of writing an article, since this is the tradition that she is trained in?

It is interesting here to reflect on the results from the survey that the article talks about (Camp 1998). The way the survey was formulated and the issues it focused on created the problem and thereby the suggested solutions in certain ways. The reasons for female under-representation, and thus the solutions, are mainly identified on what I call the individual level (role models, mentoring, raising girls' self-esteem, providing girls with more training with computers, etc). Some suggestions target structural and cultural issues, but these are noticeably few (classroom climate, nerd perception of CS). The respondents were asked to rank different activities that they believed would help increase the number of women. 111 computer scientists responded to the survey, and the *only* alternative that could possibly be seen as touching on the discipline: "modify curricula", was regarded as important by only 16% of the respondents.

Concluding Remark

I believe that this kind of analysis can be fruitful. By pointing to the problems behind the representations and their relations to existing discourses, I hope that it might be able to gain a complex understanding of a complex issue. I have showed how a text can be interpreted from different positions, thus making visible difficulties and tensions between different subject positions, even when their goals are similar.

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Paper B3

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What Does it Mean to Know Computer Science? Perspectives from Gender Research

Abstract

The approaches to knowledge and epistemological basis for computer science (CS), on which research and education as well as development of applications are founded, are fundamental for its production of knowledge. These have however been fairly little reflected upon and studied, in contrast to societal impacts of CS. In this paper we raise the issue of how gender research developed within science and technology can be used within computer science, to approach and discuss foundations of the discipline, and what the implications of this reflection are for CS education. After an introduction, which serves to motivate the questions raised, we discuss issues concerning the foundations of computer science. We then introduce gender research, as we use it, and present some points where this type of research can contribute to the question "What does it mean to know CS?".

Introduction

> "From its inception just half a century ago, computing has become the defining technology of our age." [1]

Computer science (CS)[2], as one of the core disciplines within the broad area of

[1] ACM and IEEE-CS *Computing Curricula* 2001, Computer Science Volume, chapter 3. http://www.sigcse.org/cc2001/

[2] We use the term 'computer science' (CS) in a broad sense, including software engineering and all relevant parts of computer engineering. For a discussion concerning the usage of 'computing' and 'computer science', see the section 'Computer Science'.

information technology, has become one of today's most important disciplines by virtue of its influence on the shaping of technology and thus also society. There is little technical research, development and production done today that does not, in one way or another, involve results from (mostly in the form of applications of) CS. Computer science thus strongly influences the direction and content of technical research and development. This is an example of how science is in society. However, the reverse process must not be ignored: how society at the same time actively participates in CS, thus creating iterative processes. Computer science comprises both internal and external theories or stories[3] (Fox Keller 1992), which must be considered not the least in CS education, where future computer scientists are shaped. Education is in our opinion fundamental for the development of the discipline.

It is reasonable to assume that the influence of CS on the current and future developments of technology will continue to grow, and that the discipline will remain at the centre of information technology. Thus, CS as a field of knowledge and technology holds a dominant position. In order to take responsibility for this dominant position, we argue that there is a need for CS to be a multifaceted discipline with many angles of approach. It is not enough, as we see it, to merely include more areas into CS. Rather, we want to take a more radical step, and introduce the notion of *epistemological pluralism* (i.e. different ways of knowing and learning) (e.g. Wagner 1994).

Equally important as a multifaceted discipline is a broad representation of developers of knowledge and technology within CS. A more diverse understanding of CS is likely to result in a more diverse representation of people being attracted to the field. However, this is not the case today, when CS mainly attracts a fairly narrow group of students, mostly young males with a passion for, and also often experience with, computers and programming[4].

There is a need to get rid of the 'nerd' image, which is a prevailing image of the 'pure' computer scientist, and which is known to cause many students, both male and female, to choose more application and socially oriented subjects (or other disciplines that they find more diverse and thus more interesting) instead of choosing core CS. This demand for change is gaining recognition within the community of computer scientists. Maria Klawe eloquently expresses this (Klawe 2001 p. 67-68):

> "The point here is that computer science also needs to attract students with broader interests and abilities than the traditional computer scientists—nerds.[…] But nerds are not enough. We need more computer scientists whose passions are art, language, literature, education, entertainment, psychology, biology, music, history, or political science. We need them because computers have an impact on all areas in our world. We need people with passion and vision

[3] Internal theories / stories are those developed and told within the disciplinary context. External theories / stories are those appearing for example in the context of application and context of implication in society.

[4] The issue of under-representation of women in CS has been extensively discussed in the literature, for an overview and critical discussion see Björkman (2002).

> from every area to drive the development of computer technology as well as the applications. […] We need non-nerds in computer science, so let's figure out the proper approaches to integrate their talents and perspectives into our field."

We claim that this narrow recruitment basis is one indication of a too limited understanding of what it means to "know CS". We argue that the issue of narrow recruitment to the discipline not only concerns the image of computer science, nor educational structure and culture (though these are certainly important issues to address), but that it is also necessary to look at the disciplinary foundations and approaches to knowledge in CS. How knowledge and learning processes are formed, mediated and reflected, e.g. in education, is a large, but so far mostly overlooked, part of the complex problem of narrow representation patterns in CS.

We thus argue that there is a growing need for a more complex and integrating understanding of knowledge processes, by which we mean integration and acceptance of different approaches to knowledge, epistemologies, methodologies etc, i.e. epistemological pluralism. We note two main reasons for this need:

- The narrow recruitment base for CS is becoming increasingly problematic as practices of society and practices of CS are interlinked in progressively more sophisticated ways
- The influence of CS on the current and future development of technology is escalating.

These issues are interrelated and of vital importance in the development of computer science.

In this paper, we approach and discuss the foundations of computer science. We also discuss how gender research within CS enables possibilities to develop more complex understandings and interpretations of CS. We strongly believe in the contribution from this discussion to facilitate discursive space for transformation trials[5] within computer science, with a particular focus on education.

Computer Science

What 'is' computer science? Or rather, how is it constructed and perceived? What constitutes the 'core' of the discipline? Is CS a mixture of other disciplines or does it have its own unique core? What fundamental 'paradigms'[6] guide knowledge processes within the discipline?

[5] By discourse we mean a pattern of understanding that counts as meaningful in a certain normative context. By a discursive space for transformation trials we mean an environment, where what counts as meaningful for transformation, is broadened and developed. For a discussion of discursive space or discursive practice see Barad (2003).

[6] We use the word 'paradigm' here in a loose sense. By using it, we want to point to foundational ideas of importance for knowledge in CS. In this meaning, it is also used by for example Denning et al (see below).

CS is fairly young as a discipline in its own right and is still being formed and the subject of many discussions regarding its core character and content. The boundaries of CS are constantly debated: what is to be considered to be within the discipline and what is to be considered to be outside (but connected to) it, for example where does software engineering and human-computer interaction belong? The foundations for computer science, on which all education and research, as well as development of applications, are based, are fundamental for the production of knowledge. Methodology and epistemology are intertwined with what we do and how we do it, thus underlying all research and knowledge production (Harding 1987).

One dilemma we face is related to terminology. The term 'computing' is often used in a more inclusive sense than computer science. Some researchers use the term computing to mean (more or less) the whole field of IT, some use it to disconnect the discipline from the physical computer (Dijkstra, see McGuffee 2000), and others use it to mean "all of computer science and computer engineering" (Denning et al 1989 p.10). In the works referred to below, we have taken pains to identify what the authors mean when they use the word 'computing', and unless otherwise stated, it can be understood as synonymous to our use of the term 'computer science' in all relevant matters[7].

One of the most well known contributions and attempts to define computing was made in 1989 by the ACM Task Force on the Core of Computer Science (Denning et al 1989). They identify three major paradigms or "cultural styles": *theory*, rooted in mathematics; *abstraction* (modelling), rooted in the experimental scientific method; and *design*, rooted in engineering. These processes are seen as closely intertwined; they cannot be separated but are nevertheless distinct, since they each represent different competences. Thus, the task force concludes: "Computing sits at the crossroads among the central processes of applied mathematics, science and engineering" (Denning et al 1989 p.11). A short definition of computing is given as:

> "The discipline of computing is the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation and application. The fundamental question underlying all of computing is, "What can be (efficiently) automated?"" (Ibid p. 12)

In this definition, the notion of 'algorithm' is seen as a central concept in CS.

The algorithmic side of computer science is emphasized by Judith Gal-Ezer and David Harel in their discussion "What is CS" (Gal-Ezer and Harel 1998 p. 78):

> "The point is that CS is not only the scientific basis of a major technological revolution, but has at its heart a special and powerful way of thinking—algorithmically—which is required in dealing with the ever-complex modern world, and which is becoming crucial in many other scientific and engineering disciplines, too."

So then, what does an algorithmic definition of CS entail for the understanding of

[7] We use CS to emphasise the discipline aspect, an aspect that is not always clear from the word 'computing', and at the same time argue for a broadened understanding of the discipline of CS.

knowledge within the discipline? Abelson and Sussman directly address this (Abelson and Sussman 1985[8], quoted in Denning et al. 1989 p.11-12):

> "The computer revolution is a revolution in the way we think and in the way we express what we think. The essence of this change is the emergence of what might best be called procedural epistemology – the study of the structure of knowledge from an imperative point of view, as opposed to the more declarative point of view taken by classical mathematical subjects. Mathematics provides a framework for dealing precisely with notions of 'what is'. Computation [9] provides a framework for dealing precisely with notions of 'how to'".

What are the implications of this "procedural epistemology" for knowing within the discipline?

Judith Gal-Ezer and David Harel recognise two sides of CS: the algorithmic side and the systems side, and claim that "CS itself is an unusually dichotomic subject – one facet is more mathematical and the other is a type of engineering." (Gal-Ezer and Harel 1998 p. 79). They argue that there are also dichotomies within these facets: mathematics encompasses computability, complexity and logic on the one hand as well as numerical analysis on the other, while engineering encompasses the design and construction of hardware as well as the development of software.

So, what are the implications of a discipline based on inherent dichotomies, and what tensions, useful as well as restrictive, exist because of this dichotomic nature? Is it possible to deconstruct and go beyond these dichotomies, and if so, what would that entail for the discipline?

One side of the dichotomy discussed above refers to mathematics. Abelson and Sussman bring up issues of knowledge in connection to the discussion of mathematics vs. computing, and it is interesting to note that they see computing as different from mathematics. The role of mathematics in and for computer science is a cause of much dissent within the community of computer scientists. A fairly strong and influential group within CS defines the discipline as closely related to mathematics. In a famous paper from 1989: "On the cruelty of really teaching computing science", Edsger Dijkstra claims that "computing science is—and will always be—concerned with the interplay between mechanized and human symbol manipulation usually referred to as 'computing' and 'programming', respectively" (Dijkstra 1989 p. 1401), and that computing should be localised in "the direction of formal mathematics and applied logic" (Ibid p. 1402). He even goes so far so as to propose that computing science be called 'VLSAL' (Very Large Scale Application of Logic) (Ibid p. 1402). The discussion about mathematics is far more complex than a mere discipline issue; to a large extent it is historically conditioned, but it is also about power, about 'who is best/right', and about what counts as 'superior' knowledge.

Many other definitions of CS have been suggested too, some quite simple: "computer

[8] Abelson, Harold and Sussman, Gerald Jay (1985) *Structure and Interpretation of Computer Programs*. Cambridge, Mass: MIT Press.

[9] 'Computation' in this quote should be understood in the same sense as 'computing'.

science is the study of computers" (Newell, Perlis and Simon[10] quoted in McGuffee 2000 p. 74), or the Computing Sciences Accreditation Board: CS is "a discipline that involves the understanding and design of computers and computational processes" (McGuffee 2000 p.74).

Another interesting question is whether any recent changes can be seen in the view of computer science. In the ACM Computing Curricula 2001, Computer Science Volume (ACM CC2001), the rapid evolution of the discipline is discussed. There is no attempt to define CS in this document[11], since the report is focused on curricula for CS education, but the report observes that technology has undergone radical changes during the last decade, not the least with the development of networking and the WWW. It also recognises that cultural factors affect computer science and CS education. What this report calls computing has become broader, encompassing more areas. However, the acceptance and inclusion of more areas does not necessarily by itself entail a fundamental change in the understanding of the knowledge processes within CS.

One of the central changes that can be seen in CC2001 is the inclusion of professional *practice* as an integral component in the CS curricula. Where the 1989 report identified three paradigms, this could now be seen as expanded: "All computer science students must learn to integrate theory and *practice*, to recognize the importance of abstraction, and to appreciate the value of good engineering design" (ACM CC2001, chapter 4, our italics). However, whether the integration of practice in the curricula should be interpreted as a change in the view of the discipline is not clear, and many computer scientists are likely to argue that practice might be part of the profession, but not part of the discipline. What would it mean if practice were actually regarded as part of the discipline? Such a change could be fundamental, if it were really incorporated into the core, opening up new views of what is important knowledge for a computer scientist. What to include in 'professional practice' is still an open question, but in our opinion this includes knowledge of the area of use as well as of users and how society and technology are intertwined.

Peter Denning is one of the prime movers in the ongoing discussion of "the profession of IT" and the related topic of practice within computing[12]. He argues for accepting the importance of professional practice: "Practices are as important a part of knowledge as discourses, mental models, conceptual frameworks, processes and rules" (Denning 1999 p. 2). He claims that "applications domains are the front lines of the profession" (Ibid p. 2) and that "Value skills connect a professional's technical performance with

[10] Newell,Allen, Perlis, Alan and Simon, Herbert (1967) "What is computer science?", *Science*, no 157, pp. 1373-1374.

[11] In chapter 4 of the report, the committee lists what they see as the areas encompassing the body of knowledge within CS. This list includes for example Software Engineering, Human–Computer Interaction and Information Management.

[12] Peter Denning uses the term 'computing' in the same sense as defined on page 3, i. e. as equivalent to our use of computer science.

the customer." (Denning and Dunham 2001, p. 24). Peter Denning regards computing as the discipline and IT as the profession, and he claims that there is currently a gap between the two. Computing is no longer the driving force, controlling the field, and he advocates that it should cross the chasm and seek leadership within the new profession, by for example accommodating "embodied professional knowledge" (Denning 2001, p. 24). A similar argument is made by Steve Cunningham: "Any computing education that does not pay attention to the user's role in computing is missing the most vibrant and exciting part of computing today." (Cunningham 1998, p. 4a).

Another noteworthy point in CC2001 concerns what the committee regards as important for a curriculum, in the sentence: "Development of a computer science curriculum must be sensitive to changes in technology, new developments in pedagogy, and the importance of lifelong learning" (ACM CC2001, chapter four). This puts focus on technology and knowledge, but no reference is made to society or issues such as risk, sustainability, accountability etc.

A discipline does not exist on its own; it is defined and held together by its practitioners. Computer science and computer scientists are constructing, and are constructed by, each other in a mutual and constantly ongoing process. What then is a computer scientist? How is a computer scientist 'formed'? How do computer scientists understand CS, what ideas and concepts do they find central to the discipline, how do they understand and create knowledge and images of concepts? How is CS 'thought' and 'talked'?

James McGuffee (McGuffee 2000) argues that a good alternative to defining CS is to describe what a computer scientist does. He quotes Dirk Siefkes: "As computer scientists we discuss problems, describe solutions, design and use computers and formalisms" (Siefkes 1997[13], quoted in McGuffee p.76). It is interesting to note the concept of 'problems' in this, indicating an engineering relationship, as well as to note the absence of 'use' and 'users' of products of CS. How generally accepted is this definition within the community? There is a tendency to discuss CS as something separate from computer scientists, existing on its own. This becomes especially clear when looking at how issues of women and computer science are commonly discussed (Björkman 2002). In these discussions, focus is almost always and solely on the first word: women, and the discipline itself is usually taken for granted. From this kind of perspective, adaptation comes solely from the side of the (prospective) computer scientist, and the mutually constructed character of the relationship is obscured. This creates the image of CS as existing on its own, independent of people.

We introduced this section by asking what fundamental paradigms exist within CS. Above we have acknowledged the notion of algorithm and the mathematical foundations as paradigms of this nature.

New paradigms or metaphors for computing are surfacing; the most important one today seems to be *interactivity* or *interactionism*. This concept has been discussed by a

[13] Siefkes, Dirk (1997) "Computer science as cultural development: Toward a broader theory", in *Foundations of Computer Science: Potential-Theory-Cognition*. Berlin and New York: Springer.

number of researchers. Lynn Andrea Stein argues the need for a shift in the underlying metaphor of computing, from the traditional metaphor, "computation as calculation", towards a metaphor of "computation as interaction" (Stein 1999). Such a change, Stein argues, would affect how CS is viewed and thus also what is taught and how, as well as how computer scientists think. Peter Wegner writes about "why interaction is more powerful than algorithms" (Wegner 1997). Frances Grundy discusses a new conception of computing that she terms "interactionism" (Grundy 2001) and Heidi Schelhowe sees interaction as a successful approach to development of software (Schelhowe 2004). What could the effects of these emerging paradigms be? In what ways could they support 'epistemological pluralism' (Turkle and Papert 1990, Wagner 1994), or other ways of knowing? Can different metaphors or paradigms for computation affect the learning processes in CS?

Another emerging trend, so far mostly within robotics, are concepts of embodied and situated computing.

Paradigms or metaphors of importance within CS will take on a significant role in education. We see the teaching of programming as being of particular importance. What are the paradigms and views of knowledge of CS and programming in programming courses? Is this visible in the courses or not recognised but taken for granted? The concept of programming is one of the first things that students learn. How has the knowledge foundation in programming (theories, methodologies, methods and languages) evolved? What constitutes the fundamental knowledge base, and what assumptions and choices have been made during the course of time? Is there support for different styles of approaching programming (see for example Turkle 1984, Turkle and Papert 1990), and what would be the implications of that? What role does for example skills knowledge, "knowing how" (Adam 1998), play in the learning of programming?

Does object-orientation in any substantive way constitute a 'paradigm shift'? Or is it just a minor change in methodology, neatly incorporated into existing paradigms? And if it is something entirely new, what would that mean for the discipline and its practices? For example, Abelson and Sussman talked about the "procedural epistemology" within CS. Does object-orientation have an effect on this? Is the procedural thinking still valid in times of OO? Sherry Turkle and Seymour Papert argue that a shift towards object-orientation might potentially mean a shift in thinking and the legitimising of alternative methods of programming (what they term 'bricolage' as contrasting with the commonly taught 'planning' approach, Turkle and Papert 1990). As it is now, it seems as if the potential power of object-orientation has not brought on significant changes within the teaching of programming, but has rather been incorporated into existing methodologies. If and how a different paradigm or metaphor can promote learning of programming is a question that ought to be of great interest to the whole computer science community.

What constitutes the core and the foundations of a discipline can always be the focus of study, it can be debated and perhaps reformulated and changed, since production of knowledge and our understanding of it are ongoing processes. There is nothing 'natu-

rally' inevitable about how computing is constructed. As argued in the introduction, we claim the need to consider the possibility of creating new, additional approaches to knowledge within the core of CS.

Gender/Feminist Research in Science and Technology and its Relevance to CS

Gender/feminist[14] research concerning computer science has to a large extent focused on issues of gender in relation to computer science, for example the lack of women within computing, and gender equality aspects (see the overview and discussion in Björkman 2002). In these studies, CS is often seen as firmly defined, and the underlying perceptions of development and knowledge in CS are seldom brought into focus. We want to show in this article how gender research can be a resource *within* CS, for discussions concerning the discipline. Time might be ripe for us, "as partakers in the modern research complex, to develop a readiness to think and feel ourselves as part of the problem, and learn how to use our implicatedness as a resource for transformatory projects." (Trojer and Guldbrandsen 1996, p. 131).

Gender research represents many theoretical and methodological approaches, and the meaning and focus of the research is different within different disciplines. We here want to give a brief introduction to gender research as it has developed within science and technology.

Gender research can have two general focuses: sex/gender on the one hand, and feminist frameworks for science itself on the other. Gender research within natural science and technology mainly concentrates on the second of these, focusing science itself, its theories, methodologies and other knowledge processes. This type of gender research discusses and studies the bases of the disciplines and broadens the epistemic point of departure in order to help approaching the foundations of the discipline and its knowledge production.

The emphasis on *transformation*, out of identified needs, as a prime goal for gender research, is essential. From the very beginning it was perceived inadequacies and imbalances in established research that motivated a growing feminist critique of science. This science critique developed from issues concerning women, to realising and focusing on problems concerning how science is constructed and practiced. Sandra Harding formulated this in her groundbreaking book "The Science Question in Feminism" (Harding 1986). Harding argued for a shift of focus, from "the woman question in science", by which she meant, "What is to be done about the situation of women in science?" (Harding 1986, p. 9) and towards what is often called "the science question in feminism", where she argued for and pointed to a reflexive turn, where feminists' transformation work also includes ourselves, as part of the problem and part of the solution.

[14] We use the term 'gender research', which is the most commonly used term in Sweden. However, many researchers, mainly from Anglo-Saxon countries, use the term 'feminist research'. An older term is 'women's studies'.

Knowledge and knowledge processes within science are of particular interest for gender research. A number of questions are relevant to ask around knowledge issues, such as: what knowledge is valid and why? Who can have knowledge? Who has the preferential right of interpretation and why? And "Whose science? Whose knowledge?" (Harding 1991). Finally, but not the least: How could it be different? Such questions can throw light on implicit scientific practices of importance for our understanding of what it means to know CS.

Important work concerning theory, epistemology and methodology for this type of gender research has been advanced by for example Sandra Harding (e g Harding 1986, 1991), Evelyn Fox Keller (e g Fox Keller 1985, 1992) and in particular Donna Haraway (e g Haraway 1991, 1997). Epistemological pluralism within feminist methodological development contributes with expanding the notions of knowing, accepting other and different ways of knowing than the dominating propositional view of knowing ("knowing that", e.g. Turkle and Papert 1990, Adam 1998). Important issues in feminist epistemologies are for example situated knowledge, partial translations (Haraway 1991), and embodied knowledge. Focusing situated knowledges is a base we strive after for our knowledge claims. We don't believe in universal claims of truth. Included in this is the notion of situatedness as part of an epistemological consciousness. Situated knowledge increases possibilities for relevant knowledge claims however partial interpretations they must be. Haraway (1991, p.196) stresses that what we can reasonably bring about in our knowledge production can never be more than partial translations. Translations are always interpretative, critical and just partial.

> "We do not seek partiality for its own sake, but for the sake of the connections and unexpected openings situated knowledges make possible. The only way to find a larger vision is to be somewhere in particular." (Haraway 1991, p. 196).

For a thorough account of feminist/gender research within science and technology, see Trojer (2002, in Swedish) and Mörtberg (1999).

Gender Research within Computer Science

> "The interaction of women's studies and CS should expand and improve our information revolution." (Thelma Estrin, professor in CS, in Estrin 1996, p. 46).

How can gender research in CS contribute to the goals outlined in the Introduction, such as broadening the meaning of "knowing CS"? The body of gender research into computer science done by computer scientists is still small, but growing. In this section, we want to give examples of issues where gender research in CS contributes significant work, as well as point to issues that need to be further investigated. Using and developing gender research within CS opens up possibilities for new approaches, which we will give examples of below. Theories and methodologies from gender research offer new opportunities to explore issues around knowledge in CS. We believe that especially feminist epistemological thinking has the potential to enrich computer science. In this way, gender research can become an active participant, in particular within CS

education. This is supported by other gender researchers in CS, for example Norwegian informaticians[15] Tone Bratteteig and Guri Verne, who "see epistemological inquiries to establish alternative understandings of knowledge" as being the most challenging and having the greatest potential for contributing to change in CS (Bratteteig and Verne 1997, p. 60).

Paradigms of computer science

As discussed above, paradigms of importance within CS will take on a significant role in education. A rethinking of these could likely have considerable impacts on *what* is taught as well as *how* it is taught.

Frances Grundy raises questions concerning the 'fundamental nature' of the discipline of computer science. She challenges the three major paradigms identified within CS: mathematics, science and engineering (Grundy 2000a, 2000b, 1998). She discusses the role of mathematics in computing, and in particular what role mathematics actually plays for abstraction. Her argument is that mathematics is only one type of abstraction involved in computing, and she further claims that mathematics is a status symbol and has been used as an argument for making CS into a science.

Abstraction is considered very important for CS. However, the products of CS are very concrete. Why is abstract, formal and logical thinking and knowing seen as superior within CS? Sue Clegg (Clegg 2001) argues that computing is neither an extension of mathematical thinking nor an applied science. She sees the reasons for these views of CS as historically conditioned. Instead, she suggests that computing should be seen as a concrete science, concerned with materiality and social practices. The implications of such a change in perception of the discipline could potentially have almost revolutionary effects within CS education.

Frances Grundy has developed a concept around what she terms *interactionism*. In her version, this is a cluster of ideas, involving for example a blurring of the distinction between the subject and object (Grundy 2000b). "Interactionism emphasises the practicality of computing; it also recognises that much computing is about communication and it recognises the importance of pluralism." (Grundy 2001).

Integration of use and practice

In a preceding section, we pointed to the discussion concerning integration of *practice* into CS education. The practice of many computer scientists concerns production of software, including design. An important focus for gender researchers has been issues of design and use (e.g Bratteteig 2004). Software design and development is a complex activity, requiring knowledge not only of the technology involved but also knowledge of the area of use. Gender research, with a foundation in situated knowledge, may contribute to the discussion about use and design, and to develop other theories and

[15] "Informatics is the term for computer science departments in universities in Norway, indicating that the discipline is defined more broadly than in traditional computer science departments." (Bratteteig and Verne 1997, p. 59).

methodologies, for example to account for complexity and for heterogeneity among users, in order to develop responsible and sustainable technology (Mörtberg 2003).

Tone Bratteteig and Guri Verne (Bratteteig and Verne 1997) argue that use of technology and applications ought to be included as an integrated part of computer science and that alternative understandings of knowledge are developed through the experience of application. Different "models of the world" will result in different computer systems – and thus also different consequences for the users. How systems are constructed depend on who construct them, and what world-view and understandings of knowledge, experience, values and needs they integrate in the development and the final products. *Who* influences development is thus important to take into consideration (Mörtberg 1997).

What is excluded from CS? Referring to excluded issues such as missing accountability, the absence of subjectivity and the excluded views of the system users, Ulrike Erb argues that "in particular if we do feminist research inside the discipline of computer science, one main purpose of this research might be [….] to reveal the excluded and to integrate the excluded in order to enrich computer science by means of the forgotten perspectives" (Erb 1997 p. 206). What must not be dismissed, however, is that the actual integration processes should be transformative rather than merely additive.

Knowledge and learning

> "Knowing is not necessarily a matter of saying and representing what is the case but can also be a kind of practical involvement with the world." (Belenky et al.1997[16]).

Questions concerning 'what knowledge?' and 'whose knowledge?' are among the most central issues for gender research to focus on. Alison Adam has extensively discussed epistemological issues in her work on artificial intelligence (AI)[17] (e.g. Adam 1995, 1998). She discusses issues of knowledge, such as 'whose knowledge' and 'what knowledge' is represented in AI systems. Among other topics, she discusses the differences between propositional knowledge ('knowing that') and skills knowledge ('knowing how'), or mental vs. embodied knowledge, and how the former has been seen as superior to the latter (Adam 1995).

Computer science does require a certain amount of abstract thinking. However, there is no doubt also need and room for what can be called concrete thinking, and not least concrete learning. Thelma Estrin, professor in CS, sees "concrete thinking" as one way where feminist epistemologies can influence CS, and she takes her examples from programming education. By concrete she means practical involvement:

> "Every science is incomplete and always in the process of extension and expansion from new

[16] Belenky, Mary, Clinchy, Blythe, Goldberger, Nancy and Tarule, Jill (1997) *Women's Ways of Knowing: The Development of Self, Voice and Mind*. New York: Basic Books.

[17] AI is often regarded as a sub-discipline of CS – or at least some aspects of AI are. It can be argued that AI is a separate discipline, with its own epistemology. However, the issues concerning knowledge are highly relevant in CS.

ideas. Feminist epistemology, with its dedication to concrete learning introduces new ideas for gaining knowledge that may make CS more relevant…" (Estrin 1996, p. 46).

This could introduce new ideas for gaining knowledge that may make CS more relevant to a more diverse group of people. Knowledge and acceptance of different types of knowledge construction (see e.g. Alsbjer 2001) is essential for extending the view of knowledge within CS, and thus potentially accommodating greater diversity in its practices and among its practitioners. We strongly believe that CS education would gain from cherishing "epistemological pluralism".

Programming and the object-oriented paradigm

We see the teaching of programming as being of particular importance. Maria Alsbjer has used gender research and feminist epistemological theory to discuss programming education, in particular the processes involved in learning to program (Alsbjer 2001).

Whose knowledge is built into objects in object-oriented design? Cecile Crutzen and Jack Gerrissen have analysed the ontology and epistemology of the object oriented paradigm (OO) (Crutzen and Gerrissen 2000). They argue that OO enhances the idea of the controllable and deterministic:

"[It is] based on the same illusions of objectivity and neutrality of representation; the negating of power and dominance by translating it into 'natural and obvious', and on the existence of truth by transforming it into progress." (Crutzen and Gerrissen 2000 pp.132-133).

They claim that object orientation is based on the idea that everything and everybody can be represented in terms of objects, an idea that they object strongly against. They argue that OO should not be used for the analysis of human worlds, but only for what it was originally intended: the realisation of software[18].

It is interesting to compare this analysis of OO with the views expressed by Sherry Turkle and Seymour Papert ten years earlier (Turkle and Papert 1990) where they see OO as potentially revolutionising programming methods and also as challenging traditional ways of thinking and knowing.

Representation and metaphors

Computer science builds competences on consensus-marked classifications, standardisations and formalisations. Christina Mörtberg discusses representation in a way that can serve to illustrate the reasoning (Mörtberg 2000 p. 58):

"Formal representations are created in processes that entail abstractions, quantifications, hierarchisations, classifications, standardisations and simplifications […]. In these processes, there are negotiations about borders and content and in these negotiations, technology and gender are shaped."

Categorisation is not only a means of structuring the outside world – it also limits and

[18] Note that what they criticise is the paradigm of object-orientation at a fairly high level, for example for making analysis of "human worlds", *not* the low level object-oriented programming, used for "realisation of software".

affects our way of thinking. By leaving established categories, new forms of understanding can be created.

What kind of presumptions, choices, standardisations, classifications etc. are involved in the knowledge processes? So far, for example gender-marked representations and metaphors are neutralised, made implicit and integrated in the development of models, computer systems, etc. The use of language has proved to be very important in our understanding of ideas and the images they call to mind. The presence of clearly gender-marked metaphors can be a factor in supporting the gender structure within the discipline. Metaphors create images that will be of importance in the knowledge processes (Fox Keller 1995).

Furthermore, design of computer products are not value or gender neutral. The knowledge and experience of the designer influences his or her design, and in our society gender is one factor influencing experience. What is integrated into design, and perhaps even more important, what is *not* integrated? However, it is not easy to isolate the gendered aspects of technology, since they are integrated socio-cultural phenomena (Bratteteig 2003). Uncovering cultural aspects in software is an important issue, which is likely to require knowledge about design and construction of software.

Concluding Discussion

In the introduction, we argued for a growing need to develop a more complex and integrating understanding of knowledge processes within computer science. This need is based on the fact that CS has an increasing influence on current and future technological development. We recognize practices of society and practices of CS as interlinked in progressively more sophisticated ways.

We believe that using gender research based within science and technology to study and transform CS and its knowledge processes provides potentials for the development of new conceivable understandings and interpretations of CS, and what it means to "know CS". In this article we have discussed and pointed to issues where gender research can contribute:

- By asking questions per se, decisions and assumptions underlying technology can be made visible, thus avoiding 'black-boxing' (Latour 1999)
- By showing how technology and science are closely intertwined
- By pointing to how CS does not exist in itself, it is constructed by people and can thus be reconstructed
- By paying attention to how views of knowledge implicitly exist in syllabi and curricula, and question these assumptions
- By querying the role of different paradigms and metaphors in the discipline, and show possibilities for, in specific contexts, more functional alternatives
- By unveiling how software is laden with cultural values and choices, including gendered aspects

- By promoting reflexivity concerning issues of knowledge and their implications for practice, e.g. the assumptions implied in teaching
- By concretely fostering and working with integration of epistemological pluralism into CS.

We believe that reflection around issues of knowledge is important for every discipline, especially for teaching and for meeting potentially new groups of students. Can computer scientists[19], by becoming aware of their own views of knowledge and understanding, also become aware of, respect and accommodate for, greater diversity among students and their backgrounds, interests, motives and understandings? Can we, as feminists and computer scientists, thus in the long run, change the discipline into one that is more attractive to a broader range of students, for example women?

[19] Christina includes herself in 'computer scientists'.

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Invitation to Dialogue: Feminist Research Meets Computer Science

Abstract

In this paper I discuss how feminist research focusing epistemological issues can be used within computer science (CS). I approach and explore epistemological questions in computer science through a number of themes, which I believe are important to the issues of *what* knowledge is produced as well as *how* it is produced and how knowledge is perceived in CS. I discuss for example paradigms and metaphors in computer science, the role of abstractions and the concept of naturalisation. In order to illustrate epistemological views in CS and how these can be questioned from the viewpoints of feminist epistemology, I also do a close reading and commenting of a recent book within the philosophy of computing.

Introduction

Can feminist research be used in computer science[1]? And if so, can it be used not only for studying and criticising CS, but also for transformation, contributing to the development of the discipline? In this article I want to invite to a dialogue between feminist research and computer science. My interest and goal concerns how to broaden the concepts and approaches to knowledge in CS, with the main issue being: can CS cherish epistemological pluralism, i.e. different ways of knowing and learning?

Feminist/gender research concerning computer science has to a large extent focused on issues of gender in relation to computer science, for example the lack of women within computing, and gender equality aspects (see for example the overview and discussion in Björkman (2002)). In these studies, CS is often seen as firmly defined, and the

[1] I use the term 'computer science' (CS) in a broad sense, including software engineering and most parts of computer engineering. In all relevant aspects, I use this term as synonymous to the word 'computing'. I use CS to emphasise the discipline aspect, an aspect that is not always clear from the word 'computing'.

underlying perceptions of development and knowledge are seldom brought into focus. In this paper, I want to give some examples of how feminist research can be a resource within CS, for discussions concerning the discipline itself, and its practices.

My approach is threefold: I highlight some feminist research that has been done within CS, which can serve as inspiration as well as foundations for future work. I also point to issues within CS that I consider relevant to study further, by asking questions that I see as important to pursue. In order to highlight both some strongly prevalent views of knowledge in computer science, and to show how feminist epistemologies can interrogate these views and offer alternatives, I end the paper with a close reading of some texts from a recent collection on the philosophy of science in CS.

Theoretical Starting Points

Feminist epistemologies

Feminist research represents many theoretical and methodological approaches, and the meaning and focus of the research is different within different disciplines. I will here discuss some of the epistemological ideas and concepts that I use as starting points[2].

Sandra Harding, in her ground-breaking book "The Science Question in Feminism" (Harding 1986), emphasizes the importance of epistemology, or as she phrases it, "concepts of knowers, the world to be known, and the process of knowing" (Harding 1986, p. 140). It is particularly important here to note that she does not primarily talk about 'knowledge' as a noun, but of the activity of knowing, and of knowing subjects. She points out (Harding 1987) that methodology and epistemology are intertwined with what we do and how we do it, thus underlying all research and knowledge production.

The feminist epistemologies I build my work on, do not accept the (still strongly prevalent) ideas of science and the scientist as neutral and objective. Sandra Harding eloquently expresses this:

> "…observations are theory-laden, theories are paradigm-laden, and paradigms are culture-laden: hence there are and can be no such things as value-neutral, objective facts." (Harding 1986, p.102).

Feminist epistemologies are thus critical of objectivity paradigms, and of the neutral and objective observer, what Donna Haraway terms "the God-trick of seeing everything from nowhere" (Haraway 1991, p. 189). Instead, Donna Haraway develops the concept of *situated knowledge*:

> "I am arguing for politics and epistemologies of location, positioning, and situating, where partiality and not universality is the condition of being heard to make rational knowledge claims. These are claims on people's lives; the view from a body, always a complex,

[2] Lena Trojer gives a thorough account of feminist/gender research within science and technology in Trojer (2002). Christina Mörtberg has also developed and discussed these issues (e.g. Mörtberg 1999).

> contradictory, structuring and structured body, versus the view from above, from nowhere, from simplicity." (Haraway 1991, p. 195).

Situated knowledge is a far-reaching concept, which I understand and use as implying an epistemological standpoint. Thus, *situatedness* refers to conscious epistemological positioning. It is not simply a matter of an individual place or state, it is part of practice and knowledge production, and it means actively taking a stand. And there is no such thing as an innocent position.

The feminist epistemologies that I talk of here attempt to refuse the choice and dichotomy between on the one hand universalism and on the other relativism. Instead, Donna Haraway puts forward a feminist concept of objectivity:

> "I would like a doctrine of embodied objectivity that accommodates paradoxical and critical feminist science projects: feminist objectivity means quite simply situated knowledges." (Haraway 1991, p. 188).

Thus, her alternative to relativism and universalism is partial, locatable, situated knowledge.

Knowledge

The common definition of knowledge in (analytical) philosophy is on the form of: 'S knows that P'. However, this is only a definition of one type of knowledge, often called propositional knowledge (or sometimes simply theoretical knowledge). This has come to be seen as the only important form of knowledge, at least within western science (e.g. Turkle and Papert 1990). What about the knowing subject in this definition? S is not defined here, and thus takes on the form of a universal, disembodied knower, having a view from nowhere in particular. This is also the knowledge of the mind, building on the dualisms between mind and body, culture and nature, man and woman etc. Abstract and theoretical thinking and knowing ("knowing that") is seen as superior while bodily knowing and practical thinking ("knowing how"), is seen as inferior. In this view, the body is seen as a hindrance for the 'pure' intelligence of the mind, thinking and reasoning are presented as fundamentally mental. Skills and tacit knowledge, on the contrary, are seen as a lower form of knowledge compared to that of the mind. To put it bluntly: knowledge that is not propositional is not considered knowledge. These different types of knowledge have traditionally been connected to men and women respectively; and the 'true' knower has been a man (Adam 1998).

Some feminist thinking, as a contrast to the view above, wants to call attention to other kinds of knowledge, such as those derived from practical experiences of the world. This includes the body as an inseparable part of knowledge, and not only the mind. Thus, feminist epistemologies acknowledge (embodied) experience as a valid basis for knowledge, and argue for a unity of knowledges, to borrow Hilary Rose's expression, of "hand, heart and brain".

Feminist Research Meets Computer Science

Both feminist research and CS are competence areas, but they also bring with them modes of thinking about the world. My belief is that feminist epistemological thinking has the potential to enrich computer science, as do Norwegian informaticians[3] Tone Bratteteig and Guri Verne, who see "epistemological inquiries to establish alternative understandings of knowledge" as being the most challenging and having the greatest potential for contributing to change in CS (Bratteteig and Verne 1997, p. 60).

> "We do not accept the dichotomy between feminism and technology. The challenge is to learn to live with, and possibly harvest from, the contradictions and alleged paradoxes that arise." (Bratteteig and Verne 1997, p.70).

Knowledge and knowledge processes within science are of particular interest for a feminist analysis. In the sections below, I approach knowledge issues in computer science through a number of themes that I find to be of particular interest to focus, and I do this by asking questions. These are generally not questions that look for immediate answers; they should rather be seen as comments from a feminist position. Asking questions is a way of starting a reflective process as well as it can be a way to communicate. These questions are meant to take into respectful, shared conversations; I want to invite to dialogues where feminist researchers and computer scientists together look for potential answers.

What knowledge? Whose knowledge?

Questions about knowledge are particularly important in the field of Artificial Intelligence and so called expert systems. Alison Adam has contributed extensively to the critique of AI from a feminist perspective, for example in Adam (1994, 1995, 1998). She claims that using knowledge and experiences from feminist epistemology, it is possible to get more radical insights into epistemological issues in AI, than when using more traditional approaches (Adam 1994). Most critique of AI de-emphasises the cultural production of AI, thus being as Alison Adam sees them, "epistemologically conservative" (Adam 1998, p. 50).

Traditional criticism of AI concentrates on whether it can create true intelligence, while feminist critique looks to the cultural settings of AI – whose knowledge and what knowledge that are represented. What world-view comes with the concretisation of knowledge in an expert system? Alison Adam is worried about "the taken for granted nature of the expert and expert knowledge" (Adam 1998, p. 42). For example, it poses big difficulties to represent skills knowledge ("knowing how") and common sense in AI-systems, which means that only some types of knowledge will be represented in the systems.

[3] "Informatics is the term for computer science departments in universities in Norway, indicating that the discipline is defined more broadly than in traditional computer science departments." (Bratteteig and Verne 1997 p. 59)

Issues concerning knowledge are by no means limited to the area of AI. An equally important question as "whose knowledge is represented in an AI system" is the question "whose knowledge is built into objects in object-oriented design?". Cecile Crutzen and Jack Gerrissen have made a feminist analysis of the object oriented paradigm[4] (OO) (Crutzen and Gerrissen 2000). They make a case for making visible what is hidden:

> "OBJECTS should stop acting behind their surface, even if this would render our self-created OBJECTS unpredictable or unreliable." (Crutzen and Gerrissen 2000, p. 134).

Crutzen and Gerrissen argue that object orientation is based on the idea of objectivity and neutrality of representation, as well as the idea that everything and everybody can be represented in terms of objects.

It is interesting to compare this analysis of OO with the views expressed by Sherry Turkle and Seymour Papert ten years earlier (Turkle and Papert 1990), where they see OO as potentially revolutionising programming methods and also challenging traditional ways of thinking and knowing.

Many other questions regarding knowledge are important to ask in the context of computer science, such as the crucial question: "What does it mean to know CS and how could it be different?" As a member of the community of computer scientists, I also want to ask: "can we extend our view of knowledge within CS?" I see these questions as important for many reasons. For one thing, they relate to the learning of programming, which is one of the fundamentals of CS education[5]. These questions can also be important with regard to the under-representation of women within computing (Alsbjer 2001, Björkman 2002, Turkle and Papert 1990). A broadening of the meaning of "knowing CS" could potentially accommodate greater diversity in the practices of CS as well as among its practitioners.

Paradigms[6] and metaphors in computer science

CS is often seen as growing out of and combining other disciplines: mathematics, natural science and engineering. Tensions between these roots exist within the discipline, they do in some sense compete with each other, and to study their influence on knowledge production is important. Frances Grundy has raised questions concerning the 'fundamental nature' of CS, and has challenged these three major paradigms from feminist viewpoints (Grundy 1998, 2000a, 2000b).

The three important paradigms identified in Denning et al (1989) *theory, abstraction* and *design,* are in ACM and IEEE-CS Computing Curricula (2001) complemented

[4] Note that what they criticise is the paradigm of object-orientation at a fairly high level, for example for making analysis of "human worlds", *not* the low level object-oriented programming, used for "realisation of software".

[5] Maria Alsbjer has shown how feminist theories of knowledge can be useful in studying the processes involved in learning to program (Alsbjer 2001).

[6] I use the word 'paradigm' here in the loose sense that it is often used within CS, where it is often talked about for example different programming paradigms.

with the concept of *professional practice*. This addition of practice can mark a potential change in the view of CS, having effects in education, as well as for the question "What does it mean to know CS?"

New paradigms or metaphors for computing surface, the most important one today seems to be interactivity or interactionism. This concept has been discussed by a number of researchers. To take some examples: Lynn Andrea Stein talks about a new computational metaphor: "computation as interaction" (Stein 1999) and Peter Wegner writes about "why interaction is more powerful than algorithms" (Wegner 1997). From feminist perspectives Frances Grundy discusses a new conception of computing that she terms "interactionism" (Grundy 2001), and Heidi Schelhowe sees interaction as a successful approach to development of software (Schelhowe 2004). Metaphors create images that are of importance in the knowledge processes, different metaphors call for different ways of thinking. Can new and different metaphors or paradigms also support other ways of knowing?

Paradigms or metaphors will take on a significant role in education. A rethinking of these could likely have significant impacts on what we teach and how we teach. I see the teaching of programming as being of particular importance. My feminist comments here are: What are the paradigms and views of knowledge, CS and programming behind programming courses? Is this visible in the courses or not recognised but taken for granted? If and how a different paradigm or metaphor can promote learning of programming is a question that ought to be of great interest to the whole computer science community.

Abstractions, formalisations and representations

In computer science, abstractions, formalisations and representations are important. However, there is little discussion about the role of these, and how they are used.

Representations, categorisations and thus simplifications are necessary, but it is also important to look at how they are chosen. How is knowledge represented within software? I suggest that exploring the concept of situated knowledge could be useful: How can knowing situated in social and cultural contexts be represented, so that its situated nature does not disappear into universalising and de-contextualising?

Another important issue for research is the role of abstraction in CS. Abstraction is held to enable methods to be value-free. Computer science focuses on understanding the world via a rationality based in the abstract (Stepulevage and Plumeridge 1998). However, the products of CS are very concrete. Why is abstract, formal and logical thinking and knowing seen as superior within CS? This question is connected to the issue of how CS relates to mathematics. I argue that, even though mathematics is important, CS is in many (maybe most) aspects not a mathematical discipline. In contrast, CS could be viewed as concrete science where important aspects are materiality and social practices (Clegg 2001).

Problems can arise when extending abstractions, formalisations and de-contextualisations too far out of their right environments, and applying them in other areas, which do

not readily lend themselves to these kinds of descriptions, e g. systems design. I believe that the use of (necessary) abstractions could easily lead to abstracting away also ideas, values and meaning. Thus, abstractions, maybe without being noticed, diffuse into areas where they might not belong, and make us forget and realise complexities and social and cultural circumstances.

Computer science does require a certain amount of abstract thinking. However, there is no doubt also need (and space!) for what Thelma Estrin calls 'concrete thinking,' by which she means practical involvement (Estrin 1996), and not least concrete learning. This could introduce new ideas for gaining knowledge that may make CS more relevant to a more diverse group of people. Knowledge about, and acceptance of, different types of knowledge construction (e.g. Alsbjer 2001) is essential in order to extend the view of knowledge within CS.

Naturalisation

Closely related to representations is the concept of *naturalisation*[7]. In the process of naturalisation, something (an artefact, an idea, a concept etc) is stripped of its origins, context and consequences, and is seen as given, as self-evident.

An example of naturalisation within computing is the computer itself. This becomes very clear in meetings with undergraduate students. To most of them, 'computer' does not only mean an artefact, but also a very special artefact – the PC of today! They (and probably most of us) take the construction of the PC for given; not only in the way it appears, but most of all in the von Neumann-model it builds on, and in the digital technology used. The historical contingency of the way that today's computer is constructed has disappeared. However, there is nothing 'natural' or given with the construction of the present-day computer, not even the digital technology used. For example, Heike Stach (Stach 1997), shows how von Neumann, in his design of the model, was greatly influenced by ideas within neurophysiology and psychology (behaviourism) of the time, and not the least of the emerging cybernetics and its ideas of self-regulation and control. He came to formulate his design in terms of the prevailing beliefs of that time concerning how the human brain works. Quite soon, however, the brain came to be thought of in terms of the computer. So – the computer is a brain, and the brain is a computer! The computer is thus an obvious case of naturalisation, where the choices that were made 60 years ago, and the reasons for these choices, are, if not forgotten, so at least never brought to the fore. A feminist question/comment to this is: What does this naturalisation mean not only for our understanding of the computer, but also for our applications, which are, at the deepest level (machine organisation), completely dependent on this model?

[7] "By *naturalization* I mean stripping away the contingencies of an object's creation and its situated nature" (Star, Susan Leigh (1994) "Misplaced concretism and concrete situations: feminism, method and Information Technology", in *Gender-Nature-Culture Feminist Research Network Working paper,* No 11, Odense: Odense University).

What consequences can naturalisation have? For one thing, it is easy to see how everything, from hardware to software tend to be taken as 'natural', as something given, once they have existed for some time. This means that the reasons why things are constructed in a certain way are forgotten, and hence there is likely to be a tendency not to question whether this was actually 'the best way' to do something, thus contributing to technical inertia. Designers, machines and software are made invisible, thus hiding the choices that have been made during the processes.

Christina Mörtberg (Mörtberg 1997) points to how this not only affects artefacts, but the making of these as well. Actions and processes are reduced to structures and things, and technology becomes a naturalised object:

> "In the processes, doings and actings are transformed, through collective oblivion, into 'taken-for-granted-ness', which entails that verbs become substantives, with reification as result." (Mörtberg 1997 p. 147, my translation).

Feminist analysis can contribute to de-naturalisations of the objects created, for example software, in order to understand what intentions and choices that are built into the technology, and can help bring back the active and process nature of technology creation. This will mean that the objects and the processes will become *situated* in the context where they were created, and this situating brings with it valuable knowledge about the different circumstances surrounding the creation.

Technology as culturally situated

All processes that produce knowledge are situated, socially, culturally and historically. Sandra Harding discusses this:

> "Most engineers would argue that their technologies are not social at all in any meaningful sense of the term […]. By excluding from their definition of a "technology" not only its social applications and meanings, but also the knowledge of how to make it, use it and maintain it, they can perpetuate the illusion that technologies are not cultural at all." (Harding 1996, pp. 283-284).

To exclude social and cultural aspects from knowledge and artefacts relates to attempts at universalising, a process that Donna Haraway, along with naturalising, sees as connected to the "view from nowhere", the disembodied knowledge. I find it hard to claim universal validity of products of computer science. Software is tightly interwoven with cultural and other pre-understandings of western culture (as mostly interpreted by Microsoft!). Just to mention one example, Lucas D. Introna and Helen Nissenbaum (2000) have shown how the design of search engines is laden with value choices.

It is necessary to become aware of, even emphasize, that technology is both created by and creates cultures. Furthermore the cultures of science cannot be separated from the production of knowledge, these are closely intertwined.

Examples of Epistemological Views in CS with Feminist Comments

In order to highlight both some strongly prevalent views of knowledge in computer science, and to show how feminist epistemologies can interrogate these views and offer alternatives, I have chosen to do a close reading of a recent collection regarding the philosophy of science in CS: *The Blackwell Guide to the Philosophy of Computing and Information*, edited by Luciano Floridi (Floridi 2004, below simply called GPCI[8]). This volume "seeks to provide a critical survey of the fundamental themes, problems, arguments, theories and methodologies" (p. XII) in philosophy of information. In this collection, many prominent scholars within CS as well as within related areas write about different aspects of the 'nature' of computing and information, which thus give a picture (although of course not the whole or only picture) of CS.

The overall feeling I get when I read the GPCI, is that most of the authors (though not all, see below) assumes a 'traditional' view of "science – as – usual", supporting objectivism, realism and empiricism. These aspects are held out as foundational for computer science. For example, there is an almost total absence of the embodied subject. However, with a different epistemological point of departure, the picture can look very different. I argue that in this context, it is very appropriate to pose questions such as "Whose knowledge?" and "What knowledge?" as I will show examples of below.

I will also point to how quite different views of computing can be seen depending on the position and background of the author. In GPCI, the authors who are closer to 'pure' computer science tend to lean towards a preference for the abstract, logical and formal, while those that discuss the broader aspects of information technology or the use of computers, talk about embodiment, interaction, interpretation and hermeneutics. The views of these different authors reflect different philosophical traditions and different epistemologies.

Information, knowledge and truth

Information is a basic concept in the GPCI. A common definition of information, for example used by the editor and chief proponent of the new Philosophy of Information, Luciano Floridi, is that information is considered to have *objective semantic content*. He defines objective as "mind-independent or external, and informee-independent" (p. 42). This means that information exists independently of its encoding and transmission. This view tends to prioritise a view of information as 'object', rather than as process. Primarily, the informee-independence can be interpreted as 'independent of a particular receiver', or assuming a 'standard receiver', in which case the obvious feminist question becomes: who is this standard observer? However, Floridi also argues that an instance of information "can have a semantics independently of any informee" (p. 45), or, in other words, information does not require an informed subject. Can information really be said to exist if there is no receiver, and if no communication is going on? Is

[8] If nothing else is said, the references in this section are to pages in GPCI.

information just lying around, waiting to be exposed? In a different view, it can be argued that information in itself always involves interpretation (see e.g. below on the chapter by Carl Mitcham). Floridi also points out that information requires that data is both well-formed and meaningful. But can data be meaningful without an informed subject? Or, is it meaningful for any receiver, independently of who this is?

I oppose to this view of information. Instead, I take the position that information is, (at least to a non-trivial extent), dependent on the position and situation of the informed subject, dependent upon his or hers (situated) interpretation. This means a view that focuses on the subject and the process, instead of on the object. I agree that data can exist 'in itself', but I think this is doubtful when it comes to information.

Floridi argues in favour of a centralised approach to information, a view of information that has "a core notion with theoretical priority" (p. 41). At the same time, he makes a strong attack on what he terms "decentralised or multicentered approaches" to information (p. 41[9]), according to which there is no key concept of information. Words like 'core notion', and 'priority' suggests a hierarchical and I would say also possibly authoritarian view. Floridi presupposes factual information, i.e. information about 'reality' – but what reality and whose reality does he talk about?

Carl Mitcham provides a different view of information in the chapter on "Philosophy of Information Technology". He sees information as much more related to humans and human activities such as language, while in many other chapters, information is strongly connected to computing and data processing.

Mitcham puts information and information technology into its historical context. He provides an in-depth interpretation of Martin Heidegger on IT. This view emphasises the processes of interpretation of information, and the necessity of a more holistic perspective: "all information technology is part of a larger life-world and cannot be understood apart from such an implicit whole." (p. 333). Heidegger claims that information technology not only reveals, at the same time it conceals. This thinking casts another light on the use of formalisms and de-contextualising, and one feminist question becomes: what is concealed and hidden from view, for example in software?

According to Fred Adams in the chapter on Knowledge, only two types of knowledge count: empirical and logical-mathematical. He furthermore claims that: "It is uncontroversial that knowledge requires truth and belief." (p. 228). The standard definition of knowledge in mainstream (analytical) philosophy is "knowledge = true justifiable belief", but it is *not* uncontroversial when read from a feminist view, mostly because it contains that very tricky little word 'true'! Even if the term is used as meaning something limited and even contingent, it is problematic since it brings with it connotations of grand theories and universal, objective truth beyond the subject. But 'truth' is a carrier of values; it automatically carries with it the value of accepting something as true.

[9] "Thus, philosophers like Baudrillard, Foucault, Lyotard, McLuhan, Rorty and Derrida, are united by what they dismiss, if not challenge: the predominance of the factual" (p. 41).

Abstractions

> "The computer scientist's world is a world of nothing but abstractions." (Colburn in Floridi (ed) p. 322).

Taken out of its context, this is a stunning, and quite fearsome statement. However, it becomes clear in the rest of the chapter (Timothy Colburn: Methodology of Computer Science), that Colburn discusses the abstraction of the physical machine, of "the mundane and tedious level of bits and processors" (p. 322) that computer scientists learn to abstract away from. This means some kind of "bottom-up" abstraction, in contrast to the "top-down" abstraction involved in translating real-world problems to be solved into program systems. The kind of abstraction Colburn talks about is of course very important. However, there is the question concerning where, at what level, shall these abstractions meet? At the level of design? Or at the implementation level? Somewhere, a computer scientist must in the end consider the limitations of the machine and system software she/he has at hand, the machine cannot be completely abstracted away.

To Colburn, abstractions are fundamental. He argues that "software developers need to become conversant in the analytical tools of philosophers", such as logics, classifications, hierarchies "and other convenient abstractions." (p. 325). This again, reveals a view that prioritises the abstract, disembodied knowledge. I want to argue that that is *not* what software developers primarily need today, instead they need the competencies connected with the domains of use, for example to understand and account for complexity and heterogeneity among users.

Through many chapters of the book runs this thread of computer science as abstract, formal, logical and objective, and its (supposedly strong) connection to mathematics. Is the world understandable and describable in formal terms? My position is that it is not. Whose world is captured in the formal methods/models? I believe a fundamental question becomes: what is computing mostly about: formal systems and abstractions or 'thinking things', i.e. people? The answer to this question will depend to a great deal on the view one takes not only of computer science, but also of technology on the whole, and of course, of one's epistemology.

Colburn (p. 319) gives an interesting example regarding two fundamentally different views on programs: one that sees computer programs as mathematical expressions, and another that sees them from the perspective of functionality. These examples signal contrasting interpretations as to how computer programs ought to be designed, built, and used. Which of these views dominates within different computer science communities? This is likely to depend on the particular context and history of the community in question, but I also believe that the formal view (mathematical expressions) used to be the strongest, but is losing ground to the more use- and functionality oriented view. This can potentially mean an important twist in the view of what computer science is about.

The (dis?)embodied subject

In a section above, I discussed some feminist critique of AI. This critique can be applied to the view held out by Barry Smith in the chapter on Ontology. According to Smith,

AI should concentrate on the task of "formalizing the ontological features of the world itself, as this is encountered by adults engaged in the serious business of living." (p. 160). But who are these adults? The AI researchers themselves? The idea that the experiences of a human being are independent of which human being is selected is seductive and very dangerous. Feminist scholars have shown that this 'archetype' for a human being is most often a white, western, even middle-class man, and how well does he represent humanity?

This can be contrasted with the views expressed by Charles Ess in the chapter on Computer-mediated Communication and Human-Computer Interaction. He discusses the work of Terry Winograd and Fernando Flores[10]. They have explored how tacit, non-articulated understandings are built into computer technology. A design of a tool includes certain assumptions, including world-views, and "tools thus embody and embed these assumptions while excluding others." (p. 78). This is what Winograd and Flores express as "in designing tools we are designing ways of being." (quoted on p. 78). They see much of the world-view underlying design of computer artefacts as 'rationalistic', and instead want to highlight social interaction.

Concluding Remarks

As I wrote in the introduction, this article is full of questions. The questions have implications for practice, such as what we convey to students. What (implicit) assumptions and commonly accepted views underlie the knowledge processes in CS, e. g. (teaching of) programming? As for curricula and syllabi, what assumptions about knowledge and the subject do they presuppose? I believe that reflection around issues of knowledge is important for every discipline, especially for teaching and for meeting potentially new groups of students. Can we, as computer scientists, by becoming aware of our own views of knowledge (and hopefully also challenge these), become aware of, respect and accommodate for, greater diversity among students, and their backgrounds, interests, motives and understandings? Can we thus, in the long run, change our discipline into one that is more attractive to a broader range of students, for example women? I believe that this can be one contribution to the large task outlined by Maria Klawe that I deem to be of great importance for computer science to pursue:

> "We need non-nerds in computer science, so let's figure out the proper approaches to integrate their talents and perspectives into our field." (Klawe 2001 p. 68).

I strongly believe that one of the most important things for feminist research in technology in general as well as within computing is to work on broadening the concepts and understandings of technology. There is nothing inevitable about how computing is constructed, thus it can be re-visioned and re-conceptualised. I want to conclude by quoting Christina Mörtberg:

[10] Winograd, Terry and Flores, Fernando (1986) Understanding Computers and Cognition: A New Foundation for Design . Reading, MA: Addison-Wesley.

"Feminism is a resource that can be used to formulate alternative goals, visions and dreams about our existence […] Feminist research may contribute to re-configure, re-formulate or to give technoscience […] other directions." (Mörtberg 2003, pp. 57, 66f).

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Introduction to Part C: Trying Translations

This part deals with a project with computer science university faculty at Malmö University in which I participated 2003-2004. The project was called "Knowledge and learning in computer science from gender research perspectives". It intersected three areas that are strongly related: integration of gender issues into computer science education, feminist research about knowledge in computer science, and pedagogical development. For my research, this was a concrete 'intervention', where my aim was to investigate how feminist research can contribute to computer science education. In this project, the issues of communication and translation came to appear as central for me. The focus in this part is communication between computer science educational practice and feminist technoscience research.

Paper C1 is a joint paper with Carin Dackman and Steve Dahlskog at Malmö University. In this paper we present and discuss the project: the ideas behind it, the project process and its outcomes. We write with three different voices, from different perspectives: the project leader (Carin) one of the computer science teachers (Steve) and the feminist researcher (me).

One goal with the project was to bring the practices of computer science education together with feminist theory and research, on the assumption that the latter can be a fruitful resource within CS and contribute to the processes of improving education and accommodating diversity among students. For me, one of the aims of the project was to start a reflective process concerning knowledge among practitioners of CS (including myself!), to reflect over our own understanding and basic assumptions of the subject – what do we mediate to students?

During this project, focus for my part came to shift from an interest in how the participants approached knowledge in computer science, to issues of communication and translation.

Paper C2 marks the final point of my PhD research. Here, I use empirical material from the project in a discussion on epistemology, language, communication and translation.

With a starting point in the discussions during the project, I discuss how epistemology is intertwined with language. I describe my interpretation of the different 'voices' that represent the "worlds" of computer science educational practice and feminist research respectively. The experiences of communication problems, or communication 'breakdowns' as I call them, raise the issue of translation between these two "worlds", and how translation work can be accomplished.

In the end of the article I summarise and point to issues that I believe are important for future interventions and encounters between feminist research and educational practice in science / engineering. I conclude the article with a discussion of how epistemological cracks are visible and manifest themselves in conversations.

In this article, communication and translation becomes the focal perspective in the work for change. This entails engaging in co-operation and dialogues with practitioners in which awareness of differences between the "worlds" is necessary, as well as upholding critical self-reflexivity.

Contribution. The contribution from this part is twofold. Firstly, it is the experiences from the project, from the three different perspectives. These are summarised in a list of recommendations for these types of projects. The project also resulted in two of the teachers doing their own 'interventions' in their teaching. Secondly, I came to realise that transformation comes about through communication and co-operation, which in turn require translation. This led to formulating a number of issues that I believe are important to consider in future transformative work within science/engineering.

Paper C1

By Christina Björkman, Carin Dackman and Steve Dahlskog.
Accepted for presentation at the gender research conference
"Teori möter verklighet" [Theory meets reality], Malmö,
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Gender Research and Feminist Theory Meets Computer Science Educational Practice

Introduction

What happens in the encounter between feminist theory and computer science practice? How can feminist research in computer science be a resource in the work of integrating gender perspectives in computer science education?

During 2003-2004, we worked with a project at Malmö University aiming at integration of gender perspectives in computer science education. The participants were teachers in computer science, a project leader from gender studies and a PhD student working with feminist research in computer science. The project was called "Knowledge and learning in computer science from gender research perspectives". It intersected three areas that we consider strongly related: integration of gender issues into computer science education, feminist research about knowledge in computer science, and pedagogical development.

In this paper we present and discuss the project: the ideas behind it, the project process and its outcomes. We write with three different voices, all having slightly different goals, perspectives and interests for the project. The voices are those of the project leader, one of the computer science teachers and the feminist researcher. What did we learn and which goals were reached? What difficulties did we meet? Did gender research and feminist theories have any influence and in what ways?

Brief Background

At Malmö University gender perspective is one of three "perspectives"[1] that are meant to be integrated into all education (Genus, Miljö, Migration och etnicitet, 2004). Carin

[1] The other two are migration and ethnicity, and environment.

Dackman works as project leader for integrating gender perspectives at the technical faculty.

Bringing up issues of gender in relation to technology, there is always a risk that the discussion comes to focus either on the missing women, and what could be done to increase the number of women, or on differences between men and women. The problem with these approaches is the underlying assumptions of technological determinism and/or essentialism in the view of men and women. This can result in a tendency to see women as the problem. As Judy Wajcman puts it:

> "Feminists have pointed to all sorts of barriers – in social attitudes, girls' education and the employment policies of firms – to account for the imbalance in the number of women in engineering. But rarely has the problem been identified as the way engineering has been conceived and taught." (Wajcman 1991 p. 19).

To bring the discussion further it was decided to take advantage of the research done in computer science using feminist theory and to take pedagogical questions as a starting point.

The interests and purposes described above coincided with those within a project in the research group Technoscience Studies at Blekinge Institute of Technology[2], in which Christina Björkman works as a PhD student. With a starting point in feminist theory and research, her research project concerns knowledge processes within computer science (CS). A special focus is education. These issues are connected to gender issues in CS, but the approach here is to move focus from women to the discipline of computer science itself.

Setting the Scene – About the Project

The project, which was ongoing from Fall 2003 to Fall 2004, was called "Knowledge and learning in computer science from gender research perspectives". It was fairly complex, having three explicit perspectives:

- Integration of gender issues and perspectives into CS education
- Epistemological issues and discussions concerning knowledge in CS, with contribution from feminist theory and research
- Pedagogical development.

The goal of the project was that the participants should deepen their knowledge about gender, teaching situations and learning within computer science through reflection over their own practice and experiences, and with contributions from gender/feminist research.

This was sometimes also expressed as attempting to bring computer science educational practices together with feminist theory and research, on the assumption that the latter can be a resource within CS and contribute to the process of creating better education and accommodating diversity among students.

[2] See http://www.bth.se/tks/teknovet.nsf/.

A starting point for the project was in the belief that an important aspect in all education (although seldom talked about in CS education) are the more or less implicit and unconscious thoughts and images, for example of CS, programming, knowledge etc, that teachers as well as students carry. If these differ too much, the "meeting" between teacher and student, which is necessary for learning, might not happen, and the student's learning is rendered more difficult. This is emphasised by pedagogues Ference Marton and Shirley Booth:

> "In order to bring about a meeting of awarenesses, the teacher has to take the part of the learner,…see the experience through the learner's eyes, become aware of the experience through the learner's awareness." (Marton and Both p. 179).

Are these ideas and images made explicit or are they implicit, seen as so self-evident and taken for granted that they are never brought out and articulated? In the project, we intended to discuss and make visible the participants' views of programming in particular and knowledge in computer science in general and to relate these to students' views and expectations.

The intended 'method' was expressed in the project description as:

> "In the project we will for example work with reflection as a method. The participants' experiences of their profession, of programming and teaching of programming, make up the frame of the project. We will use current research within the area of gender/feminist research to deepen the discussions around the experiences."

The computer science faculty who participated in the project (a total of 10 people, most of them lecturers), had different backgrounds and experiences, thus creating a dynamic group. During the meetings the number of participants varied, some of them participated in practically every meeting while some only participated a few times.

The form of the project was half-day meetings (with the exception of one full day meeting), a total of 9 meetings. Every meeting had a particular theme within the field of gender, knowledge and computer science. The themes were chosen together with the participants. The format of the meetings varied, but they often included some preparations for the participants (reading a text, collecting examples from their own practice, preparing some material for discussion etc), and sometimes an introduction by one of the project leaders. In appendix A we present a more detailed description of the topics of the meetings, as well as the literature used.

Gender concepts were introduced as a tool for discussing cultures of teaching, gender inclusive teaching, and images of masculinity and femininity, men and women. The approach used could be summarized as: Gender and technology can be understood not as fixed and given, but as processes, which are constantly formed and re-formed in on-going negotiations.

The practice of teaching computer science was discussed and related to research concerning gender issues within education. A special focus was teaching of programming, the 'paradigms' implicit in this teaching and what it means to "understand programming". An example of texts that we used is a bachelor's thesis in which the author uses gender research and feminist epistemological theory to discuss programming education (Alsbjer 2001).

One important issue discussed during the project, which relates both to gender and to knowledge, concerned how to teach for diversity, meeting and accommodating new groups of students within computer science.

Three Perspectives, Three Stories

Each of us will tell our story about the project from our own perspectives: the project leader, the feminist researcher and one of the computer science teachers. We discuss our motives for participating, the expectations we had and how we experienced the project and its outcomes. Our intention is to give a more complex picture, not telling the story as is commonly done, merely from the researcher's point of view. We emphasise the importance of telling the story with our own words, our own language. The text is therefore not a coherent story. We have purposely not tried to make it smooth and univocal. Instead it is multifaceted, including possible inconsistencies and contradictions, in line with what feminist researchers claim that they want to bring out, to cherish: many voices and different experiences.

The project leader: Carin

I work as a coordinator for the integration of gender perspectives in programs and courses at the school of Technology and society at Malmö University. I initiate and run projects with teachers focusing integration in their subject area. The project described here was part of this work.

I chose to work with teachers at the department of computer science partly because of my interest in their previous work with the introductory programming course developed by Lynn Andrea Stein and Deborah Weber-Wulff[3]. To my understanding this is a teaching concept with intention to change the traditional approach, instead aiming at opening up for students with other backgrounds than the traditional. Many of our engineering students attend courses in programming, so changes here would benefit many students. Interesting enough, two of the teachers participating in the project were students during the period when Stein's method was used, and I thought this could give valuable input to the discussion from both "sides": the students and the teachers.

To engage Christina in the project was important to me. She represents a computer scientist with great experience and interest in reflecting on teaching and learning through questions raised from a gender research position. With this experience she could bring valuable knowledge to the project. During the project meetings Christina and I could complement each other, she being able to discuss computer science in the terms of the teachers and I, not familiar with computer science as a subject, could listen to their discussions as an 'outsider' and help bring the focus back to more general questions, when the discussions sometimes tended to focus on practical details.

[3] This concept and course is presented and discussed in the section "the feminist researcher" below.

Integration of gender perspectives can, as I see it, be done in different ways in relation to computer science education. Students can be given tasks and questions that clearly articulate a gender problematic. These could relate to situations that students are likely to meet at their coming work place, such as gendered structures in organisations, the gendering of technology in general, or the views concerning 'experts' and 'users'. But integration of gender perspectives can also include critical analysis of pedagogical situations and the view of the subject computer science. Teachers can consciously analyse gender assumptions and work for change. This can also be described as revealing norms regarding what is considered to be the 'right' ways of learning in the subject. However, this kind of integration might not always be evident to the students.

One aim with this project was that we together should come up with ideas about how to integrate gender perspectives in computer science and make the ideas concrete in the sense that they could be described in the course syllabus and be implemented in teaching practice. The teachers would at the same time develop their knowledge about gender as a concept. A second aim was to initiate discussions about pedagogy in relation to diversity in the student groups regarding e.g. previous knowledge and experience in programming, learning style and gender. In relation to this the alternative teaching concept of Lynn Andrea Stein (see above) would be discussed and reflected upon.

Questions about gender are often perceived as difficult to articulate in relation to technical subjects and fields, as technology is often seen as neutral. So instead of beginning the project by putting gender questions in the centre I wanted to find a platform where we could establish a common ground to articulate different questions concerning gender and computer science. Pedagogical questions are central to a teaching situation and thus something that most teachers are interested in. I thought that taking such issues as a starting point would be a good way for reflexively questioning the subject area computer science, as well as underlying conceptions of men and women and how we see them in a teaching situation. These questions articulate at the same time assumptions about the subject, its core and limits, epistemology and view of learning, as well as assumptions of how relations in the classroom can be gendered.

All the meetings have generated interesting discussions that were valuable to the project. However, I will only discuss the meetings when we talked about gender explicitly.

One of the meetings focused the concept of gender, and questions raised within gender research. We talked about how gender can be understood at the individual, structural and symbolic level, and how these levels interact in the construction of gender (Harding 1986). This discussion gave new insights to the participants on how the concept of gender can be understood and used in computer science. At the individual level, gender is discussed for example in terms of women not having the same previous knowledge and experience in programming as men have. Furthermore, the attitude of women, not being interested in the subject, is seen as the problem, not computer science in itself. On the structural level, issues such as hierarchies within the academy, the design of educational programs, pedagogy, course syllabus, arrangements of project groups etc

can be analysed as the result of gendered processes. At the symbolic level gender can be identified in the manifestation of the male dominated computing culture. Assumptions of what is seen as masculine and feminine as well as what it is to be a computer scientist are gendered in a symbolic way. Talking about gender in these terms brings the discussion from differences between women and men to how gender is constructed.

Another meeting was assigned to discuss ideas and suggestions about how gender perspectives can be integrated into existing courses. I had great expectations that we at this occasion would come up with several concrete ideas. The teachers attending this meeting had, in my view, different attitudes to the idea of integration of gender perspectives. Two of them were basically positive, while the others were more sceptical. At this meeting their view of problems and difficulties with integration dominated the discussion. I suggested that articles from newspapers or magazines could be used as texts from which to start discussions with students. But the discussion in the group continued to focus on problems. It was obvious that these teachers held the view that integration of gender perspectives in technical subjects and mathematics is not possible, because these subjects are neutral. Integration would be like putting gender questions on top of the subject and their suggestion was that integration should instead be done at program level[4] (over three years) rather than at course level. A consequence would be that the program leader and not the individual teacher would be responsible for the integration. So in a way these teachers free themselves from thinking about integration of gender perspectives. The dominating view of science and technology as neutral activities that is expressed here shapes the way we can think about the perspectives and how we can approach the integration work.

However, the meeting resulted in one concrete idea for integration of gender perspectives in a course in basic programming (von Hausswolff 2004). A teacher with knowledge in the area would be invited to lecture on the theme of gender in computer science. This lecture is then followed by a seminar held by the ordinary teacher where the students should discuss a text and questions relating to the lecture. This idea has been tried once and the experience was positive.

Christina and I tried to give the prerequisites for discussions where we could reflect concrete educational situations in epistemological questions and vice versa. To feed the discussion, we chose suitable texts and also asked the teachers to reflect over their own practice. However, the discussions tended to be about quite practical issues on how to do in very concrete situations and only seldom connecting to views of knowledge. As an 'outsider' I never got involved in the discussions about "how to do", but tried to 'push' the discussion in the direction of connecting to general terms. At one meeting the bachelor's thesis "To find entrances in gaining programming knowledge" (Alsbjer 2001) was the focus of our discussion. During the meeting I listened to the discussion between the teachers and tried to make them interested in connecting the examples from

[4] Most of the courses in computer science are taught as parts of three-year educational programs.

their own experience to a discussion in more general terms, in the way Alsbjer does in her thesis. The following quotations are examples of how I express myself:

> "One tries to find out something about some kind of reality, from the outside, that makes it possible to give a number of different descriptions of this reality, and of course it is coloured by one's own approach, but the interesting part is how much you let it be coloured. The question is: how can we make use of this description of reality? How can we apply it in this discussion about what knowledge is? How do you as teachers in a learning process approach the students? How can we apply this terminology, for example to help systemise and understand a teaching situation?"

And from the same discussion:

> "How can we discuss your experiences in her [Alsbjer's] terms of views of knowledge, process, and learning processes? Can we translate this so we can get a general discussion that allows us to regard our teaching and the students' learning in some other way than this highly practical way, like we usually do?"

When I listen to the recording of the meeting I realise that the way I express myself is rather imprecise. This could be one reason why the teachers cannot follow up on my questions. It becomes clear to me that we need to formulate good examples and maybe also illustrate in pictures or sketches on the blackboard, to make it more clear to all of us what we discuss and where we want to go.

The teaching concept of Stein that I was curious about was discussed at one meeting. As I understood it, the method has a potential and can open up for new ways of approaching programming. One of the former students meant that even the word 'programming' is problematic and argued that 'implementation' is a better word to describe what is actually done.

From my point of view, the project has been valuable, and we achieved in part the aims I had set up for myself. The texts we used[5] helped initiate interesting discussions among the teachers concerning programming and computer science. Unfortunately, the teachers did not have time to work with log-books taking notes on the daily work. Having had such concrete situations from their own experience, we might have come further in our work relating practice to views of knowledge. One concrete outcome of the project is the idea about how integration of gender perspectives can be done in programming courses (von Hausswolff 2004). The experiences are valuable and can be used in work with other courses.

The discussion around gender concepts and the understanding of gender as an analytical category should be given more time. If we want to talk about more than women and men in relation to computer science we need to work with the understanding of gender as an analytical category also at the structural and symbolic level and we need to do this on several occasions. Work with finding ideas and material for integration could also have been given more time, as this was an important aim of the project. But on the other hand, we have laid the ground and I will follow up on a regular basis as a discussion partner in the formulation of concrete ideas.

[5] see Appendix A.

The feminist technoscience researcher: Christina

My participation in the project came out of my research on epistemological issues in computer science (CS). I have worked more than 15 years as a lecturer in CS at the university level, before starting my post-graduate studies in feminist technoscience studies at Blekinge Institute of Technology. One of my initial aims with this project was to get empirical material concerning how computer science teachers think and talk about issues of knowledge within their discipline.

However, I was not only interested as a researcher who takes the perspective of 'outsider'. The long-term objective for me is transformation, change (Björkman, Elovaara, Trojer 2005). My interest and goal concerns how to broaden the concepts and approaches to knowledge in CS, with the main issue being: can CS cherish epistemological pluralism (e.g. Turkle and Papert 1990, Wagner 1994), i.e. different ways of knowing and learning?

I was interested in trying to make hidden views visible, for example concerning the large and overall questions "what is computer science", "what does it mean to understand programming" and "what is knowledge in CS and programming". This in turn I regarded as aiming at accommodation and acknowledgment of greater diversity of knowers and learners in CS, such as concerning students' backgrounds, interests, motives and understandings.

Thus, one of the aims of the project for me was also to start a reflective process concerning knowledge among practitioners of CS (including myself!), to reflect over our own understanding and basic assumptions of the subject – what do we mediate to students? My motive for this is a conviction that reflection around issues of knowledge is important for every discipline, especially for teaching and for meeting potentially new groups of students.

The main reason why I was particularly interested in a project at Malmö University was that the teachers there had experiences from different models for teaching beginner programming. Object oriented programming using Java is used for the first programming course. There have basically been two strands in this teaching, on the one hand what could be called a "traditional" approach, building on structured programming; and on the other a more experimental model, focusing interaction. This latter model builds on the ideas of Lynn Andrea Stein about the need for a shift in the underlying metaphor of computing, from the traditional metaphor, "computation as calculation", towards a metaphor of "computation as interaction" (Stein 1999). Such a change, Stein argues, would affect how we view CS and thus also what and how we teach, as well as how we think. She has developed an introductory programming course based on these ideas[6]. A version of this MIT course has been tried at Malmö University[7].

Since I find Stein's ideas and arguments interesting in how they confront issues of knowledge and thinking in CS, I was interested in pursuing and discussing questions

[6] http://www.ai.mit.edu/projects/cs101/.

[7] The course and ideas behind it are described in Weber-Wulff (2000).

such as: What do these different models of teaching programming mean? What are the views of knowledge, CS and programming behind these courses? Can a different metaphor for computation affect change in the learning of CS? During the project my aim was to discuss different aspects of these models, not only pedagogic and practical aspects, but what I saw as more important in the long run: the underlying views of CS, programming and knowledge.

We did discuss these issues in the group, but never quite reached the level of "how we think" and how this relates to fundamental metaphors, that I had probably hoped for. We touched on these issues once when we came to discuss which model (the linear or the interactive) that was the 'right' one. Otherwise, the discussions tended to concern mainly the courses, practical issues and difficulties with labs that did not work etc, fairly 'technical' questions. It came to a large extent to be about which of the two different approaches is the best one for beginner students. These are no doubt interesting and very important issues, but not really what I had hoped for (though I might not have been very concrete, even to myself, about exactly what I wanted).

Our aim had been to try to reflect educational practice in theory from gender/feminist research. During the course of the project, problems with this idea became increasingly evident. The discussions had a tendency to be very lively and engaged as long as they concerned practical matters, concretely associated to teaching practice. However, more general and theoretical discussions, particularly when it came to issues of the 'nature' of knowledge, were, from my perspective, more difficult to obtain.

During the meetings and the course of the project, I noticed all the repeated times when communication did not seem to work, when the attempts Carin and I made to talk about thoughts and experiences from teaching practice on a more abstract level, in a more 'theoretical' language, 'failed' as we expressed it at the time. This was a source of confusion for me, since I could not quite express what the 'problem' was. Towards the end of the project, I became more aware of, and started to frame this, in terms of language, not being able to understand each other, lacking partly a common language for creating a dialogue. But it is not until I listened carefully to the recorded meetings that I started to hear this lack of communication in a shared language clearly. What struck me then is how strange the language and speech of the feminist researcher(s) must sometimes be to the computer science teachers.

Focus for my part came to shift from an interest in how the participants approached knowledge in computer science, to issues of communication and translation, of creating language to communicate across boundaries, which disciplines, or rather world-views, create. As Lucy Suchman expresses it, what hinders us is "…discontinuities across our intellectual and professional traditions and associated practices" (Suchman 2002, p. 97). If we cannot talk about gender, epistemology and feminist theory and research in computer science, then there is no point in asking how the former can change practice in the latter. Is communication and translation possible (Björkman 2005)?

I now realise that my approach at the start of the project was like a 'traditional' researcher's – to listen to participants, creating a picture of how they construct and talk

CS. I thought maybe my role would be more of one who is partly outside, who does not fully take part in the process but who has the function of participating as catalyst. As a consequence of this stand, I did not want to be very explicit when it came to approaches to knowledge in CS. This way, I believed I could get the participants' approaches and their views untouched by my expectations. If I did not clearly formulate myself, maybe they would be able to think and reason more freely. The result however, was that questions and issues discussed were often too vaguely formulated; they should have needed more grounding in concrete examples, relevant to the practices of the teachers.

At the same time as my focus changed, my interpretation of my part in the process changed from seeing myself as the catalyst and observer, to being completely involved in and part of the process, where the positions I had and took came to affect what happened in the discussions. I inhabited a complex, and also complicated, position, where my role in the project might have been perceived as strange, or at least unclear. I was one of the project leaders coming from feminist research. In this, I acted as an agent of change as well as a researcher collecting empirical material. But I was also a fellow computer science teacher. I experienced clear problems with this: how to behave, who am I? On what 'side' am I? I did not make this clear to myself however, until I could look at the project afterwards, with some distance. I now see this project as very rewarding for me. I learnt about communication and translation. I learnt about the need to develop "the ability partially to translate knowledges among very different … communities…" (Haraway, 1991, p. 87). Further, I learnt some self-reflexivity regarding my role as feminist researcher, as Elisbath Gulbrandsen points out (Gulbrandsen 1995): we need to implicate ourselves in the problem as well as in the solution. I also learnt to listen both to myself and to others, with a focus on language, by which I mean how we talk, and how epistemology is always present in our language, how language is a carrier of epistemology, and how this language comes to present barriers for communication[8].

The computer science teacher: Steve

My main motivation for joining the project and its sessions seems to have been my interest in pedagogic issues and among them my strong belief that I, as a teacher, should focus my energy on empowering the students in their learning experience and use different methods to try to let the students learn in their preferred way in accordance to the thoughts of David A. Kolb (Kolb 1976, Kolb 1984).

During the early stages of the project it seemed that my colleagues and I shared a common goal of finding tools or methods to help us meet the tide that was about to turn on us. Our department, Computer Science at Malmö University, had prior to the start of the project, tried to tackle the decreasing number of applications to our courses and programmes by developing new courses where the prerequisites no longer demanded knowledge in natural science or mathematics. Being forced to meet greater diversity among students and differences between ourselves and the 'new' type of students, felt like a challenge for us, the educators. Another issue was that we were trying

[8] I discuss these issues further in Björkman (2005).

to mix engineering students with students from social sciences, and wondered how to handle the clash between different educational cultures. Furthermore, one third of the students attending courses at Malmö University come from the city of Malmö. Malmö in itself is a scene of mixed diversities. It still somewhat struggles with the transfer from an industrial city to a city of knowledge workers. Our students have in some cases been brought up in working class style, if not materially so at least mentally. Being able to handle diversities among students, whether these are due to gender or social background, was and still is very important to my colleagues and me. I think that the project allowed us to improve our pedagogic skills because the discussions during the project inspired to new approaches by allowing us to discuss new topics as well as talking about our experiences with our peers.

One thing I found useful in this kind of project, was that the project leaders early on let us, the computer science teachers, discuss freely around some of the more classic issues in feminist / gender theory, like "What is different between men and women in computer science?", and then move on to try to establish common ground with theory and strengthening our vocabularies for the oncoming sessions.

One of our first sessions focused on the issues raised by Maria Alsbjer in her article (Alsbjer 2002), where she describes the problem of feeling that you do not understand the covered material in the programming course but still receive "pass" on the course. During that session I recalled my memories from the first course I took in computer programming, where I 'produced' a mark something along with pass with distinction but inside I did not feel as confident as my mark showed. Sure enough, I knew all about the mechanics and syntax of the programming language as well as how to solve some computational problems, but had I really all the programming knowledge that was needed for subsequent courses or for that matter all the knowledge that the course syllabus stipulated? This issue seems to be very important for computer programming educators as well as other educators – what knowledge can be perceived by the student as not understood but perceived by the educator as well understood? Is it only with computer programming that this is experienced or are there other fields of knowledge that have the same problems? What mechanism makes the student so uncertain of her/his abilities, or do we only have to ensure and strengthen the students' view of their own knowledge? Should not the mark the student is given be enough in itself? Should every examination involve the creating of a qualifying piece of work, a test like the ones journeymen take? How can we observe with detail the way software is crafted in the short time examination usually takes place? Sometimes the level of knowledge in programming is directly in inverse proportion to what you say you know – the beginner often claims that he or she is very skilled as opposed to the expert who states that he or she knows a little about their field of expertise and almost nothing at all in other areas. Later on, my colleagues and I discussed the possibility of how different types of examination are more or less suitable in order to examine the knowledge they are constructed to do. As a teacher I feel it is important to constantly re-evaluate the types of examination used, in order to ensure that they are suitable for the knowledge that is being examined.

One of the articles in the issue of the journal NIKK (NIKK 2002) that was used in the project, "Information technology in everyday life" (Mörtberg 2002), discussed a difference between men and women that I have myself sometimes experienced during my work as a teacher. The article states that (young?) men often seem to inflate their technical knowledge and women often seem to deflate their technical knowledge. One might argue that this behaviour is consistent with the created gender – men are supposed to know more about technical devices than women, and if you do not fit into that pattern, you are seen as unfeminine or unmasculine. In addition to this, one of my female colleagues who participated in the project alerted us on how technical knowledge is connected to the male gender. For instance, she had on occasion in a way been forced to be "without" gender because of her technical expertise when participating in a discussion about a technical matter. The situation could for instance arise when a "techno-male" incidentally could argue that women do not know anything about that techno-stuff and when she pointed out that she in fact is a woman, she was not considered to be a 'real' female.

I have enjoyed participating in this project because of what I have learned during these months, even though it sometimes has been a bit slow moving. One rewarding 'spin off' from this project was when I tried a small exercise in my class in large software projects where the students were given the chance to reflect on their view of norms, the opinion concerning norms and how far a certain norm really reaches. The exercise is disguised into an exercise where the students are training teamwork. The different teams get a passenger list containing ten persons briefly described like; a clerk, the clerk's pregnant wife, an intelligent female actor, a professional ice hockey player etc. The passenger list is for a spaceship that will launch from Earth in a couple of hours just prior to Earth's doom. The problem, however, is that only seven of the passengers can be onboard because of a technical error. Which persons should the group remove? After a while the students realise that the information is very sparse and they need to know more. For instance, the students often wonder why only the women are labelled as "woman" and not the men labelled as "man". I usually ask them why it took them so long to react on the clumsy formulation on the passenger list and they often respond – the passenger list is formulated according to the norm. Here I usually open up for a discussion about whose norm this really is, before having a short lecture on the topic of "norm".

The lecture goes something like this: as an individual, one has one's own private values and they dictate one's attitudes towards issues and persons. A value is abstract and personal; if we take two people, for instance, they might have two different definitions of what "honest" is. An attitude is a collection of the values we have regarding a certain issue. The attitude guides the prejudices and expectations we might have of a person, for instance. The attitudes affect our behaviour, our 'signals' that can be detected by the surrounding environment. How true we are to our values is sometimes dictated by how much they cost to preserve in relation to others. If our closest friends all state the same opinion as we do ourselves, it does not cost us any goodwill within this small community. However, if we carry an opinion that is not politically correct and we behave according to it, we are very likely to lose face in the community.

Opinions or values that are common within a community are often looked upon as the norm in that particular community. However, since a community often has a limited number of members, this norm might not be the norm for the larger community. For instance, a community that mainly consists of a certain type of individuals tends to forget to ask how others (or the minority) feel about certain issues. If there is a community with the opposite composition, the norm possibly is the opposite of the first group.

The goal of the lecture is that the students shall re-evaluate which opinions that often are considered as being the norm, and perhaps find other ways of stating an opinion or perform an action than always going along with the norm. The seminar on sex and gender as well as the one on how a gender perspective can be integrated into education were very useful in elaborating this "exercise".

After participating in this project I feel that my CS colleagues and I have increased our ability to handle student diversity in the classroom by being aware of diversities, and by sharing knowledge about how to interpret classroom situations with our colleagues. It is not the students who should change – it is computer science that should change and evolve by incorporating different ideas of how the students perceive the subject.

Discussion

Carin:

I am glad that I had the possibility to run this project and it has been rewarding in many ways. It is interesting to see how our three stories overlap but also take different directions depending on our partly different aims. For me as the project leader, Steve´s story is interesting as the outcome/benefit for him and his colleagues is important. The ideas they come up with concerning pedagogy and formulations of gender perspectives in computer science are what will make a difference for the students. His story also shows me that one important outcome of the project is the discussions among peers that the project has generated. These discussions create common ground for continuing the work with or without my support. It was also good to get positive response on the way we had decided to work with gender questions in the project.

Both Christina and I talk about the communication problems that we experienced. Language is important, and the recordings from the meetings have made us aware that we sometimes are too vague in our formulations. But Christina goes further in her analysis saying that different approaches to knowledge and epistemology are the main reasons why we do not succeed in establishing the discussions we intended. However, these problems might also be a question of how much experience from discussions concerning views of knowledge and epistemology one has, and not necessarily about different approaches. Discussion about knowledge in general terms is also a learning process. But it is not a natural part of our daily work as teachers in engineering and natural science.

Steve:

For me as a teacher at the computer science department, I have truly valued the discussions that have arisen during the project. Not that we do not have discussions on a daily basis, but I feel that we have covered a lot more than we usually do, in these short months. The project has allowed me to learn from my colleagues and the participants in a pace that is more intense than usually, perhaps because of the topics chosen during the discussions, or perhaps because we had moderators from the outside. It can be valuable to have external people coming in and guide the discussions so that you do not get stuck in a rut with your usual topics.

I want to give a short list of recommendations for this type of projects:

1) Invite a variety of people to ensure that you get a variety of opinions and experiences in order to keep the discussions going
2) Value the knowledge and experience present within the group in order to ensure that the participants share their view
3) Do not be afraid to add or remove participants during the project; however try to keep some participants to ensure continuity. Some participants may not be interested in the whole project and some may provide valuable resources during a short time
4) Ensure that the project moves at a constant pace, and do not have meetings too seldom
5) If the project is run in addition to other projects, try not to overload the participants with information – it is very easy for the participants to overlook some vital information.

Christina:

I have very much enjoyed the project, it was continuously exciting and gave me many thoughts and lessons concerning communication between gender/feminist research and theory and computer science practice.

It is also my belief that one of the most important values with a project like this is to promote and contribute to discussions among the teachers, discussions that can perhaps take on other topics and issues than those usually talked about. Hopefully, these discussions continue when the project is finished.

I find Steve's list above very good, and completely agree with it. In addition to what Steve points out, I have some recommendations from my point of view:

6) The 'roles' in a project like this need to be made clear, who has responsibility for what and what is expected from the participants regarding preparations, reading etc.
7) The theoretical issues and questions need to be concretised, grounded in very concrete examples
8) It is important to recognise the differences in how we talk about science, learning and knowledge within different scientific traditions. The different epistemologies and approaches to knowledge need to be made explicit, in order for us to be able to talk about them

9) Since understanding each other can be difficult between different traditions, the issue of communication needs to be addressed directly. Do we understand each other or not? What is needed in order for us to really understand each other?

10) The feminist researcher needs to learn to talk about and present feminist theory and epistemology in ways that are comprehensible and interesting to computer scientists, and to learn to speak so they understand what s/he says.

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Appendix A:

Meetings in the project and their themes

1. Introduction. Maria Klawe's article (Klawe 2001) is distributed. Participant's write about "Me and computer science" till next time.
2. Discussion of Maria Alsbjer's article "Godkänd men ej förstått" [Passed but not understood] (Alsbjer 2002).
3. Programming education at Malmö University 1998-2003. Head of department presents, participants contribute with examples from their own teaching.
4. Discussion of Maria Alsbjer's bachelor's thesis (Alsbjer 2001).
5. Sex and gender. Introduction by Carin Dackman. Survey of concepts and discussion in relation to computer science. The articles by Mellström (1999), Gansmo (2002) and Margolis, Fisher, Miller (1999) are distributed.
6. Full day meeting. Paradigms and metaphors for computer science and programming, implications for teaching. Introduction by Christina Björkman. Discussion of the articles by Lynn Andrea Stein (1999), Deborah Weber-Wulff (2000) and Sherry Turkle and Seymour Papert (1990). Experiences of different models for teaching programming at Malmö University. Two former students participate.
7. Discussion of the issues concerning how gender perspectives can be integrated into teaching and how computer science can be problematised out of gender perspective. The articles in NIKK 2/2002 used in this discussion.
8. How to meet diversity among students. Concrete tips and discussion, for example from the book by Fredrik Bondestam (2003).
9. Computer Science and approaches to knowledge. To this meeting the participants were asked to reflect from a starting point in questions and issues concerning computer science presented by Christina Björkman at a lecture at Malmö University in October 2004.

Literature used in the project:

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Paper C2

Trying Translations – Encounters Between Computer Science Educational Practice and Feminist Technoscience Research

Introduction – Motives, Questions and Context

> "Feminist research has developed figurations and metaphors in order to keep heterogeneities, multiple understandings, and diversities alive in knowledge production. We love our words and metaphors, but where, how and with whom do they work? Can they be used outside our own academic circles? How do they translate into situated, concrete everyday practices?" (Björkman, Elovaara, Giger and Mörtberg 2004).

What happens when the "words and metaphors" common within feminist research meet other words and metaphors? What happens when the 'world' of feminist research meets other 'worlds' of knowledge production and practices? When feminist research "confronts its own language games with those of other communities of practice." (Wagner 1994, p. 262)?

As a feminist technoscience[1] researcher and a computer science lecturer, I am particularly interested in the question: What happens when feminist research meets the educational practices of computer science (CS)? For me, this issue is pivotal, since it is in my interest and my goal to use feminist technoscience research to broaden concepts of and approaches to knowledge in CS. My aim is to work for accommodating greater diversity in computer science: among its practices as well as among its practitioners.

I believe that feminist epistemological thinking, with its emphasis on plurality of voices and perspectives, as well as its insistence on epistemological pluralism, i.e. different ways of knowing and learning (e.g. Wagner 1994) has the potential to enrich and change CS education.

Several researchers in the intersection between feminist research and science / engineering suggest that education constitutes an area where feminist thinking can exert an influence and make a difference (e.g. Bug 2003, Estrin 1996). If we, as feminist researchers, want to participate in transforming a discipline, we need to co-operate with

[1] For a discussion of feminist technoscience as practised in the research group Technoscience Studies at Blekinge Institute of Technology, see Björkman, Elovaara and Trojer (2005).

the disciplinary practitioners. We all share a common interest in and commitment to students and education, to working towards 'improvements' and 'development' (without discussing at this point what this might mean) in CS education, and to creating education that is better suited to meet the needs of students and of the changing world we live in.

In order to co-operate and bring about change, we need to be able to communicate across the potential boundaries between our disciplines. Both feminist research and CS are fields of competence and knowledge, but they also bring with them ways of thinking and talking about the world. Is it then possible to communicate, to enter into respectful conversations? And if so, *how* can this be accomplished? How to create fruitful encounters between these different actors and 'worlds'? As Donna Haraway puts it: "How can people rooted in different knowledge practices 'get together', especially when all-too-easy cultural relativism is not an option, either politically, epistemologically, or morally?" (Haraway 2003, p.7).

I brought these questions concerning communication to a project with computer science university faculty in which I participated 2003-2004. For my research, this was a concrete 'intervention', where my aim was to investigate how feminist research can contribute to computer science education. The project was called "knowledge and learning in computer science from gender research perspectives"[2]. It was fairly complex, having three explicit perspectives:

– Integration of gender issues and perspectives into CS education
– Epistemological issues and discussions concerning knowledge in CS, with contributions from feminist research
– Pedagogical development.

The cornerstone of the project was our common concern for and interest in students and our desire to contribute to good education in CS. One goal was to bring the practices of computer science education together with feminist theory and research, on the assumption that the latter can be a fruitful resource within CS and contribute to the processes of improving education and accommodating diversity among students. The project yielded many questions, thoughts and insights regarding communication between feminist research and computer science.

This story is about epistemological encounters, about communication and attempts at translation between different scientific communities: communities that do not share the same epistemology, or 'world-view'. My focus in this article is not the project per se, which is presented and discussed in Björkman, Dackman and Dahlskog (2005), but the different epistemologies and how these are intertwined with language, what happened in these epistemological encounters, and how this raised issues concerning translations.

[2] While still ongoing, the project was presented at the symposium Gender and ICT: Strategies of inclusion, Brussels, 20 January, 2004 (Björkman and Dackman 2004). The project is also described and discussed in Björkman, Dackman and Dahlskog (2005).

Before discussing communication between these 'worlds', I present some methodological considerations and comments, and introduce the concept of *'voices'* that I use. After these introductory comments, I describe my interpretation of the different voices that represent the 'worlds' of computer-science educational practice and feminist research respectively. I do this with an emphasis on how epistemology is present in language and complicates communication. This raises the issue of translation, and how translation work can be accomplished. After a summary of what lessons can be learnt from this project that I believe are important for future transformative work within science/engineering, I conclude the article with a discussion of epistemological cracks and how they manifest themselves in conversations.

Methodological Considerations

Positions

> "Feminist embodiment resists fixation and is insatiably curious about the webs of differential positioning." (Haraway 1991, p. 195).

In the various stages of working on this material (analysis, interpretation and writing), I consciously move between several different positions[3]. I call these positions the *computer science educational practitioner,* the *feminist technoscience researcher* and a third position, the *feminist computer scientist*, in which the first two positions are in the process of integration. Moving around between these positions does not imply taking discrete steps; rather it is a continuum, where the location is not fixed. I am simultaneously both inside and outside positions, I simultaneously accept *and* reject the positions as feminist researcher or computer science practitioner. This means that I can adopt these positions, move between them, use understanding, humour, engagement and forbearance as well as a critical gaze towards both. I can also work on the integration of both into the feminist computer scientist. Adopting this latter position means that I bring the epistemology and (critical) reflexive practice learnt as a feminist researcher to the computer scientist position. This makes it possible for me to understand and reflect on what the computer scientist says, but also to be able to write about it from the perspective of feminist technoscience research, *without* assuming the perspective of an outsider. I am both computer scientist and feminist technoscience researcher. This both doubly and partly inside perspective means that what the computer scientist says makes perfect sense to the feminist researcher.

I do not want to write 'the other' into the text, even though that might be hard to avoid. We are all insiders and outsiders, simultaneously, in different ways. For me, the computer scientist is not the other, nor is the feminist researcher. Both are me and I am both. I partly integrate both; both should be within the text. Both are the other – and at the same time the norm, thus dissolving dichotomies. By consciously and simultaneously both using and rejecting dichotomies, these can be elucidated. At the same time, through sheer juxtaposition, the dualism can be made inessential. What is essential is what we have in common – a passion for doing a good job, a dream of the good life – in this case 'improvements' in CS educational practice.

There are no innocent positions (Trojer 2002, p. 56). Thus, as a feminist technoscience researcher I must take a critical look at myself. "What happens when we turn the critical questions…to ourselves as researchers and feminists?" (Gulbrandsen 1993 p. 25). We need to see ourselves both as part of the problem and as part of the solution

[3] I take the concept of position mainly from Donna Haraway (Haraway 1991). "*Positioned* implies the use of power or strategy and a subject (and sometimes also an object). A position can either be forced upon me by others, in which case my subjectivity is limited, or I can choose it, take it strategically and use it as a conscious subject. Thus, I can either be *positioned* or I can *position* myself." (Björkman 2003, p. 158).

– at the same time. Elisabeth Gulbrandsen stresses the need for *reflexivity*[4] as a crucial aspect in transformatory projects (Gulbrandsen 1995). Thus, self-reflexivity is part of my moving between positions.

In the project, during meetings with computer science teachers, I rather concretely, though certainly not always consciously, also moved between positions. My role and function might have seemed strange, or at least unclear, to the participants. I was a feminist researcher, but at the same time a fellow computer science teacher. This raised questions in me from time to time during meetings: Who am I? How should I behave and talk, in what position am I? This moving between positions during the project itself, and the language changes entailed, are central to my interpretation of what was going on during the meetings, in terms of communication.

Perspectives – epistemology

> "Epistemology is a lens to see the world through." (Thomas Hylland Eriksen, key note, Third Space Seminar, Lund, 30 Nov 2002).

The different positions also indicate different epistemological standpoints. Later in the article, I will elaborate on how these epistemologies can be 'heard' in the spoken language from the meetings.

The inherent epistemology in computer science is in all relevant matters the same as the 'traditional' epistemology within natural science (and engineering)[5]. However, I want to emphasise that this is for the most part not an *explicit* epistemology in CS; rather it is implicitly present in how science is talked and practised[6]. Here I will briefly sketch the most important traits of this epistemology.

Firstly: *objectivity* and the *neutrality* of the observer. The knower is taken to be a "rational individual, in a 'normal' situation, perceiving the world through his (sic) senses and with no dependence on others for knowledge of the world." (Adam 1998 p. 69). But this knower, the subject of knowledge, remains unanalysed, invisible, taken for granted as "one of us". This is a universal, objective and neutral observer, engaged

[4] Elisabeth Gulbrandsen follows Sandra Harding (e.g. Harding 1991) in her use of reflexivity. This is a critical or strong reflexivity, which Donna Haraway recognises as being close to her figuration of *diffraction* (Haraway 1996, p. 439).

[5] Within social science, this epistemology is often (somewhat simplistically) called *positivism* (Auguste Comte, 19th century). "Characteristic of a positivist tradition is the emphasis on "scientific attitude" and "scientific method" within the frame of an empirical theory of knowledge … knowledge based on observations and testable law hypotheses." (Molander 1988, p. 178). Natural science, and in particular physics, are held up as model sciences. The "scientific method" should prevail in all areas of life, and the social sciences in particular should learn from it, implying that there is no fundamental difference between social and natural science.

[6] By using the term *implicit*, I want to point out that the individual scientist whose language conforms to this traditional epistemology, does not necessarily subscribe *explicitly* to the foundations and values of this epistemology. An alternative could have been to say that the epistemology is largely unconscious. I discuss this further in the final section of this article.

in "the God-trick of seeing everything from nowhere" (Haraway 1991 p. 189). The individual 'discovers' and is the carrier of knowledge. This means that the influence of society, history and culture are largely ignored.

Furthermore, knowledge is defined in the form of "S knows that P", i.e. it emphasises what is usually called propositional knowledge and says very little if anything about skills knowledge, i.e. "knowing how".

Terry Winograd and Fernando Flores (1987) argue that computer science, and all thinking around computers, is shaped by what they call a 'rationalistic[7]' tradition, pointing out how this tradition is completely and totally self-evident within natural science and technology:

> "The rationalistic orientation not only underlies both pure and applied science but is also regarded, perhaps because of the prestige and success that modern science enjoys, as the very paradigm of what it means to think and be intelligent." (Winograd and Flores 1987, p. 16).

In this tradition, symbolic logic and formalisms are emphasised.

Realism is also an important part of this epistemology. The world, reality, exists independently of human perception and theories (Molander 1988, p. 183), and science can give us knowledge about this real world, the world beyond its semblance (Chalmers p. 203). Science mirrors nature.

The epistemology within much of feminist research differs fundamentally from the epistemology described above. I here briefly outline the epistemological foundations for feminist technoscience research[8]. I characterise this epistemology as emphasising *situated knowledge* and *partial perspectives* (Haraway 1991)[9]. This epistemological positioning is critical of paradigms of objectivity, and of the neutral and objective observer, as is expressed by Sandra Harding:

> "Observations are theory-laden, theories are paradigm-laden, and paradigms are culture-laden: hence there are and can be no such things as value-neutral, objective facts." (Harding 1986, p.102).

Furthermore, feminist epistemology wants to call attention to other kinds of knowledge than the propositional, such as those derived from practical experiences of the world. This includes the body as an inseparable part of knowledge, and not only the mind. Thus, feminist epistemologies acknowledge (embodied) experience as a valid basis for knowledge. This means recognition of epistemological pluralism, i.e. different ways of knowing and learning (Wagner 1994).

[7] Winograd and Flores note that "the rationalistic tradition might better be termed the 'analytic' tradition." (Winograd and Flores 1987, p. 16). They use the term rationalistic in order to avoid a debate with analytical philosophy. "We are not concerned with the debate between 'rationalists' and 'empiricists'. The rationalistic tradition spans work in both of these areas." (Ibid p. 16).

[8] Which also means that these are the epistemological foundations for my research.

[9] See also Björkman (2005a).

Feminist epistemologies refuse the choice and dichotomy between, on the one hand, universalism and, on the other, relativism. The alternative to both is partial, located and situated knowledge.

Most feminist researchers prescribe to the basic ideas of (social) constructivism, in the sense that it acknowledges that all knowledge, including scientific, is socially and culturally constructed, existing in particular historical, social and cultural contexts.

It is also important to note that much feminist research aims to build on *explicit* epistemological positionings, feminist researchers *talk about* epistemology on a meta-level. This is in contrast to the *implicit* epistemology within computer science, which means that the practitioner mostly *is in* epistemology without reflecting on it[10].

On material and method

The empirical material for my analysis and discussion mainly consists of recordings from the meetings in the project presented earlier. We were two feminist scholars in the project: the project leader (a lecturer and researcher in gender studies) and myself, a feminist technoscience researcher. The computer science faculty participating (a total of 10 people, most of them lecturers) had different backgrounds and experiences, thus creating a dynamic group. All of them had academic qualifications in mathematics, computer science or engineering, but apart from that, some of them had also studied subjects such as psychology, philosophy and art. A few of the teachers had professional experience from teaching at upper secondary school (*"gymnasium"*), or from the military. These varying backgrounds are visible in the conversations, something that I will also point to and discuss. The number of participants at meetings varied: some people participating in practically every meeting, others participating only a few times.

My analysis and interpretation of the material hasve been inspired by the discussion about reflection in Alfvesson and Sköldberg (1994, in particular chapter 8).

> "When reflecting, one seeks to think around the premises for one's own thinking, observing and language use." (Ibid p. 321).
>
> "Reflection arises when one form of thinking is confronted with another." (Ibid p. 324).

Alfvesson and Sköldberg propose the concept of *reflexive interpretation*. I have taken this as a starting point for what I call *reflexive listening* to the recordings of the project meetings. This has been a dialogue between me and the material, where I move between positions, as described above, and let the thinking and listening from the different positions confront each other. This allows me opportunities to see different images and stories, as well as ways of understanding how to create translations. In doing this, I have tried to listen to the spaces in between in the conversations, and for what I call

[10] However, the striving for explicit epistemological positioning does not mean to indicate that feminist researchers are never un-reflected concerning their epistemology. The 'traditional' or 'positivist' epistemology can certainly be implicitly and unconsciously present in the talk and work of feminist researchers too, as I will give examples of.

communication breakdowns, when something happens in the conversation, and it does not flow.

When reading the transcripts, I have deliberately looked for words, concepts and statements where I believe epistemology is visible. I have also looked for occasions when the communication breaks down as well as occasions when it seems to 'work', when translation appears. In so doing, I have been able to see my own language and how this varies between what I call 'feminist-ish' and 'engineer-ish[11].'

I have been *in* the material, engaged with it. Identification has been a crucial part of this analysis. This is not necessarily a weakness from an analytical perspective (e.g. Fox Keller 1983). In feminist research, it is important to strive to identify with the 'object' of the research, to locate oneself in the same plane as the 'object' (Harding 1987), even though in practice it is impossible. But at least it brings a blurring of the distinction between the subject and the object.

Identification is not without problems, as Ina Wagner points out, it "may blur contradictions, ambiguities and conflict …when it may be more fruitful to acknowledge and analyse them … the ability for identification has to be combined with the ability to take distance."(Wagner 1994 p. 261). I move between positions, thus I identify with the computer scientist and with the researcher alike. The 'object' is in this article *not* the computer scientists; it is how computer science is spoken, and the communication, which includes all of us. Moving in this way makes the conflicts more readily recognisable. Conflicts, or as I have chosen to call them, communication breakdowns, become visible because of this moving identification. As pointed out above, striving for self-reflexivity is vital in this process. This involves being able to distance myself from, as well as identifying with, different positions.

Voices

As I interpreted the material retrospectively, communication during these project meetings was a complex web of entanglements, where many more issues and factors than I can account for, appeared. For example, I will not discuss the issue of "power differentiated communities" (Haraway 1991, p. 187), even though this is certainly important, though complex and not easily mapped in these meetings. Power and who had the preferential right of interpretation varied dynamically. My interpretation focuses on issues related to epistemology, language and how we talk about knowledge. Language and approaches to knowledge unite in speech.

I have chosen to use the concept of voices (think for example of the different voices or parts in a choir) for my interpretation. These voices are what I have followed and interpreted in the recordings from the project meetings. They speak in different ways; in them, different approaches to knowledge are discernible. They are carriers of epistemol-

[11] I have chosen to call it 'engineer-ish' rather than 'computer science-ish', since I am an engineer by education, and I believe that it is mainly that training that has influenced my language. However, there are no major differences between these two languages.

ogy; epistemology manifests itself in and affects language and how the voices speak. Or rather: epistemology and language are intertwined; epistemology *is* in language.

In the conversations, I hear and interpret two rather distinct voices; I call these the voice of the computer science practitioner (CSP) and the voice of the feminist researcher (FR) respectively. Most of the computer scientists in the group adopt the CSP voice most of the time. The FR voice is mainly upheld by the project leader. Then there is my own voice (i.e. when I speak during the meetings), which does not seem to know where it belongs; it meanders around between the two main strains, and can be heard harmonising sometimes with one, sometimes with the other, as well as making its own diversions.

Sometimes I hear how these voices meet harmoniously and even 'sing' in unison for a little while: this tended to occur when *dialogues* were created, when we talked to each other with respectful interest. According to Bengt Molander (Molander 1996), the essential element of a dialogue is that I try to understand myself, including my knowledge, together with other people, and then I also understand others. In a dialogue we try to reach a "justified mutual understanding of concepts, norms, reasons, theories, ways to act, etc." (Ibid p. 93). A dialogue is a movement in understanding and identity. These are the times when something fruitful happens, when new thoughts, ideas and expressions can be born, in mutual understanding.

Most of the time, however, these voices tended, as I heard them, to run in parallel, as if each were performing their own piece without listening to the other. They did not meet, sometimes they crossed each other and created disharmony, dangerous but exciting. At other times they simply diverged in different directions, and it is this that I call communication breakdowns.

I use the metaphor of voices in order to render visible how and in what ways the epistemologies, and thus the spoken language, differ. For the CSP voice, it is a working, shared professional language, developed for their own contexts, for communication within the community. Most of the time, it can be heard as largely one single voice, signifying the community through language. Nevertheless, there are certainly also individual voices that sometimes break out of the main melody, indicating differences and tensions within the group.

Epistemology and language

Epistemology and language are intertwined: with a certain epistemology comes also certain words, expressions, ways of thinking and talking. Evelyn Fox Keller has expressed this connection, how language is intimately connected with 'world-view' and the doing of science:

> "Sharing a language means sharing a conceptual universe. It means more than knowing the "right" names by which to call things; it means knowing the "right" syntax in which to pose claims and questions, and even more critically it means sharing a more or less agreed-upon understanding of what questions are legitimate to ask, and what can be expected as meaningful answers … To know what kinds of explanations will "make sense" … is already to be a member of a particular language community." (Fox Keller 1992, p. 27f.).

Fox Keller's words above do of course hold for all scientific communities, including feminist research ones. By pointing to the relations and intersections between epistemology and language, things can be rendered visible that might not be apparent otherwise (Adam 1998, p. 105).

In Sweden, it is very rare that engineering and (natural) science curricula contain courses in theory of science and the like. The epistemic tradition is thus carried on implicitly; science and how it is practised is taken as natural, as self-evident (Trojer 1995). Language becomes the carrier of epistemology, and epistemology implicitly permeates language. Epistemology is thus mostly only *implicitly* present in the CSP voice, as will be shown in my examples. It is present not only in the words and notions used, but also in attitudes and how things are said. This means that the practitioner lives 'inside' his/her epistemology, and perhaps seldom reflects on it. One thing I want to note here: there can be interesting contradictions in the spoken language, pointing to cracks and movements in the (epistemological) foundations.

By contrast, epistemology is the very cornerstone of much feminist research; for example in feminist technoscience. This kind of research aims at building on explicit epistemological positionings. The epistemology is present in the voice of the FR, it directs what is said as well as how it is said, but for a person who is not familiar with the epistemological foundations of feminist research, the reasons why feminist researchers speak in certain ways might be hidden and difficult to make sense of.

The world we live in and the language we speak are closely connected. Maria Lugones describes what it means to be at ease in a "world", and that language plays an important role in this:

> "The first way of being at ease in a particular "world" is by being a fluent speaker in that "world". I know all the norms that there are to be followed, I know all the words that there are to be spoken. I know all the moves. I am confident." (Lugones 1990, p. 397).

This indicates how language will always make communication and understanding between communities complex and not an easy task, as we are sometimes led to expect, since we all speak the same language – in this case, Swedish. The issue is thus about communication and translation between voices, which I will return to later.

In the following sections I write about how I hear and interpret these different voices, with a focus on how epistemology is intertwined with and thus makes itself heard in language. I do this by focusing on certain concepts and themes that appear frequently, and play an important role for approaches to knowledge. In my interpretation, I have moved between positions, as discussed above. Thus, I cannot say that I have interpreted each of the voices entirely from one particular position.

The Voice of the Computer Science Practitioner

What 'is' Computer Science and how is it talked?

> "The term computer science goes all the way back to von Neumann (1940s). The early views of the computing field were strongly flavored by science, both theory and experiment. The first degree programs were called computer science." (Peter J. Denning, 17 Jan 2005, on the ACM SIGCSE[12] Mailing List).

Computer science (CS) is commonly seen as stemming from three other disciplines: mathematics, natural science and engineering (Denning et al. 1989; ACM Computing Curricula 2001)[13]. In the Swedish context, the stronger of these traditions are probably the mathematical and the engineering parts, but there is a certain tension within the CS community concerning which one of these is the most important. The computer scientists participating in this project all define CS in different ways, some defining it as pure mathematics, others as consisting more of engineering. But there are also stronger tensions present, since a few of the participants see CS as broader, including elements from social science, the humanities and even art. These tensions are revealed in the conversations. There does, however, seem to be some kind of consensus. It is not explicitly formulated, but it is noticeable in the concepts and terminology used. This consensus is present in what I have called the voice of the computer science practitioner (CSP).

The statements made and how the discipline is talked about show wide variation. It is neither possible, nor desirable to give a completely consistent picture (Alfvesson and Sköldberg 1994, p. 281). Doing so would not only mean an unwarranted simplification of a complex reality; it would also conceal the interesting and fruitful tensions and conflicts that exist, which I believe are potentials within the discipline towards re-considerations and transformations. Strong discourses[14] exist concerning science, engineering, and computer science in particular in this context. But these are not unequivocal; there are spaces for cracks and alternative discourses.

How can epistemology be 'heard' when it is only implicitly present in the voice? Listening mainly from the position of a feminist technoscience researcher (with close connections to the feminist computer scientist), I have tried to deduce epistemological views from words, statements, assertions and ways of speaking. On the whole, there seems to be an implicit consensual view of what knowledge is, but it is seldom articulated.

The language that the CSP voice speaks is close to what can be called an engineering language, being quite clear and direct. The engineering approach also shows up as "well-known truths", building on well-tried experience within the CS community, that

[12] Special Interest Group for Computer Science Education.

[13] See Björkman and Trojer 2005 for a discussion concerning the 'nature' of computer science.

[14] "Discourse … determines what is 'allowed' to be said or done and what is not allowed to be said or done." (Johansson, Nissen and Sturesson 1998, p. 39). "A discourse is a fixed way to talk about and understand the world (or a segment of the world)." (Winther Jörgensen and Phillips 2000, p. 7).

repeatedly appear in conversations. However, these are rarely questioned or theorised. An example of such a 'truth' concerns programming[15]:

> To try out things and test them, that is the only way they learn to program.

Other examples of engineering approaches can be recognised in the need for seeing *how* things work, on a concrete level of realisation:

> … want to see how it works, understand how it works. You don't just want to take something, you want to program from scratch …
>
> … to understand programming … I give this instruction, and then that happens; I feel that I have a certain control over a small part …

… and a certain emphasis that it is important that things should work:

> …in X's classes, you could get away with almost nothing working … some people got high marks even though they hardly ever got things to work …

This does not necessarily mean that *only* something that works (a program in this case) is considered important, but engineering has a strong tradition of emphasising "making things work", which can all too easily result in other types of knowledge (such as understanding *why* something does not work), being undervalued. If basically only this "making things work" type of knowledge is recognised, results will tend to be judged against this benchmark.

Problems and problem solving

'Problem' and 'problem solving' are concepts that constantly pop up in the conversations. This also implies an engineering view. The world consists of (or presents) problems to be solved, usually in the sense of tasks to be accomplished. For anyone acquainted with those cultures in science where the notion of problem solving is common, the term is self-evident and need never be explained or discussed. It has been naturalised.

The word 'problem' is also used in the everyday common-sense meaning of "I have encountered a problem", e.g. my program does not pass the compiler.

Many CS teachers regard programming as a problem-solving activity. Consequently, they consider problem solving central for learning to program, which is commonly emphasised in courses (e.g. Alsbjer 2001). These are some examples of how the participating computer scientists talked about programming:

> Programming is the transfer of a thought, an idea, a problem solution to making a computer perform just what one wants it to.
>
> Programming … when one thinks more logically, structuring things and problem solving.

When I asked the participants what they meant by problem solving, they found it difficult to explain. For them it was self-evident. It just 'is'. The question seemed strange and difficult. As an answer, they commonly quoted examples of problem solving:

[15] In this section, unless otherwise stated, the quotes are from the CSP voice speaking during the project.

> The simplest answer is that we train people to write and produce software for a wide range of different contexts. For example, it could be some kind of real-time software in a control system for an industrial process. The problem is: how to control the process and automate it. This is the problem, and it is our task to find a solution. It is the same for all computer programs – they are made as a solution to a problem people have detected. This is why we can move to the abstract level, forget about the program itself and talk about problem solving, as it is the main thing. The realisation is often secondary, in a certain sense.

Computer science can in itself be defined as being primarily about problem solving, rather than about computers, a view one of the participants expressed in response to a direct question from me:

> I[16]: What is computer science?
>
> The study of how to automate problem solving, to make an artefact solve a problem. It is normally done with computers, but there are many other ways …

This seems to be a not-uncommon view within the community of computer scientists:

> "I define computer science as the science of solving problems. Mathematics and programming are tools." (Leslie D. Fife, 15 Jan 2005 on the ACM SIGCSE Mailing List).

Problem solving is regarded as goal-oriented, rational and linear:

> You start with a position A … and then a little bit … and then we have position B with the solution. OK, how do we get from A to B?

Winograd and Flores (1987) consider problem solving, together with systematic representations, as constituting the core of what they call the 'rationalistic tradition'.

From my feminist technoscience perspective this raises the question: Where does the problem come from (who's problem is it) and who sets the goal to be attained?

As for the linear thinking in problem solving, such a linear view permeates not only the doing of science, but also science and technology politics. The linear approach is, however, being challenged both from within the community of (natural) scientists and by researchers studying knowledge production and its relation to society (e.g. Gulbrandsen 2004).

At one point, one of the participants talked about how to teach problem solving:

> … [teach] problem solving in a way that reflects how we know that *people*, i.e. we ourselves, actually attack problems.

Taken at face value, this is clearly an epistemological statement. The feminist technoscience researcher has several questions to this statement: can it really be assumed that there is only *one* universal way of solving problems? And are *all* types of problems solved in basically the same way? And who are the "we" this person is talking about? Alison Adam, referring to Kathryn Pyne Addelson (1994)[17] talks about "we-saying". This means assuming that "we" will all agree, that the knowing subject is obviously and

[16] 'I' before a quote means that I speak here.

[17] Addelson, Kathryn Pyne (1994) *Moral Passages: Toward a Collectivist Moral Theory*. New York and London: Routledge.

non-questionably universal. In this case it means that 'we' all solve problems in the same way. Addelson "suggests that 'we' is not given, but rather is enacted. The 'we' might be made through the bonds that grow between people living or working together." (Adam 1998 p. 77). In this case, the 'we' is the computer science community (or at least parts of it).

Had I explicitly asked the person making this statement whether s/he really believed that problem solving is universally similar, I am not sure that s/he would, on closer consideration, have sustained that opinion. S/he might well have acknowledged the possibilities of, for example, culturally varying ways to "attack problems", as well as different problems being solved in different ways. However, so strong is the taken-for-granted and non-visible traditional epistemology in science and engineering that this is the common way that a person within this community speaks.

Tool: drawing boundaries between 'science' and 'use'

The engineering concept of 'tool' appears repeatedly. Many things are spoken of as tools, such as programming itself, as well as tools for programming (compilers, development environments, etc.):

> I: What will students do with their programming skills?
>
> They are a tool …
>
> … tools for a problem solver is what this course is intended to give.
>
> It takes time before you can start choosing between different types of spanners, screwdrivers, etc. It is not given that you know how to use one specific type of screwdriver.

The computer itself is also sometimes regarded as a tool, and often in a somewhat derogatory way, it is 'merely' a tool. In the following quote, the concepts of use and 'scientific method' also appear, in connection with the tool metaphor:

> … science is something that adheres to the scientific method, observation and experimentation. In art and similar fields, they do not do computer science, they do art and use the computer as a tool. It is still a computer, a thing, a gadget, but it has nothing to do with the actual science.

There are several interesting points to note in this statement. First: the claim that science is science because it follows a specific method, namely the traditional method inherited from natural science. Second: in order to draw a boundary between science and art (where art here is what artists do), the concepts of 'use' and 'tool' are employed. Svante Beckman (Beckman 2002) discusses the idea of perceiving the computer as a tool. According to him, it was theorists within the humanities and social science who during the 1970's insisted that computers are tools.

> "The public awe and fascination with computers made room for a critical trivialization of them as just another tool, just another instrument in the hands of its reigning human masters." (Beckman 2002, p. 67).

This means, as Beckman points out, that the computer is reduced to serving its master (who is 'the human' without further specification), but also that it is evaluated in the way appropriate for tools: what is evaluated is the "instrumental goodness or efficiency" (ibid

p. 67) of the computer. But the computer is definitely not only and always conceived of as a tool; what it is depends on what function we want it to serve at a particular instance[18]. The view of the computer as a tool given here may be applied if, for example, someone (say, from the CS camp) wants to diminish the importance of the use of computers. But this view can also be employed by the other side, for example, if a 'user' wants to avoid having to engage in the construction and development of this tool.

The conversation concerning the topics of tool, use and science continued later. In this conversation, there are two distinct persons talking, both computer science practitioners, rather than the 'official' CSP voice. I denote this by distinguishing them as individuals by giving them numbers:

> I: Why do you regard the computer as a tool?
>
> CSP1: It can be used for all kinds of purposes: writing, searching for information, browsing the Internet, creating pictures – basically, whatever you want: it is a multi-purpose tool. But computer science is not about this tool …
>
> CSP2:… but what about, say, how to introduce a computer system in a workplace – is that computer science?
>
> CSP1: It is an application of computer science. Talking about a device that helps people to do something is not science…
>
> CSP2: …but the study of how people perceive a device – isn't that science?
>
> CSP1: No.
>
> CSP2: …so you are saying that social science, which investigates how people perceive things, is not a science?
>
> CSP1: I don't regard most of the social sciences as science…

These two computer science teachers obviously hold divergent views regarding science. The view held by CSP1 is not uncommon; I have met it fairly often, although certainly not all computer scientists hold this view. However, whether use of computers belongs 'within' CS or not, is a rather controversial issue in the community. Claiming that use is not part of the discipline is a fairly common view in more traditionally oriented CS communities. The dilemma is a tricky one, having several perspectives.

One aspect is that maintaining the view of computers and computer programs as tools, is a way of keeping 'science' and 'use' apart. Issues of power, preferential right of interpretation and politics are entwined in these boundary drawings. Keeping the discipline 'pure' and away from the messiness of social practice is a way of retaining one's academic power.

But there is also an element of practicality in this, of being able to work on your scientific enterprise without getting drowned in the boundless sea of use of technology. Categorising, drawing boundaries, might be necessary in order to handle complex realities, but the crucial questions and issues involved are seldom brought to the fore: who gets to draw the boundaries and where? Are they drawn tightly around a 'hard'

[18] Beckman suggests that computers can also be *toys*, *totems* and *texts*. To this I would like to add the importance of the computer as an *agent*.

core or do they permit inclusions? How firm are the boundaries, are they flexible and elastic so as to permit changes? Can they be crossed or do they create complete inclusions and exclusions?

Programming – contesting traditional academic knowledge?

As already mentioned, within 'traditional' epistemology, knowledge is equated with propositional knowledge, "knowing that" (or theoretical knowledge). This has come to be seen as the only important form of knowledge within western science:

> "The formal, propositional way of knowing, has been recognized traditionally as a standard, canonical style. Indeed, philosophical epistemology has generally taken it as synonymous with knowledge." (Turkle and Papert 1990, p. 114).

Other types of knowing, such as practical or skills knowledge ("knowing how") is seen as inferior to propositional knowledge.

The relationship between programming and the overarching field of CS is not entirely straight forward, but programming must be seen as an essential part of computer science, even if one holds a mathematical view of the discipline. This is clear at least from an education point of view, where programming is commonly one of the first things that CS students learn. Another reason is that in the end, basically every 'problem' solved within CS aims at a working implementation, i.e. a computer program (or system of programs). Given this central role of programming, what does it mean to learn to program and to know programming?

Programming and learning to program seem to break at least partly with the tradition that claims propositional knowledge as the only important type of knowledge:

> Programming is a craft: it requires skill and can only be learnt by training.
>
> Programming is like riding a bicycle, you can't tell somebody how to do it, you have to learn this balancing act on your own somehow. Programming is the same.

These statements clearly indicate that programming is considered a skill; it is "knowing how", not "knowing that". This is in line with engineering, and furthers the inherent conflicts in CS between a mathematical and an engineering view. Judy Wajcman (Wajcman 1991 p. 14) points out that this "know how" within technology is often tacit, being impossible to capture in words, and even less in mathematical language, but it can nevertheless be taught in education.

Programming has the character of a craft, practical knowledge, which is often stressed by those who practice it, as well as by researchers (Alsbjer 2001, p. 58). This is expressed by one of the participants in the project:

> Programming is a craft … to be good at a craft, you have to spend a lot of time in the forge hitting the iron until you have the desired result, otherwise it does not turn out well … you have to practise, practise, practise.

Note that programming is compared to a very traditional craft here.

But programming knowledge, even when compared to a skill and a craft, still builds on propositional knowledge. As well as being a skill, programming has foundations within mathematics, so there might be a difference between the *concept* of programming

as such (building on algorithmics, mathematics, etc.) and the *art* of programming as it is practised. However, it is not easy to keep the two separate, and they are often confused, for example in education, where the theoretical foundations on the one hand might be emphasised in teaching, while students at the same time become pre-occupied with the hands-on training of the craft.

Knowledge of programming, understanding and being knowledgeable in programming are also expressed in ways that are not fully consistent with a traditional view. This was formulated by one of the participants in a dialogue with the project leader:

> CSP: We discussed what knowing how to program meant. Then I said that you know how to program if you can reach a goal you have set for yourself, i.e. make a program that works the way you want it to. If I have a programming problem and I can resolve it using Java or C++ or C or something, then I can program on the basis of this problem.
>
> Project leader: And then I will understand too?
>
> CSP: Yes, then I will understand too, since I have a problem that I can then transform into a solution…

The view of knowledge expressed in the formulation above is not absolute, but rather context-related. I called it goal-related in the continuation of the discussion, which was accepted as a suitable term by the participants[19].

What consequences for teaching and learning does this view have and is this really expressed in the courses?

> I: So understanding is simply something that is goal related? It is not possible to say that I understand programming: in fact, that is a meaningless remark – rather we should say I understand exactly this? In this way, even a novice can understand?

This was met with several yes's from the computer scientists participating.

> I: In relation to the specific tasks they are performing? Again several people agree.
>
> I: Do we communicate this to the students? Do we really help them to realise that their understanding is growing all the time?

Surprised sounds, short silence.

> CSP: No.

The surprised reaction here raises the question of whether this is a new pedagogical insight, or if this is something they actually do, or at least partly, but have not formulated before. The importance of providing a language, of giving space for formulating thoughts, are issues I will return to.

Models, abstractions and reality

I will conclude this section concerning the language and epistemology of the CSP voice with a brief discussion of how *models* and *abstractions* are talked about.

[19] Calling it goal-related reveals that I too am still partly bogged down in the tradition of problem solving. On second thoughts, I would say that a better term is context-related, since this was what I really wanted to stress.

Modelling and representing are fundamental in CS; they are necessary in order to deal with 'reality'. Just as in natural science, models are used to capture important properties of this reality. Object orientation[20] is claimed to be a way of accurately modelling reality:

> … now we are going to learn something so that we can design on the basis of how it functions in reality. We attempt to break the data down into objects, functions,… it should be attributes there, and then we try to mimic reality…
>
> … it is a kind of world, and this world has lets us call it problems. We believe this thing [the world] exists and then we believe there is something else that is a little smaller, which is a kind of sketch – model is a good word – of a world, and such a model of a world is of course always a reduction of information – an abstraction. The next step is to try to create a realisation of this model. In other words, something that is executable, an executable solution, and this world is really very square.

'Reality' is expressed and talked about as independent of the person experiencing it. It is taken for granted that reality exists and that 'we' can all agree about what it is like[21]. This indicates realist epistemology rather than constructivist epistemology, thus the feminist inspired questions "what reality?" and "whose reality?" simply do not make sense if one holds a realist view.

However, models and abstractions do not necessarily mean limitations. Accepting and realising that there are many ways to create models and many ways to abstract can open up new possibilities. This is expressed by one of the participants:

> CSP:… if you remember that it is only an abstraction and model, then it is possible to see various different models.

Using this aspect as the starting point, for example in teaching software design, might allow for a plurality of approaches, if students are encouraged to think in new ways and try to find several different models from different perspectives, rather than merely hitting upon the appropriate standard model, as is usually the case.

The Voice of the Feminist Researcher

Turning my reflexive ear to the voice of the feminist researcher, listening from a computer scientist oriented position, this voice sounds vague, searching, indistinct, always trying to avoid categorisations, in contrast to the clear and direct voice of the CSP. The language and speech of the feminist researcher may sound strange to the computer science practitioner. It uses concepts that are 'natural' to the feminist researcher, in the same way as computer scientists use other concepts that are seen as self-evident within the CS community. The same processes of socialisation into a community are going on.

The epistemology, which emphasises situated knowledge and rejects the universal knower, presents itself in the language and speech of the feminist researcher.

[20] Object orientation is currently a popular 'paradigm' within computer science, for the whole process of software production: analysis, design and implementation of software.

[21] See also the discussion on "we-saying" under "Problems and problem solving" above.

Let's look at an example from a conversation on pluralism among learners, where the FR voice clearly opposes easy categorisation, instead talking about how ideas and values become institutionalised in cultural processes[22]:

> What is being institutionalised? This is what we need to catch sight of, rather than sitting here pointing out that this person is this way and that person is that way. Have the goal that the teaching situation shall be possible for different knowers and learners, students from different backgrounds, then what is important is not to quantify them and say they are like this or like this, but to find out what we have institutionalised and how I can help break this pattern …

I will point to some 'typical' concepts used by the feminist researcher, concepts that it is not common for computer scientists to use, and comment on how these can be interpreted differently from a more 'traditional' CS perspective.

'Understanding' and pre-understanding

These concepts are repeatedly heard in the FR vocabulary. They have become naturalised for a feminist researcher, their meanings are implicit, self-evident, in the same sense as the meaning of 'problem-solving' is obvious to the computer scientist.

Some examples:

> How do I understand leadership? Do I have an essentialist understanding of leadership?
>
> You are reading in to it that her pre-understandings affect how she deals with these answers to the questions.
>
> The understanding of gender you have is the approach into different projects, and the interpretation is decisive for the direction change will follow …

The way computer scientists normally use the word 'understanding' is in the more common-sense meaning of comprehension or knowing, as in understanding something, understanding how something works for example.

These different uses of the same word can lead to confusion and communication problems between the two language communities. As the teacher of a course on "gender and technology", I once used the formulation "what is your understanding of IT" by which I meant "what is your view of IT". However, it was misunderstood by an (engineering) student and taken to mean instead "how much do you know and understand about IT".

'Construction' and 'production'

The concept of construction is used by the FR voice throughout, as if it were quite obvious or even self-evident why it is being used and what it 'means'. The examples below are taken from a meeting where gender was on the agenda:

> What is constructed in this type of article? (referring to an article about gender and programming education).

[22] In this section, unless otherwise stated, the quotes are from the FR voice speaking during the project.

Leadership is co-constructed with masculinity…

Constructions of girls and boys and computers respectively…

'Construction' is very much an engineering term: constructing, building something. However, for engineers, the word 'construct' refers to doing something according to a drawing, scheme or plan, it is a controlled and highly conscious activity (Mats Björkman, personal communication). Thus, an engineer would not use the term in the sense that the feminist researcher uses it, in the sense of socially constructing something. An engineer might actually get confused by the feminist's use of 'construction' and be under the impression that it refers to a conscious activity, which is not what feminist (or other researchers) mean when they say that something is 'constructed'. The engineer / computer scientist would be likely to use the term 'create', by which s/he means a less conscious activity, i.e. 'create' is closer to what the feminist researcher means by 'construct'. During one meeting, I realised this mid sentence and immediately switched from 'feminist-ish' to 'engineer-ish':

I: what do you construct ... what do you create when you write like this?

In the same vein as 'construction', the feminist researcher also talks about 'knowledge production', implying that knowledge is *produced*, not *discovered*. This is again an example of a notion that is in keeping with the epistemology. People are *producers* of knowledge:

FR: In what way do we also make the students into knowledge producers?

The discover vs. produce dualism is a fundamental epistemological issue (e.g. Nowotny et al. 2001). This is illustrated in the short conversation below between two of the participants, which took place during an intense discussion about whether there are natural laws within computer science:

CSP1: Then I say to XX, I'm talking about the fact that we discover computer science, then XX says now hold on a minute …

CSP2 [XX above]: so everything is invented, created. We are not investigating nature, but something created by human beings, with certain conditions of course. It is not a law of nature; it is not inherent in nature.

Obviously, CSP2 shows a more constructivist view here.

Discovering 'reality' is a cornerstone within realism, which is challenged by the epistemological stance of *producing* knowledge. Focus is shifted from a passive observer to an active subject. An interesting and important aspect of *producing* is illustrated in the continuation of the dialogue above (note that the more common engineering word create is used):

CSP2: if you think that we create things rather than discover things that already exist, you allow yourself far greater freedom. There is a difference in how people relate to things they have created and things they have discovered.

CSP1: if you discover, you have a passive attitude, you are weaker …

Again, we see that CSP2 has a slightly different epistemological view, which CPS 1 has obviously also taken in.

'Problematise' and 'critique'

'Problematise' is another example of a notion considered self-evident by the feminist researcher, but which is likely to be misinterpreted by someone not familiar with it. It can be interpreted to mean being critical, i. e. as implying critique, claiming that something is a problem.

In the light of this interpretation, I ask myself how one of our central questions in the project was actually interpreted by the participating computer scientists: *How can computer science and its disciplinary issues be problematised from the perspectives of gender?*

For feminist researchers, 'critique', being critical, is also vital, and one does not need to think that something is poor or wrong in order to take a critical stance. But this is not how the same concept is perceived by most computer scientists and engineers. I have had to learn to be careful when using expressions such as "feminist critique of science" in conversations with scientists / engineers, since they tend to assume a defensive attitude as soon as they hear that word. This is illustrated by the following quote, taken from a discussion concerning the importance of self-criticism for teachers:

> CSP: I wonder what we are talking about. We are implicitly criticising things we do … but what is it that is bad? Why do we do it? Aren't we satisfied with [our courses]? Can't we talk in more concrete terms? What is it that makes the discussion take a path where we become self-critical?

My voice – both feminist researcher and CS practitioner or neither?

During the project meetings, I rather concretely, though certainly not always consciously, moved between positions. This moving entailed language changes, sometimes conscious, in order to translate or make myself understandable, sometimes quite unconscious. In my description of how I write about voices, I noted that my own voice shifted back and forth between the two main ones: that of the computer science practitioner and that of the feminist researcher. I could say that I have an epistemological accent, I sometimes speak what I call 'feminist-ish' and sometimes 'engineer-ish' (or 'CS-ish'), but I speak both languages with an accent. I will give some examples.

Engineer-ish…

> …we know that this student has not really understood, but has nevertheless managed to pass the exam…

…attempts at speaking engineer-ish (or in the first case perhaps mathematics) from the epistemological positioning of the feminist researcher:

> We can never describe in a non-contradictory and completely consistent manner how all people experience something … it is not possible to be objective in that sense.
>
> I have become rather curious as to whether there is perhaps more than one possible approach to programming. Can we do it differently to the way it is usually done? We teachers here belong to a group that easily grasped the way we were taught, and it suited us, but can it be done differently, and will it be as good?

On a conscious level, these are attempts on my part to express my thoughts, emanating from feminist epistemology, in the way an engineer / computer scientist would speak.

However, this is problematic since the engineering language in itself is inseparable from the 'traditional' epistemology, so in practice the result tends to be a diffuse mixture of epistemologies on an implicit level.

In the example below, I conform to the voice of the FR:

> I think this formulation is very wise, very promising, that we must always regard understanding in light of who we are.

"Is This Text Essential?" – Epistemological Clashes

I found that sometimes epistemologies and scientific traditions suddenly and unexpectedly became explicit during project meetings. This caused confusion but also created possibilities for increased understanding and communication, when taken seriously. I want to illustrate this more closely with an example.

In preparation for one meeting, the participants read a BSc thesis (Alsbjer 2001), the topic of which is why it seems so hard for some students to learn programming at university level. Maria Alsbjer discusses knowledge and the formation of knowledge in programming, taking her starting point in feminist epistemology and methodology. Her empirical material consists of interviews with students and teachers in programming courses at two quite different educational programmes, both of which are however within the technical faculty. She reflects her empirical material in theoretical texts, both explicitly feminist ones, and other texts dealing with different 'kinds' of knowledge, and uses this as a starting point for reflection on the formation of programming knowledge.

Both I and the project leader regarded this thesis as very interesting, because of the way in which it throws light on issues not often dealt with in programming education. We considered the empirical material as the starting point for a discussion, rather than a study yielding explicit results. For me as a programming teacher, I felt quite stricken by some of the discussions. For example, Alsbjer points out that the idea of treating everyone equally (a cornerstone in Swedish society as a whole, as well as within education), which is regarded as a question of fairness and believed to *prevent* inequalities, in fact *creates* inequalities, since not all students have the same background and resources when they embark on a course of study.

To our surprise during the meeting, the participating computer scientists voiced quite different reactions to those we had anticipated. Instead of discussing what we saw as the core issue, i.e. learning programming, the focus came to dwell on the scientific method used in the thesis. Several of the participants pointed to what they recognised as a bias, or as they expressed it, a lack of objectivity, on the part of the author. Since Alsbjer clearly discusses her own standpoint, the 'spectacles' she uses when analysing the material, we (the feminist researchers) had never found this problematic. The discussion came to concern the question of 'what is science?' and 'what is scientific?' Connected to this are traditions concerning how (scientific) texts are read, how their contribution is judged. This time the discussion was explicitly epistemological, and it became obvious that traditional values of science were being reproduced.

CSP1: Objectivity vs. subjectivity. I feel that in general she is not being sufficiently objective …

CSP2: Initially, she writes that you just have to tell you are subjective and how you are subjective. I guess that is how it is in her science.

I: She is talking about what is sometimes called situated knowledge. I don't think she is talking about things being right and wrong, simply that everything is reflected through her eyes. This is why she tells us who she is and a little bit about her background, so that we can understand that this is her view of things.

The discussion came to focus on objectivity vs. subjectivity, which was constructed in the traditional way as a dichotomy, hovering close to issues of "good science / bad science". In attempting to understand how the concepts are being used, we reached some kind of common construction of their meaning:

CSP: perhaps you are always necessarily subjective, you are always subjective even if you want to be objective, but I think it sometimes happens that you slip into thinking that it is OK to be subjective, i.e. you no longer try to be objective. But I think that you would perhaps want to try to be objective, if you shall report on people's opinions for example.

I: it sounds to me as though you are not really talking about being objective, but about allowing all views an equal airing? Is that what you were saying, that we should try to see all sides?

CSP: that is what I meant. These are two different matters. It is one thing to claim that perhaps there is no such thing as objective knowledge, but another matter entirely to switch over to being completely subjective.

It seems that the interpretation of objectivity in this case does not conform fully to the idea of a neutral observer or researcher having a 'view-from-nowhere'. But it remains unclear how much is actually implied by using the word 'objective'.

The conversation continued to deal with what is considered 'scientific', where the concept of repeatability from natural science is taken as a model for scientific method:

CSP: [I query] the method and execution … chapter 3, which is actually supposed to be rooted in objectivity so that it is possible to repeat the experiment ,there it slips a lot…

Further, being 'scientific' is constructed as the opposite of 'having an opinion'

CSP: What she writes is all personal opinion, and what I am saying is my personal opinion. That is all, and that is what I think we should take it as ….

The voice of the feminist researcher attempts to respond to this:

FR:One tries to find out something about some kind of reality, from the outside,that makes it possible to give a number of different descriptions of this reality, and of course it is coloured by one's own approach, but the interesting part is how much you let it be coloured. The question is: how can we make use of this description of reality? How can we apply it in this discussion about what knowledge is? How do you as teachers in a learning process approach the students? How can we apply this terminology, for example to help systemise and understand a teaching situation?

Does this make sense? Does it bridge the epistemological and linguistic gaps? Probably not, since some kind of communication breakdown occurs here. The next person to speak continues on the topic of science vs. experience, where the latter is not 'scientific' but is nevertheless regarded as a foundation for knowledge. It is also interesting to note

that s/he talks about getting 'answers' – is this about finding solutions to problems experienced?

> CSP: this paper does not provide any sort of foundation. However, I have experience, years and years of experience, and of course the situation looks slightly different to me. I find more answers in my experience than there are in this piece of work, but I do not have all the answers anyway.

Helen Jøsok Gansmo illustratively discusses this contradictory construction of experience in traditional approaches to knowledge in her essay on the social dilemma of "girls and computing" (Gansmo 2002). She shows how decision-makers' own experience and observations (e.g. concerning their daughters) makes up a large part of the knowledge basis for policy decisions. On the other hand, good qualitative research, even though it points in the same direction as their own experience, is dismissed as not being general enough. In contrast to this view, feminist epistemologies acknowledge experience as a valid basis for knowledge.

One conclusion from the discussions of this text is that the participants had read it using their ordinary, 'traditional' spectacles from science / engineering. Looking back now, this seems self-evident: could anything else really have been expected?

After this meeting, one of the participants asked me if I considered this text essential. I remember being startled by the question, and I answered that I saw it as important. However, after having pondered the question for some time, I came to wonder whether the person who asked it actually meant if I believed that the text was 'right", that it provided 'answers' of some kind. The question would then imply that s/he had read the text as a traditional scientific article within natural science, i.e. presenting hypothesis, facts, and conclusions based on the facts. If this interpretation of the question was correct, my answer did not 'work' so to speak. Probably, my answer was interpreted as suggesting that I thought the article provided 'correct' answers to problems, whereas what I meant was that I deemed it important precisely because it raises and discusses issues concerning knowledge in programming.

When I later interviewed this person, I raised the matter of the question that had puzzled me so much:

> I: Do you expect this kind of text to provide a factual basis where you can recognise that she has come across something that is useful to you … that there are more facts …
>
> CSP: Something like that …
>
> I: …my interpretation of "essential" was that it raised some interesting questions for me. Later, I realised that that wasn't really how you interpreted the term essential…
>
> CSP: No, it wasn't. I would be much happier if there had been a stronger presentation in general, then we could have said that this is interesting, it raises some of the same thoughts, but we could also have said that here we have really found something.
>
> I: …so you think that there is too much opinion and not enough data?
>
> CSP: I thought there was very little foundation for the opinions expressed.

Summarising the discussions around this article, a number of strong epistemological ideas concerning traditional views of science and knowledge have been rocked by approaches from feminist research:

– The objectivity discourse

– Ideas concerning production of knowledge, what knowledge 'is' and how it can be attained

– The problem-solving, linear attitude, demanding answers to posed problems

– Feminist researchers' insistence on reflexive practice, which is unfamiliar and 'strange'.

As another example of how diverging views concerning science exist among the computer scientists in the project, let us look at the following example concerning reflection. At one meeting, one of the participants pointed out to his/her colleagues that knowledge can be reached in other ways than by measurement, for example through reflection (which was the 'method' we attempted in the project):

> CSP: Perhaps it is just as well that not everything can be measured; for example, issues can be discussed, or, like in this project – this is a project where we are trying to achieve something not by measuring, but by means of reflection as a scientific method …

Reflection: Reflecting Practice in Theory

So far, I have illustrated different epistemological standpoints and how these are intertwined with language. Taking these examples as my starting point, I will now discuss some thoughts and reflections that I had during the project, but which changed with time.

The previous section showed an example of an attempt to bring the participants' practices together with feminist theory and research. The idea was to reflect[23] the participants' experiences in literature on gender, programming and knowledge. The intention was to see how theory could inform educational practice. This was not as straightforward as we (the feminist researchers) might have thought, something we realised during the project, and which was a cause of confusement to me at that time. The discussions had a tendency to be very lively and engaged as long as they concerned matters concretely associated with teaching practice. However, it was much more difficult to engage the participants in general and theoretical discussions, particularly when it came to issues concerning the 'nature' of knowledge. When talking about it at the time, we often perceived this as our 'fault', for letting the conversation drift off into too much practical detail, and not being able to keep focused during the discussions. We made several explicit attempts to discuss thoughts and experiences in a more theoretical terminology, e.g. (this took place during the discussion of the BSc thesis):

> FR: How can we discuss your experiences in her [Alsbjer's] terms of views of knowledge, process, and learning processes? Can we translate this so we can get a general discussion that allows us to regard our teaching and the students' learning in some other way than this highly practical way, like we usually do?

[23] As Donna Haraway has pointed out (e.g. Haraway 1996), reflection can be problematic, if this is taken to mean mere mirroring. However, we used the concept in the sense of critical reflection, using theory for reflexive discussions.

The question was left hanging and the discussion took another route.

My interpretation of these difficulties to bring about theoretical discussions, changed with time as the project progressed. I began to think more in terms of differing scientific traditions: that computer scientists are are not trained in theorising and reflecting on a meta-level over one's own subject, a trait inherent in technical education and practice, as well as in natural science. These disciplines do not foster this kind of reflective practice. Evelyn Fox Keller has commented on this strikingly and to the point:

> "The reality is that the "doing" of science is, at its best, a gripping and fully absorbing activity.… The net result is that scientists are probably less reflective of the "tacit assumptions" that guide their reasoning than any other intellectuals of the modern age. […] Indeed, the success of their enterprise does not, at least in the short run, seem to require reflexivity. Some would even argue that very success demands abstaining from reflection upon matters that do not lend themselves to "clear and distinct" answers." (Fox Keller 1992, p, 27).

The ideas of 'explaining', of thinking in very strict dualistic terms of 'right' and 'wrong' and 'failure' were still very much present in my thinking, and as I see it now, this can be quite dangerous, risking closing off possibilities for communication and translation.

So, at that time I had two 'explanations' for these difficulties[24], and as pointed out above, they had a dualistic relation: either the feminist researchers had failed or the computer scientists had failed.

Helen Verran, in her account of teaching of quantifying (measuring) in Nigerian schools, is faced with the same situation, where two 'explanations' of her disconcertment in a particular situation are both equally likely, explanations that are both framed in terms of failure and inadequacy.

> "… to adopt either one of these cause-and-effect stories is to explain away the disconcertment which, as I felt at the time, and still feel, is the kernel of whatever truth lurks in the episode and its telling. To tell either of these stories would betray participants in the episode in unacceptable ways. In explaining away the disconcertment, the above explanations foreclose and legislate. … I want to keep the puzzlement of sameness and difference … to privilege the disconcertment. It seems to me that, this way, we can tell stories which have a chance of articulating how the truths they tell came to be and, also, of understanding how this might be done responsibly." (Verran 1999, p. 142f.).

Being a participant telling a story makes it irrelevant, even inappropriate, to give causal and "morally legislative explanations" (ibid p. 148) 'from above' of what happens, since doing so will eliminate possibilities for furthering other understandings. For me, rejecting the all-too-easy explanations of 'who failed' instead opened up opportunities to focus on the more important issues of communication and translation. Instead of only seeing failure and difficulties, I could see that what I experienced as the participants' (sometimes explicit) reluctance to leave practice behind and 'talk theory' should be

[24] A third 'explanation' would be to conclude that the two 'worlds' are so completely different that trying to communicate is pointless. That the languages, both of which claim to deal with "the world", are in fact incommensurable. This would mean rejecting the idea that feminist perspectives have something valuable to contribute to computer science practice, a standpoint I refuse to adopt.

interpreted as something strongly positive: practice, courses, teaching, students: that is where interest and commitment is.

Before going on to the issues of communication, I want to problematise the idea we (the feminist researchers) had concerning "reflecting practice in theory". In fact, we used to talk about this as "lifting practice to theory", which is an expression that is highly problematic. It is not only about the notion of 'lifting', but also who sets the arena and the agenda (which would in this case obviously be the feminist researchers, although not really consciously). And the expression in itself is certainly related to knowledge, it indicates a view where theory is seen as superior to, as 'above', practice. On a more conscious level, we strongly object to this idea, how come we used the expression anyway? Language reveals how we are stuck in ways of thinking and grading knowledge. This expression can be seen as a 'slip of the mind', as showing how difficult it actually is to move beyond the ways of thinking that we have been used to[25].

Looking further to the expression of "reflecting practice in theory" this leaves out some crucial and important aspects. The sentence in its whole is: Reflecting *computer science educational practice* in *feminist epistemological research and theory.*

Looking at the two different parts of this sentence makes it clear that these are indeed two different 'worlds', and the question of reflecting the first in the second does not make any sense. First of all, it is not really a question of reflecting something in something else, as if it were a two-dimensional mapping. It is more complex than that. Is there a mapping at all between these two 'worlds'? And if there is, can it be said to be one-to-one? Most probably not! There is simply no, or at least very little, correspondence between these two 'worlds' that are trying to meet and find some kind of mutual language. Lucy Suchman is explicit about this:

> "…[disciplinary distinctions] all orient not only to different problems but more significantly to different, sometimes incommensurate conceptions of the social/technical world … [there are] discontinuities across our intellectual and professional traditions and associated practices … the need for mutual learning and partial translations". (Suchman 2002, p. 97).

Communication and Translation

In trying to deal with the confusion, the disconcertment, that I experienced in the attempts at communication between feminist research / theory and computer science practice, I started to formulate this in terms of the need for *translations*. This need results from the experience of, or rather becomes visible in, the communication problems, or communication 'breakdowns' as I call them.

Communication breakdowns

Besides the examples given earlier in this article, there were many more instances of communication breaksdowns, often manifesting themselves as silences in the conversation. The voices suddenly diverged, talking about different things.

[25] Both of us have a background in natural science and/or engineering.

An instance of a silence, of a communication breakdown, when the voices diverged, occurred when we talked about understanding programming:

> I: So how do we go about trying to mediate these ideas concerning understanding? The students have to acquire understanding themselves, but what can we do to help them acquire this understanding?

Silence. Was this question too undefined, too vague or not contextualised enough? Was there not enough practical and understandable detail? The voice of the computer science practitioner continued:

> CSP:… it is problem solving where the tool itself plays a subordinate role as long as I can reach my defined goal, i.e. find a solution to the problem…

Another example shows how I attempted a translation, in the context of approaches to knowledge:

> FR: … as teacher, what understanding of what programming is and how best to learn it do I have? How do you regard your own approaches in relation to the other approaches students may have, and how do you then link it to views of knowledge?

My translation attempt:

> I: What is my view of programming as a teacher and what is my view of how programming can best be learnt, what do I bring with me to the classroom?

Was this misinterpreted?

> CSP: Many courses are all the same, with the classic structure of lectures and practical work. Practical work is important, so you have many excercises, labs.

Did I try to steer the conversation?

> I: …so most of you have the impression that the craft element, practice, is the most important thing?

…but then the discussion went off on a tangent, about spending time in terminal rooms. The conversation seems to have taken place on two different planes, concerning different issues. The voices seem not to have talked to each other, but past each other; the CSP did not understand the FR, and she in her turn just thought that the attempt to connect theory and practice had 'failed' once more.

Listening to the silences on the tapes at the points where we tried to discuss views of knowledge or how experience from practice could be framed using theoretical concepts, I now interpret them as indicating that the parties were having problems understanding each other. It is likely that the computer science practitioners could not relate to the questions, found nothing to hook on to, to connect to their world, experience, knowledge, and language. Nor is it possible to articulate this difficulty in understanding, because in what language 'world' should it be described and expressed? Thus, the questions that the feminist researchers asked came to exist in a vacuum, or an immaterial 'cloud', which cannot be caught, analysed, materialised or described. It is not possible to explain what one does not understand.

I now believe that the issue of communication should have been addressed directly. This could have released some of the tension and led to us finding ways to communicate.

Listening to myself and invoking some self-reflection, I now believe that one reason for the communication breakdowns might be that I have started out on a journey. Along the way, I have learnt new ways of thinking, talking, asking questions, etc. than I was used to as engineer. It entails a change of world-view in a profound sense (Björkman 2005b). This process also inevitably entails that the old world-view is lost to some extent. It is not possible to hold both simultaneously, not even to clearly remember the old one. I could not quite remember how I used to think and reason before I set off on this journey, when I was a computer science lecturer – a mere five years ago. Thus I could not understand, or articulate, what was going on, nor was I able to communicate in a clear way.

Since I persist in my belief that feminist research and perspectives can contribute valuable thoughts and ideas to computer science education, e.g. concerning epistemological pluralism, the crucial questions are: where, when and how can this be communicated in computer science? How can translations be done?

On translation

> "…but we do need an earthwide network of connections, including the ability partially to translate knowledges among very different – and power differentiated – communities." (Haraway 1991, p. 187).
>
> "…we need a language that enables us to conceptually and perceptually negotiate our way between sameness and opposition, that permits the recognition of kinship in difference and of difference among kin, a language that encodes respect for difference, particularity, alterity without repudiating the underlying affinity that is the first prerequisite for knowledge". (Fox Keller 1987, p. 48f.).

The word *translation* is often used by feminist researchers (e.g. Haraway above, Suchman 2002). An alternative concept for what I intend is *interpretation* (in CS contexts, translation and interpretation are related as the job of a compiler vs. that of an interpreter; in the context of translation between 'human' languages this relates to the written work of a translator vs. the oral work of a simultaneous interpreter). In the context of the project I participated in, *translations* are what I ought to have done when preparing for discussions, while *simultaneous interpretation* might be a more appropriate term for what was needed during the actual conversations.

If translation is possible and desirable, how can it be done? It requires sufficient fluency in both languages, and being reasonably 'at home' and acquainted with the 'reality' of both worlds. However, this is not enough, since the two worlds do not overlap and the translation is in practice not from one language to another, but more about epistemological 'mappings'. These differing epistemologies cannot really enter a dialogue, they are incommensurate; thus there is a need for a bridging of some kind, a translation, or even a common language. A translator shall be true to the source (in this case feminist research and theory), but also try to make the message understandable in another language, to do the best possible translation for both the source and the receiver. Presumably, the concept of *mediation* and being a mediator is more apt for this purpose. This is the meaning I intend when I use the term translation.

Included in this is the need to "develop ways of representing the theoretical models and methods of one's discipline through images and concepts to which practitioners from other communities are able to relate", as Ina Wagner puts it (Wagner 1994, p. 263). This requirement applies not least to the feminist researcher. In this case, the need is to represent feminist theory and epistemology in ways that are comprehensible and interesting to computer scientists.

Possible translations?

The same idea can be expressed in several very different ways. As an example I take two different ways of talking about how software is laden with culture (Introna and Nissenbaum 2000). As a feminist researcher, I have expressed it thus:

> "Software is tightly interwoven with cultural and other pre-understandings of western culture." (Björkman 2005a).

In the on-going conversation with the computer science practitioners, I tried to express in essence the same thing but in 'engineer-ish':

> I: What do I do when I design a program, what values do I build in? When I decide whether a design is good or bad, what criteria do I use?

It can certainly be argued that there are essential differences between the two statements. But for the very concrete and situated purpose of mediating the idea of value-laden software, connecting it to the practice of teaching, and hopefully starting some reflections, this translation fulfilled its purpose.

Another example shows how experience of working with people from different disciplinary backgrounds than one's own are useful, in order to learn how very different associations can be caused by what could be seen as unproblematic or self-evident terminology. In this case, it concerns the popular concept of 'problem solving'. Below, I use experience from an occasion when my computer science 'language game' (Wagner 1994) confronted that of other scientific traditions, and I learnt from it:

> I: You use words like creative and innovative to describe programming, and you even use the term 'problem solving'. I think that for us [computer scientists], these terms are connected, but perhaps the term problem solving has negative associations for students: problem = difficult. This is not how we see it; we regard problem solving as constructive, as doing something. I experienced an eye-opener when I was holding a small programming course for my fellow researchers from the social sciences and the humanities. I said that programming is problem solving, and the first thing they said was: what do you mean by problem? and then they reacted quite strongly to my using the term problem, which for me was self-evident. That episode made me realise that the word problem has different connotations. Reaching a goal sounds much more positive. Programming as a creative activity: do we manage to make the students see it that way, or do we quash that idea when we talk about problem solving?
>
> CSP: You have a point there…we must test out talking about reaching goals instead.

Boundary objects as a means of creating communication and translation

Taking the standpoint that communication between the communities of computer science practice on the one hand and feminist technoscience research on the other is

not only desirable, but necessary, how can this communication be developed and take place? How can we meet, find common ground and topics of shared interest?

Susan Leigh Star has developed the concept of "boundary objects", for 'objects' that can serve as common ground when actors from different scientific (or other) communities communicate (e.g. Star and Griesemer 1989). Boundary objects can be abstract or concrete. The objects can have different meanings in different worlds, but "their structure is common enough to more than one world to make them recognizable, a means of translation." (Star and Griesemer 1989, p. 393). As Ina Wagner puts it: "To serve as common ground, a boundary object needs to be sufficiently ambiguous for actors to fill in their specialised viewpoints." (Wagner 1994, p. 263f.). Boundary objects should not be rejecting and excluding, but welcoming and inclusive.

The concept of boundary objects was developed in order to make sense of how people from different social 'worlds' co-operate in scientific work. I use it in a somewhat different sense, but it still retains the qualities described above: as a concept around which both feminist researchers and computer science practitioners can gather, because they have a shared interest and/or knowledge concerning the 'object', and as a way to communicate. In this case, the boundary objects are primarily abstract.

What boundary objects could be identified for this situation? Evelyn Fox Keller (personal communication, Oslo June 2003) suggests starting in concrete situations that are of concern to the scientists / practitioners. Boundary objects can be found in problems experienced by the computer science educators, when they are forced to face situations they do not feel equipped to deal with, where they do not have the 'tools' to 'solve their problems'. I found one such 'boundary object' in the concept of diversity among students:

I: How do you handle the diversity of interests and motivation among students?

silence…

CSP: Quickly bury my head in the sand…

Diversity can be regarded as a boundary object, if it is used as a flexible and plastic concept, and we do not attempt to impose one particular definition on it. One of the computer science teachers expressed it as "non-nerds". As a feminist researcher, one can find a whole host of explanations / definitions / conceptualisations for diversity. In this particular situation of communication, there was no need to define the concept further: our common understanding was adequate.

At this computer science department, the teachers faced a situation where their students were increasingly representing a multitude of backgrounds and interests. There was diversity in terms of gender, ethnicity, previous knowledge of the field, motives, interests, etc. The teachers did not feel adequately prepared to handle this situation, instead they were at rather a loss, since their student group had previously been quite homogeneous (predominantly young, white, Swedish men with a strong interest in computers and programming, most of whom had substantial previous experience within the field too).

In this situation we, the feminist researchers, were in a position to provide some 'help' or guidance, based on our knowledge of gender-conscious teaching. We used a very accessible yet well balanced and researched book on "Gender conscious pedagogics for university teachers" (Bondestam 2003). Bondestam frames the subject as a question of good practice, by no means limited to dealing with gender in the classroom, but very applicable in the context of a heterogeneous student group. Gender-conscious teaching used in this sense can also provide a useful foundation from which it is very easy to start talking about knowledge, approaches to knowledge, views of learning, etc. Thus, the question of epistemology can, and I claim should, be brought into the discussion, since pedagogy is not something that can be conceived of instrumentally (TyAnna Herrington and Yuri Tretyakov, seminar Karlskrona, 2 February 2003).

Summary: Strategies Towards Making Change Happen

Before concluding this article by returning to the fundamental topic of epistemology, I want to summarise the lessons I have learnt, and point to issues that I believe are important for future interventions and encounters between feminist research and educational practice in science / engineering.

Building alliances and co-operation

If we, as feminist (technoscience) researchers, want to participate in transformation work, in processes of change, we need to build alliances across disciplinary and other boundaries, starting in joint interests and engagements: "When one of the fundamental bases for change is to look for and build up alliances we have to learn to co-operate, also with people who do not always share our own epistemological and political concerns." (Björkman, Elovaara and Trojer 2005).

I believe that it is most fruitful to start co-operation and intervention in topics or situations the practitioners find relevant for their (educational) practices, or which arouse their interest and concern. Identifying 'boundary objects' on which to build functional alliances is important.

Awareness of epistemology and language

In this article I have identified *language* as one of the crucial and most difficult issues in co-operation and communication, or rather how epistemology and language are intertwined and thus complicate communication. It is important to recognise the differences in how we talk about science, learning and knowledge within different scientific traditions. Understandings and epistemologies are concretised in metaphors and words. When these do not harmonise, or differences are not recognised, communication can collapse, resulting in loss of transformation potentials. Furthermore, the different epistemologies and approaches to knowledge need to be made explicit, in order for us to be able to talk about them. Recognition of these difficulties underlines the necessity of developing translations or mediations. It is, as pointed out earlier, a translation on several levels, where the most fundamental level concerns what can be considered fairly different 'world-views'.

Memorandum for the feminist researcher

As a feminist researcher, some knowledge about and respect for scientific / engineering practice is important. This is in order to understand the language within the community, to be able to share it and translate into it.

Feminist disciplinary 'purity', e.g. concerning language, is not an option. What is needed is a willingness to change one's own language, words and metaphors, in order to keep working towards the overarching goal of intervention. However, this must be done *without* losing the fundamental ideas and epistemology. The intention is to try to mediate feminist epistemologies and theories into other language and scientific 'worlds'.

It is essential to maintain self-reflexivity in this work. I would say some constructive self-criticism is also in place. And we should not give priority to simple explanations, dichotomies or thinking in terms of 'good / bad', 'right / wrong' or failure, but acknowledge and accept differences. All the time, we should keep in mind Lucy Suchman's words about the need for "*mutual* learning" (Suchman 2002, p. 97, my italics)[26].

Contributions: providing critical reflexivity, space and language

Feminist researchers can certainly contribute much to processes of change within science / engineering education. Knowledge about gender and issues of diversity spring immediately to mind. But I believe that there is another particular competence that feminist researchers can contribute, and that is our knowledge about, and training in, critical reflexivity, reflexive thinking. We can point to and show how commitment to students and education can be strengthened and developed through critical reflection, that theory and practice can contribute to each other in a reflective spiral.

Connected to this are the issues of providing space and time for educational practitioners to think and talk about matters other than the very concrete everyday work, to afford them time and the vocabulary to reflect on a meta-level. As feminist researchers, with training both in reflexive thinking and in asking those unexpected questions, I believe we can facilitate, encourage and stimulate this kind of work. We can draw to the surface thoughts and ideas that might already be there, as well as catalyse new thoughts. As I will demonstrate in the final section, many inspiring thoughts and ideas already exist in the practice. Perhaps all that is needed are the seemingly simple and yet so-hard-to-get-at elements of time, space, encouragement and language to articulate thoughts and ideas.

I believe in small steps, in creating tiny cracks. Big movements can start as small disturbances; a grand idea can be born out of a word or conversation. It is necessary to realise that major changes are not an immediate opportunity. Fundamental changes, if possible, take time and endurance. It is in the small, down-to-earth, everyday situations and practices that I believe thoughts, ideas and experiences from feminist research can create cracks, find crevices where a seed can be planted. That is why we should never ignore minor, seemingly banal opportunities. Such issues often reveal needs, which are rarely afforded space and time in the everyday practice of the engineer / scientist.

Coda: Divergences and Epistemological Cracks

Lastly, I want to return to the topic of epistemology in computer science, and its presence in language. In the conversations related in this article, I mainly concentrated on how the 'traditional' epistemology was present in language, but I will now focus on the divergences and epistemological cracks and motions that appear in the conversations.

[26] I have discussed the differences in 'mind-sets' between engineers and feminist researchers in Björkman 2005b, where I also raise the issue of mutual learning.

I have pointed out that the participants in the project had different backgrounds, knowledges and experiences, resulting in diverging voices within the group, as I have shown examples of[27]. The importance of diversity, a heterogeneous group of teachers, cannot be overestimated. These diverging voices will continue to challenge what is done and how it is done from within, and can provide alternative views and ideas.

I have emphasised that the epistemology of the computer science practitioner is largely *implicit*. However, as I also pointed out, there is not an obvious and complete mapping between the epistemology present in language and the individual scientist's *explicit* views and values concerning science and knowledge. This discrepancy between what is said and what a person thinks and believes can surface and become clearly visible in practice. Traditionally dominating discourses concerning science are present in language, but within practice other epistemological attitudes can be observed developing.

Thus, challenges to more 'traditional' views of science and knowledge not only come from divergences in attitudes within the community, but also from the teachers' own knowledge and experience in their educational practice. I would say that this accommodates two partly different but certainly related issues:

Firstly, new ideas about learning and the learner that are not entirely consistent with the 'traditional' epistemology in natural science / engineering have started to make their way into the teaching of (computer) science. When explicitly addressing practice in conversations, there is a subtle change in language, revealing more contextual and relational approaches to knowledge and the knower. One example of this appeared in the discussion I have related concerning what it means to learn to program and understand programming. This can be seen as a 'crack' or opening in the 'traditional' epistemology.

Secondly, cracks also open up from within educational practice because of the teacher's experience-based knowledge from education. As became clear in the section "Is this text essential", there is a contradictory view of experience as valid knowledge. Teachers' own experience-based knowledge disturbs the implicit and taken-for-granted epistemological basis. They can reproduce in speech ideas for which they have well-known words (emanating from the field's traditional epistemology), but they might lack words for what they sometimes deem to be their 'subjective' experiences. The result is a collision between views, and in this, cracks open up.

To summarise, cracks are created through the influence of knowledge from other areas, and also emanate from personal practice and experience.

So the epistemological picture is not as complete, coherent, homogeneous and closed as one might think. Many things are actually going on, and these movements can be strengthened and promoted by feminist (technoscience) researchers. Donna Haraway said in an interview: "Categories are not frozen…The world is more lively than that,

[27] E.g. the discussion concerning science in the section on *tools*, *science* and *use*, and the discussion on the discover vs. produce duality.

including us, and there are always more things going on than you thought, maybe less than there should be, but more than you thought!" (Lykke, Markussen and Olesen 2000, p. 55).

These cracks create and open up arenas for change, for feminist epistemology to make itself heard and be influential. Feminist researchers can make useful contributions to strengthen, acknowledge, give words to and not least justify teachers' experience as valid knowledge, as a legitimate basis for knowledge claims.

I want to conclude this article with reflections from some young computer scientists, written at the end of the project. These words and thoughts illustrate the epistemological cracks and movements I have discussed above. They speak for themselves and give hope that transformation is possible!

> If we regard computer science as something we human beings have constructed, then there is no obvious image of what computer science is or how it is practised – it is possible for all of us within the discipline to create our reality ourselves. I hope it is still possible to influence it as it is still very young (around 60 years old). To this end, we need openness towards development and the search for new possibilities and views before we all cement the reality. If Stone-Age children had done as their parents had done, we would still be living in the Stone Age. The problem of computer science being constructed is that those who set the tone and people that represent knowledge within the field are often in a position of power vis-à-vis newcomers to the subject. The trendsetters have defined what is right and 'beautiful', while the newcomers are still struggling with their 'clumsy' attempts and are busy making mistakes and producing ugly things. Shouldn't the power perspective be put under the microscope to allow new beginnings and criticism of those with power? Who are the weak in computer science? How can they be allowed to develop computer science on equal terms with the strong?
>
> Be critical – of yourself and the accepted truths – and be open to new ideas. If you are not self-critical, you can never change your world view and what things look like… there is more beyond what we can see right now …
>
> It is not possible to get everyone interested in computer science, nor is that the goal. But by changing attitudes towards what is or is not computer scienc, and by being slightly more broad-minded about people in general, we can attract far more students with different interests to our field , which will in turn hopefully lead to a more nuanced image of what computer science is and how it will develop in the future.
>
> As I see it, computer science is an interdisciplinary subject. Mathematicians define computability, and the view of computers is that they are calculators. Engineers build the machine using electronic circuits. Power – no power, 1-0 is the language of computers. Linguists create new languages and expressions with meanings. Artists create new visual and sound effects. Social scientists look at the social aspects of computers and their use. All these different approaches to computer science bring with them different views of knowledge: artistic, sociological, scientific, technical, from the humanities. These views of knowledge and science influence the subject. The teacher's approach to presenting the subject has a huge impact. It might be an advantage if teachers had two different views of knowledge – or at least understood that there are different ways of deciding what constitutes important knowledge.

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Epilogue

In order to wrap up the thesis, I will do two things. Firstly, I will look back to what the initial research issues were, and how these relate to the final points of the thesis. The main question I have in focus here is: what happened during the journey, especially concerning the aim of contributing to change?

The second issue is to look forward. I will elaborate and discuss further what I see as feminist technoscience strategies in computer science.

What happened to 'change'?

In the introduction to the thesis I write: "A common denominator for my research is the aim of contributing to *change*: change in recruitment to CS, change in the culture of CS (both the disciplinary and the social), change in the practices of CS: in particular education. In short: to explore possibilities for change with the aim of making CS more inclusive. […] The main focus and goal of my work concerns how to broaden the meaning of "knowing computer science". This includes accommodating diversity: diversity among students, diversity in ways of knowing and learning (epistemological pluralism), diversity among practitioners of CS, and diversity of practices and approaches to knowledge in the discipline."

What happened to this ambition? It is clearly present in the first papers, but towards the end of the thesis the focus is translation. What happened during the journey is that 'change' was changed. I came to see that change is not attained in the ways that I might have thought at the beginning of my PhD studies. The goals are the same, but the means for accomplishing change have changed.

What happened during the journey that lead from 'change' to a changed 'change'?

From tools and maps…

The issue which for me led to feminist research concerned "why are there so few women

in computer science and how can this be changed?". Even if I had realised that the issue was much more complex than a mere question of changing the attitudes of women, I probably still believed in 'solutions', even if I did not yet know what the tools for 'solving the problem' was.

My experiences from "the gender question in CS" led to an interest in that which is often taken for granted in the common approaches to this question: the discipline of computer science itself. Thus, focus became to open up and question the foundations of CS as well as to point to how these could be changed. It is clear that my aim was to bring 'tools' from feminist research *into* computer science, in order to bring about change. This can be seen in my licentiate thesis, where I wrote: "I take my tools from gender research within technical disciplines, and I use them within computer science". However, I did not yet quite know what those 'tools' were, or how to accomplish change. I was still in the early phases of my journey in feminist technoscience research.

This attitude to change is visible in the first papers. In paper B1 change is perceived as coming about via challenging what I call "the epistemological level" in CS. It seems I had a strong idea that (only?) feminist research had the 'tools' for this change. I argued for what I believed were the 'right' approaches (the approaches taken by those I called feminist/gender researchers in computer science). However, doing so also meant I did not see that some of the ideas and work I critised in fact did hold promising qualities. Today, I would not draw quite as straight and sharp lines and boxes as I did when I wrote this article.

The same idea of how to accomplish change is present in paper B3, which argues for focusing epistemological issues in CS, and that feminist research can be used within computer science to approach and discuss foundations of the discipline. The question of "What does it mean to know CS?" is in focus.

My approach at this point was to start by doing some kind of map, or 'model', for what it presently means to know computer science, and thereafter suggest new and different maps or 'models', stemming from feminist research approaches. Paper B3 starts this 'map-drawing', and it is also partly continued in paper B4, though things have happened in between them, resulting in a somewhat different perspective in B4.

During the work on this 'mapping' project I started to communicate with computer scientists. I did this both in the project at Malmö university (discussed in part C of the thesis) and during a PhD course in the philosophy of computing at Mälardalen University. In both contexts, I tried to talk about change from feminist research perspectives with what I call 'ordinary' computer scientists, people who are definitely interested. It was during these conversations I came to realise that communication, talking about feminist epistemology and research and what they can contribute, is necessary if I want to work for change. A map of what it means to know CS, and how this can be changed, is definitely valuable, but will in itself not make change happen. There is not much point in suggesting new understandings if these cannot be communicated to computer science practice. One could say it was my motive of striving towards change that changed my focus towards issues of communication and translation.

Furthermore, the work of others who have tried to challenge fundamental ideas within computer science[1] has shown that creating a new 'model', and attempting to get attention for it within computer science is, depressingly enough, very difficult.

Paper B4 marks this change in focus. It is written during the time when I started to think about communication. The 'map-drawing' is continued in this paper, which also aims at using critical feminist epistemological perspectives for challenging concepts within CS. However, if in paper B3 feminist research is supposed to provide the 'tools' for the engineer to bring about change, change is in B4 more clearly seen as coming about from communication between feminist research and computer science. B4 invites to dialogue between these two.

…to communication and translation

During the last phases of my work, it became increasingly clear to me that the most realistic way of promoting and bringing about change is through dialogues and co-operation between feminist research and computer science practice. Such dialogues can be made possible by communication and translation across boundaries between these two "worlds".

In part A, in particular paper A1, as well as in part C, change is seen as being possible to attain by asking the questions and focusing the issues from part B but in dialogues and communication with computer scientists. In this work, knowledge and awareness about differences in "mind-sets" can provide a basis and an understanding needed in order to engage in communication between "worlds".

What about paper B2 then? Chronologically, this article falls into the same period as papers B1 and B3. Change here is seen as coming about via feminist inspired readings and questionings of foundations and taken-for-granted perspectives within computer science. So, in a sense, it is tools from feminist research. However, the approaches I use (partial perspectives, reading from different positions) are connected to the theme of different "mind-sets", and thus perspectives, discussed in later papers.

The spiral journey

This journey is best described as moving in spirals. A spiral is a much more open structure than a circle, since in a circle, you come back to where you started. I started within computer science education, where my interest for change rose. But I was not able to change anything there, and needed to take a step out of my everyday reality. For some time I left CS education in order to take my questions, thoughts and experiences to feminist technoscience research. This research has now taken me back to CS, but in a different way, with different ideas, thoughts, issues and questions than when I left.

[1] For example the work of Lynn Andrea Stein (Stein 1999), in which she challenges the computational metaphor in computer science. In spite of her being a well known robotics researcher from MIT, she had problems to publish it. According to her, the ideas in the article has had negligible impact (personal communication with Lynn Andrea Stein October 2002).

Was this journey with all its many bends and turns necessary? I believe so, since the road from engineer to feminist researcher is not an easy one…

> "I need only to recall my own trajectory from practicing scientist to feminist critic to appreciate the magnitude of difference between these two mind-sets, as well as the effort required to traverse that difference." (Fox Keller 1992, p. 21).

…and there are no shortcuts. The classic questions, concerning for example "whose science? Whose knowledge?" (Harding 1991), need to be formulated in one's own context. The journey is about learning new ways of thinking, talking, writing, asking questions etc. It is a change of world-view in a profound sense, meaning a fundamental change in the epistemological foundation, which is a long and on-going process. This process also inevitably brings with it that the old world-view is to some extent lost, it is not possible to hold both simultaneously, not even to remember clearly the old one. Once I learnt to see things in a new way, to see more as I experience it, it was not possible to return completely to my old way of seeing. When you have once learnt to see something, you cannot stop seeing it. Knowledge cannot be removed.

The new world-view I have acquired opens for complexity, situating, diversity etc, it gives me ways of understanding and approaching the questions I have. But how to make this 'make sense' for those who have not done the journey that I have? That is the great challenge in this work, and for the future. It is a question of being trustworthy. Therefore, remembering my old world-view, and old language, even if I have left it, is crucial if I want to work with communication, translation, transformation. So I believe I need to stay in both these worlds, to continue living and working on and across boundaries, and to keep both voices inside me alive in order to be able to translate.

If feminist technoscience research and computer science education practice can be seen as two sets, which have been basically disjunct, I want to open up a 'space' not 'in-between', but the intersection[2] of these sets. And this intersection is the space where I want to be, being at home in both worlds – or perhaps both insider and outsider in both? What should such an intersection hold? People, of course both feminist researchers and computer scientists, but also thoughts, ideas, literature, courses, students, pedagogy… I invite the reader to supplement the list!

I started out wanting computer scientists to recognise how much feminist theory, epistemology, research and thinking could contribute to CS. The point where I finish this thesis (which is hopefully the start of a new journey) is the point where I also realise that CS and computer scientists have a lot to teach us as feminist technoscience researchers. There is, as Lucy Suchman writes: "… need for *mutual* learning…" (Suchman 2002, p. 97, my italics). So it is important to do translation in two directions. In

[2] The concept of intersection is taken from set theory in mathematics. If we have a bunch of 'things', and if some of these things have such characteristics that they belong to both sets, then they make up the intersection of the sets. A simple example: let us take the set of all women in Sweden. Then we take the set of computer scientists in Sweden (defined in some way). The intersection of these two sets would be the small, but still existing, set of women computer scientists in Sweden.

paper C2, I have tried to do some kind of mediation of the computer scientist thinking and language for the feminist researcher who is not familiar with this. Once again a spiral movement: the computer scientist translating her world to the feminist researcher who can then translate her language in a more comprehensible way to the computer scientist, knowing something about that world.

To summarise, the journey is from (instrumentally) changing the discipline from a feminist technoscience perspective, where the discipline of CS is the 'object' of the engineer, to meetings of "worlds", finding meeting places or boundary objects in order to co-operate for change. It is a travel from 'hardcore' computer science to seeing and opening up for alternative voices, voices that I have also realised already exist within computer science, though not always visible from the 'mainstream' view[3]. I express it as: From change to translation to transformation. By change here I mean the instrumental 'fixing' and by transformation I want to imply something more radical and thorough, which can only be accomplished by participatory dialogues and projects. And the journey led back to computer science practice and everyday reality.

Feminist research is not some kind of magical 'tool' to 'solve problems' with. I believe that in a way it is much more revolutionary than I had realised, but in different ways.

Looking forward: Feminist technoscience strategies in computer science[4]

In this thesis I have identified three issues as important for feminist technoscience work for contributing to transformation in computer science (or similar fields). I have formulated these as: *crossing boundaries, focusing foundations* and *trying translations.* I will discuss and develop these somewhat more here.

"Worlds" and crossing boundaries

Maria Lugone's concept of "worlds" (Lugones 1990) is useful when talking about crossing boundaries and developing translations.

My experiences during these years are of two quite different "worlds". During my research, I have had to see and accept the differences between these "worlds". Just as I did not realise the differences before doing my "world-travel", I have reason to believe that many people who have not travelled between different scientific "worlds", can not be fully aware of the extent to which there are "discontinuities across our intellectual and professional traditions and associated practices" (Suchman 2002, p. 97).

Writing about different, in ways incommensurate, "worlds", will this lead to unnecessary conflicts and dichotomising? My answer to this is no. I argue that it is necessary to

[3] See the Introduction, where I discuss the delimitations of computer science in this thesis.

[4] These strategies can also be useful for tranformatory work within similar areas, e. g. engineering.

talk about and point to the differences between these "worlds" in order to do translations and participate in transformatory work. It is not to oppose feminist research and computer science that I want to do this, but I believe that if we do not acknowledge some of the actually fundamental differences we might never be able to co-operate for change. Co-operation requires us to see differences, accept them, and even cherish them. As long as we deny the differences, we will not make properly grounded and thought out, but naïve and failed, attempts of communication, which run the risk of doing more harm than good. In that case we will truly be "lost in translation". But if we see, accept, meet the differences, the obstacles, there are also possibilities. If we do not recognise and meet these differences, we can neither see the possibilities, nor do working translations. And if we diminish the difficulties involved in translations, we also diminish, even deny, the work done by those who engage in laborious translation work.

If we face the differences, this will also show how much we have in common, what unites us: commitment and passion for students, teaching, education, for creating a "better world".

Crossing boundaries is to engage in "world-travelling", learning about each other's "worlds". "Travelling to someone's 'world' is a way of identifying with them…because by travelling to their 'world' we can understand *what it is to be them and what it is to be ourselves in their eyes.*" (Lugones 1990, p. 401, original italics.). I highly recommend computer scientists to visit the "world" of feminist technoscience research and vice versa, we should remember that it is about *mutual* learning and translations! But it is also about refusing to accept the boundaries that are set up, and instead challenge them. Who gets to draw the boundaries and where are they drawn? Why are feminist research approaches not seen as 'proper' within core computer science? Those are questions we should ask. The importance of inter/transdisciplinary work on and across boundaries cannot be underestimated.

Translations

Translation is about making feminist research and epistemological perspectives communicable within the community of computer science practitioners. The work that resulted in papers C1 and C2 made me aware of how much is involved in communication and translation between these "worlds".

We speak different languages in many senses of the word, we have different traditions, look differently on concepts such as science, 'truth', theory, practice, reality, subjects, objects etc. It is important to recognise the differences in how we talk about science, learning and knowledge within different scientific traditions, and to make these explicit, in order to be able to address them.

In translation work, awareness of differences between the "worlds" is vital, as well as upholding critical self-reflexivity. It is necessary to move between positions, to be self-reflective, and to "systematically confront [ones] own language games with those of other communities of practice." (Wagner 1994, p. 262).

However, translation is not only about 'big issues' such as epistemology but perhaps even more about the simple words, those words which have become so naturalised

within a scientific community that we might not realise that their meaning is not at all self-evident in another "world". A simple example from paper C2 is the concept of 'construction', which is used in different meanings by the engineer and the feminist researcher. These seemingly small sources of confusion and misunderstandings, so easy to overlook, need to be paid attention to in translations.

Everyday life and work

My conviction is that it is in everyday life and work, everyday practices (e. g. of education) that change can be brought about, in small projects like the one I participated in and discussed in papers C1 and C2. A a concrete result from this project was that two of the participating teachers did their own interventions in their teaching (see paper C1). In everyday work change is already on-going, but it needs to be brought out, made visible and strengthened.

It is about being *situated* in everyday work: epistemologically, socially, culturally, in practice, in every way we can think of. It is about a situated awareness, and a sensitive and critical gaze, an eye for the questions that need to be asked, for the possible alternatives. It is about formulating questions, using partial perspectives and diffracted stories.

Epistemological awareness is not only about the large issues concerning research approaches etc, it is perhaps even more essential in the down-to-earth, grounded, everyday practices of teaching, talking to students and colleagues – i. e. in all activities we participate in. It is an approach and a thinking that needs to permeate everything we do.

In this situated awareness is included to *focus foundations*. This is about asking questions "inspired by feminist technology and technoscience studies. […] questions that might be unexpected and troublesome for some, because [they] … do not take the present arrangements for granted." (Elovaara 2004, p. 214). These questions should be open enough to invite to dialogues. In particular, as I discussed in paper B4, questions that aim at *situating* knowledge are important. Questions such as: Whose knowledge is built into computer software and becomes naturalised? And how can instead knowing situated in social and cultural contexts be represented, so that its situated nature does not disappear into universalising and de-contextualising? By focusing and challenging existing approaches and concepts whithin (traditional) CS it is possible to point out and show how different perspectives give different images and stories. There are always alternative ways of doing things.

Feminist technoscience researchers share a commitment to transformation. This means we have in one way or another a motive and a goal for which we have passion. I believe we need to talk more about passion. And by this I do not primarily mean the kind of passion that is already acknowledged in science and engineering: the passion for the subject in itself. Instead, I want to focus passion for what is often called 'applications' of science and technology: passion for the context of use of technology, passion for making a difference in the world etc. I believe this latter kind of passion is more important than the already accepted and acknowledged kind. Most scientists and engineers do want to participate in the making of a better world. Anita Borg, who was

a distinguished computer scientist, known for her passion for issues concerning women and social issues in computing, wrote:

> "As a field, computing has been driven by technical or scientific goals. […] Imagine the societal challenge driving the investigation…" (Borg 2001 p. 140).

To this I would like to add the "societal passion", or, as Maria Klawe writes: "we need more computer scientists whose passions are art, language, literature, education, entertainment, psychology, biology, music, history, or political science." (Klawe 2001, p. 67f).

Connected to passion is the culture within science/engineering. The cultures of science cannot be separated from the production of knowledge. These are closely intertwined. The traditional engineering culture stresses a view of knowledge production where the user, humans and society might easily be forgotten in the very daily work on some small details of a system. To this is added what Sharon Traweek (Traweek 1988) calls "the culture of no culture". By this she means an abstract, depersonalised culture of objectivity. This abstraction excludes everything that belongs to the social world, such as values and ethics, but also the everyday life of meaning. It is crucial to challenge this "culture of no culture" and instead to work for creating explicit cultures within academia, cultures which promote other views and motives than today. I believe this could contribute to making computer science, engineering and other areas more attractive to a much wider range of students.

Summary of lessons learnt

During the last parts of my research studies, I learnt about what I call feminist technoscience strategies, which I see as strategies towards making change happen. Hopefully, the lessons I have learnt can serve as inspiration and resource for others who engage in interventions and transformations, and as a start for continued dialogues and discussions.

Below is a summary of what I have come to see as important issues:

- Build alliances and co-operation with disciplinary practitioners
- Find 'boundary objects' for communication and start dialogues in issues relevant to the practitioners
- Create dialogues and bring open questions to these dialogues as well as invite questions from the practitioners
- Respect knowledge and experience of people belonging to other "worlds", without losing confidence in my own knowledge and experience
- Illustrate what feminist research perspectives can contribute by using texts and examples relevant for the practitioner. Theoretical issues and questions need to be concretised, grounded in concrete examples
- Learn about, be aware of, respect and work to bridge differences between "worlds" as well as discuss openly possible communication problems resulting from these differences
- Be alert to existing cracks and different approaches in views of knowledge and the subject matter, bring these out and strengthen them
- Use different perspectives to show how these create different images
- Take seriously diversity and multiperspectivity, to see many diffracted images and stories, and see that many of them hold important features. This means that I also need to acknowledge images and stories different from the ones that I see!
- However, do not lose sight of the overarching goal and commitment of change, which means there is a need to distinguish the useful images, those that are true to a responsible and situated knowledge. This is not easy, as Donna Haraway points out: we need "…to have simultaneously an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice of recognizing our own semiotic technologies for making meanings, and a no-nonsense commitment to faithful accounts of a 'real world', one that can be partially shared and friendly to earth-wide projects of finite freedom, adequate material abundance, modest meaning in suffering, and limited happiness." (Haraway 1991, p. 187). It is about being accountable for what we know: "…just not any partial perspective will do; we must be hostile to easy relativism and holisms built out of summing and subsuming parts." (Ibid. p.192)
- Be aware of other critical perspectives and see how perspectives from feminist research can co-operate and make common cause with existing alternative voices from cultures

that might be 'outside' of and not easily visible from within the mainstream of a discipline[5]

- It is essential to maintain self-reflexivity. I would say some constructive self-criticism is also in place. And not give priority to simple explanations, dichotomies or thinking in terms of 'good / bad', 'right / wrong' or failure, but acknowledge and accept differences. All the time, we should keep in mind Lucy Suchman's words about the need for "*mutual* learning" (Suchman 2002, p. 97, my italics).

The tasks outlined here are large, but important. It is about a commitment to working for change; crossing boundaries and working with communication and translation. It is about 'problem solving' in the best sense, if I am allowed to play with that word.[6]

However, it is necessary to realise that fundamental changes take time and endurance. It is in the small, down-to-earth, everyday situations and practices that I believe thoughts, ideas and experiences from feminist research can be used to transformatory ends.

[5] Such alternative voices in computer science exist for example within the Scandinavian school of systems design as well as other (partly overlapping) communities, see the introduction to this thesis.

[6] I believe that Pirjo Elovaara's figuration of angel (Elovaara 2004) is very apt for feminist technoscience strategies in transformatory work. These angels are skilful in most of what I have pointed out as important here.

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