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ABSTRACT This paper investigates four different inclusion strategies used to recruit women to computer science: achieving a critical mass, educational reform, redefining the gendered symbolism of computer science and changing the content of the discipline. The relationship between and the relative importance of these four strategies are explored by looking at the extensive and successful Women and Computing Initiative (WCI) that was run by the Norwegian University of Science and Technology (NTNU), starting in 1996, to recruit and retain more women in computer science. The findings suggest that a direct effort to increase the relative number of women is the most important strategy. While raising the number of women recruited seems to affect the symbolic perception of computer science, this effect is difficult to achieve through attempts to directly change the symbolic image of the discipline. In addition, a substantial increase in the number of women appears to cause an improvement in their learning environment, probably because minority problems such as too much visibility and unwanted attention became less prominent.

Keywords computer science, critical mass, gender, higher education, inclusion

The Strength of Numbers:

Strategies to Include Women into Computer Science

Vivian Anette Lagesen

In this paper, I analyse a seemingly successful Norwegian initiative to recruit more women students into computer science. I explore some of the outcomes and their implications for the understanding of gender issues in technoscience more generally.

Computer science is commonly seen as an archetypical example of a technoscience that has excluded women. For some time, the lack of women in this field has been a public issue in many Western countries (see Wright, 1997; Ahuja, 2002). In spite of these concerns, there has been a trend toward decline in the number of women students. Further, computer science has been characterized as 'masculine' (Rasmussen & Håpnes, 1991; Wright, 1996; Ahuja, 2002; Wajcman, 2004), and it has been argued that this image discourages women from studying the subject (Camp, 1997; Rasmussen, 1997; Wilson, 2003; Wajcman, 2004).

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The study of efforts to recruit or include women in a field such as computer science may provide critical insights about features that discourage women from entering that discipline, as well as similar technoscienctific fields. In this analysis, it is important to investigate not just what features may work to *exclude* women, but also what qualities that may work to *include* them. The concept of inclusion has too often been seen as a mirror image of exclusion, something that occurs when exclusionary forces have been removed. Instead, inclusion should be seen as a process where attractions are at least as important as the absence of negative features (Sørensen, 2002).

Thus, to study inclusion efforts and the underlying understanding of positive as well as problematic aspects may provide a different picture of the relationship between gender and technoscience than the one that emerges from the predominant focus on exclusion that characterizes many early studies of gender and technology (see for example, Cockburn, 1983, 1985; Wajcman, 1991). There have been important insights gained from this research, above all that technology is crucial to the performance of masculinities, and that it can be used to exclude women from attractive occupations. However, an underlying idea of this paper is that an inclusion perspective is more fruitful to further the understanding of gender–technoscience dynamics.

Previous research provides a wide variety of conceptions of the relationship between gender and technoscience, with different strategies for changing the situation of women in higher education in science, engineering and technology (Cronin & Roger, 1999). Arguably, four main categories of strategies for effecting change are prominent: first, educational reform, including improving the learning environment; second, increasing the relative number of women; third, changing the masculine image of computer science; and fourth, changing the content of the field.

The first strategy – educational reform and improvement of the learning environment – has been thoroughly analysed by Margolis & Fisher (2002). They report on a successful initiative at Carnegie Mellon University, one of the leading US universities in the field of computer science. There, the percentage of women entering the School of Computer Science increased from 7% in 1995 to 42% in 2000. In the same period, the university managed to considerably reduce the dropout rate for women to about the same low level as that for men (less than 10%).

Margolis & Fisher (2002) also discuss the second strategy, that of increasing the relative number of women. Carnegie Mellon changed its policy so that admissions criteria did not give a strong preference to highly experienced students, which were usually men. Roberts et al. (2002) make a related point when they describe strategies used at Stanford University to recruit and retain undergraduate women in computer science. Interestingly, their focus was on the *number* rather than the percentage of women. They interpreted this as an issue of critical mass, a function of the number of women participating in that community and thus as an effective means of 'sustaining a supportive peer community among women' (Roberts et al.,

2002: 84). In addition, they sought to provide role models for undergraduates at every level of the education process.

Attempts at educational reform at Stanford included the creation of a popular introductory course and the so-called Bridge programmes, intended to ease students' entrance into a technical field. For example, a summer seminar titled 'The Intellectual Excitement of Computer Science' was offered, which aimed to actively dispel the myth that computer science is only about programming. Another activity aimed at engaging undergraduates to participate in faculty research designed to encourage a deeper involvement in computer science (Roberts et al., 2002). The educational reform strategy in the Carnegie Mellon project included efforts to reduce the experience gap of men and women. In addition, more attention to good teaching was stressed, since failures in pedagogy or curricular integration turned out to affect women disproportionably.

In Norway, much research on gender and computer science has been concerned with the unattractive image of computer science among young women and girls (Rasmussen, 1997; Rasmussen & Håpnes, 2003; see also Gansmo et al., 2003a). The girls perceived computing as an activity predominantly for anti-social boys and men, and thus as incompatible with their image of themselves as young, socially active women. Among women computer science students, the hacker image played an important role in their view of the computer science culture as disagreeable because it involved an obsessive and narrow-minded relationship to computing (Rasmussen & Håpnes, 1991; Berg, 2000; Langsether, 2001; see also Gansmo et al., 2003b).

We also find the suggestion that computer science has to change in order to recruit more women. Kvande & Rasmussen (1989) argue that changing the professional localization of computer courses, from being associated with technical and mathematical subjects to becoming broader and based on social subjects and arts, will increase the proportion of women studying computer science. This assumption is based on the observation that there are more women in computer science programmes that are situated in faculties other than mathematics and science. Similarly, Cronin & Roger (1999: 653) propose to include humanistic and socially oriented features within courses, as well as a greater emphasis on communication skills and technology assessment, and history of science and technology. Consequently, these studies suggest above all the importance of changing the 'masculine' image of computers and computer science, as well as the content of the discipline, in order to undo the tendency to view the field as symbolically 'masculine'.

Changing the Gendering of Technoscience

There are many critical accounts of the problems facing women scientists and engineers, as well as the way that gender influences technoscientific knowledge (see, for example, Haas & Perrucci, 1984; Keller, 1985; Harding, 1986, 1991; Zuckerman et al., 1991; Mayberry et al., 2001; Wyer

et al., 2001). As suggested in the previous section, from the relevant research literature I have identified four main ways to get more women to study computer science. While these four suggestions are not mutually exclusive, it is important to study their relative importance and interdependence as points of departure to develop concrete inclusion strategies for women in computer science and technoscience more generally. To do so, we need to clarify these ideas in a more systematic way.

Educational Reform

The situation of women in technoscience and the question of why so few women enter and stay in many scientific fields have mainly been dealt with in terms of organizational and cultural obstacles (see Haas & Perrucci, 1984; Zuckerman et al., 1991; Sonnert & Holton, 1995; Etzkowitz et al., 2000; Fox, 2001). The lack of women may be viewed both as having to do with discriminatory practices and with flaws in the educational system and student culture. Flaws in education have also been identified as obstacles to women's ability to succeed and to be retained within computer science. Moreover, the notion that women, more than men, need to learn in a meaningful, goal-oriented and contextualized way has been a common critique of programming courses. Such courses have been depicted as repetitive, playful, and meaningless exercises (Berg & Kvaløy, 1998; Balcita et al., 2002; Countryman et al., 2002; Margolis & Fisher, 2002).

Raising the quality of computer science teaching has been seen as important in order to recruit and retain women students. It has been suggested that this could be achieved by employing faculty who enjoy teaching undergraduates, as well by maintaining a stable faculty (Cohoon, 2002), by employing more qualified faculty and using more resources on teaching assistants, and by providing better technical facilities and support (Margolis & Fisher, 2002; Roberts et al., 2002). Providing more female role models is generally seen as very important among most people dealing with this issue (Kavanagh & Richardson, 1997; Roberts et al., 2002; Townsend, 2002). In addition, the importance of networking and support communities has been emphasized (Gabbert & Meeker, 2002). Some have argued that if pedagogical changes are introduced to broaden the scope of computer science, this would also attract more women (Salminen-Karlsson, 1999). Correspondingly, it is assumed that including social and organizational aspects of technology, social issues and a more contextualized computer science would make computer science more women-friendly (Kvande & Rasmussen, 1989; Siann, 1997; Clegg & Trayhurn, 1999; Henwood, 2000).

Critical Mass

'Critical mass' should, in the context of this paper, be interpreted mainly as a metaphor for the potential impact of the relative number of women students. Originally, the concept was based on the assumption that once a

threshold level had been reached, a dynamic process would start that inevitably would lead to increasing numbers. In this regard, critical mass can be defined as the discrete point at which the presence of a sufficient number of women brings about qualitative improvement in conditions and accelerates the dynamics of change (Etzkowitz et al., 2000: 105ff.).

According to Oliver & Marwell (2001: 293), critical mass theory too frequently has been treated as a number of discrete, unconnected assertions. Particularly questionable is the notion that critical mass starts an accelerating enrolment of actors (Studlar & McAllister, 2002). There is also the issue of how many women are needed to have a 'critical mass'. According to Etzkowitz et al. (2000: 106), 'The magical statistics for a critical mass has sometimes been defined as a "strong minority" of at least 15%.' However, their own study of women in academic departments and research units found that critical mass did not always work as assumed, as a means to overcome isolation of women or as a catalyst for further enrolment of women. How women were received by the majority (men), was much more important. Moreover, they suggest that critical mass did work in the sense that a relatively high number of women faculty meant support for women students in science departments (Etzkowitz et al., 2000: 111).

In this paper, I investigate the potential effects on the gendering of computer science of the relative number of women students. In spite of the weaknesses of critical mass theory outlined above, I will use this concept partly to see if that sort of thinking was made use of in the initiative I studied, and partly to find out if some form of dynamic critical mass effects could be observed.

Changing the Gendered Image of Computer Science

The masculine image of computer science has been found to be a serious impediment for women pursuing an education and career in Information Technology (IT) (Stepulevage & Plumeridge, 1998; Wilson, 2003). Particularly among young girls, computers and computer science have been perceived as nerdy or geeky, and associated with computer games for boys and with anti-social behaviour (Rasmussen, 1997; Rasmussen & Håpnes, 2003). Margolis & Fisher (2002) found a 'geek mythology' at Carnegie Mellon University. This referred to the widespread idea among students that a 'real' computer science student is myopically obsessed with computers. They also found that most students saw themselves as different from such a person, but that this mythology was particularly distressing to women. Several US studies have shown that non-IT women graduate students perceived computer science as offering an especially unwelcoming classroom or workplace environment (Weinberger, 2004), and that they perceived computer science students as comparatively unsociable and nerdy (Jepson & Perl, 2002; Beyer et al., 2004).

The hacker figure has frequently been used as a condensed symbol of the way computers and computer science are culturally dominated by a particular form of masculinity (Turkle, 1984; Rasmussen & Håpnes, 1991;

Woodfield, 2000). With regard to the situation in Norway, Gansmo et al. (2003a) suggest that the way feminist research has employed the concept of the hacker has reinforced rather than dissolved the symbolic link between computer science and masculinity. Consequently, they propose 'to forget the hacker'. Still, it remains unclear how this may be done. For example, the question of whether the 'masculine' image of computer science (and other technosciences) may be changed by invoking images and symbols that provide a differently gendered message has not been empirically explored.

Changing the Content of Computer Science

For more than two decades, an important issue for feminist research on gender in science is how the lack of women influences technoscientific *knowledge* (Keller, 1985, 2004; Harding, 1986, 1991). In theory, there is a relationship between the relative absence of women and the presumed gendering of technoscience. Women's minority position has been argued to lead to or to facilitate the dominance of 'masculine' ways of knowing, frequently understood in terms of distance and instrumental objectivity. In turn, this could be seen to reinforce women's minority position, since the dominance of a perceived 'masculine' epistemology in technoscience would make the choice of a career in technoscience feel less appealing for women (Keller, 1985; Faulkner, 2000a).

Efforts have been made to identify the relationship between gender and technoscientific knowledge more precisely by identifying 'masculine' and 'feminine' ways of knowing through exploring the role of for example empathy, subjectivity and caring (Longino & Doell, 1983; Keller, 1985; Hacker, 1990; Sørensen, 1992). In a more concrete way, biological and biomedical research has been shown to be shaped by gender ideologies (Schiebinger, 1993; Hubbard, 1997; Keller, 2004). However, these gendered ways of knowing may not map onto individual men and women. For instance, Sørensen (1992) found that while there was a tendency for men and women scientists to choose different areas of research within their disciplines, there was no evidence that the scientists differed by gender with regard to how they *practised* their research or what *values* they attached to it. Still, some researchers, such as Keller (2004), argue that a de-masculinization of science requires substantial changes in its content.

Research Questions

Based on previous research, I have identified four potential strategies to achieve a larger proportion of women students: (1) educational reform; (2) getting a critical mass; (3) changing the gendered symbolical image of computer science; and (4) changing the content of the discipline. As shown above, previous research offers different accounts of which of these strategies are most significant to increase recruitment and retention of women in technoscience.

In order to explore the relative importance of these different approaches, I investigated a broad, successful Norwegian effort to enrol more women into computer science. This initiative, called the 'Women and Computing Initiative' (WCI), was started in 1997 at the Norwegian University of Science and Technology in Trondheim (NTNU). What makes this initiative so interesting for our purposes was its broad scope of inclusion instruments, which included a quota for women, an advertising campaign that tried to redefine the symbolic interpretation and image of the discipline and, to some extent, efforts in educational reform. The initiative increased the percentage of women from 6 to 38 from one intake year (1996) to the next (1997).

In what follows, I examine the extent to which each of the four strategies was invoked by the WCI, focusing on how each was used, and with what relative effects. In addition, I analyse the interaction between the strategies, and in particular how the relative number of women affected the gendered shaping and reshaping of computer science. Perhaps the most far-reaching question in this context is whether computer science, and by implication technoscience, must be transformed in order to make it attractive to women. To explore these questions, I analyse how the initiative managed to increase substantially the number of women students.

Design of the Study

The study is based on interviews with the main stakeholders in the WCI and with computer science students, in combination with analysis of documents, campaign material, websites and supplementary interviews. The main stakeholders were NTNU's top leadership, the faculty at the Department of Computer and Information Science (IDI) and the initiators of the WCI. Interviews were conducted with eight key informants from these three groups of stakeholders. The informants have been made anonymous. Stakeholder informants are designated by title and a letter, for example 'Professor A', while students are referred to by a chosen first name beginning with the letter K, for example, 'Kristin'.

The informants were invited to give their versions of the initiative, how it started and why. They were also asked to evaluate the initiative. What had been successful? What had not been so successful? What could have been done differently? Further, the informants were asked to give their opinion of the advertising material used in the campaign, and of the critique that certain outsiders have made of the initiative. Written sources included evaluation reports and progress reports made by the WCI team. Particular attention was given to three advertising campaigns commissioned by the initiative (Lagesen, 2003a).

In order to assess the impact of the initiative, 10 women students in their fourth or fifth year of the computer science and engineering programme were interviewed. They were asked about their motivation for applying to the programme and how they had experienced the retention efforts within the initiative. I also asked if they had been aware of or noticed

the advertising campaigns, and if so, how they perceived them. In addition, I inquired about their professional interests related to computer science, and how they experienced the social environment of the programme in general. The interviews with the computer science students lasted one to three hours. I also conducted email interviews with five women who were offered admission to the programme but did not accept, and with eight male students in their fourth or fifth year of the programme.

In order to get a broader perspective, I found it important to get information about relevant outsiders' points of view on the WCI and the gendering of computer science (Lagesen, 2003b). To that end I conducted an additional three sets of interviews: first, with three women who studied computational linguistics; second, with four women students in another engineering programme (Energy and Environment); and third, with two young men and nine young women who attended a large computer party and thus could be considered computer enthusiasts. The 11 interviews with the computer enthusiasts were conducted together with a colleague, Hege Nordli, as part of a field study of Norway's largest computer party called 'The Gathering'. This computer party has about 5000 participants. Girls are in a minority, but their numbers had been growing and had reached a level of 10–15%. We interviewed these young girls about their enthusiasm for computers and the activities they performed at the computer party. We also confronted them with the advertisements from the WCI, because they could be seen as an important target group for the campaign (see Lagesen, 2003b; Nordli, 2004).

A total of 49 people were interviewed, representing quite different positions with regard to the WCI. The interviewees do not comprise a representative sample, but they constitute a varied set of informants. This analysis draws most explicitly on the interviews with the stakeholders and the 10 women who studied computer science. However, the other interviews have been used to check the findings.

The Inclusion Strategy of the WCI

From the mid-1980s to the mid-1990s, the proportion of women pursuing a higher education in computer science and engineering at the NTNU dropped from 20% to 6%. This spurred the idea of starting the WCI. The first activities were implemented during the winter 1996/1997. By the summer of 1997, the number of women applicants had doubled. The proportion of women among first year students increased from 5.7% in 1996 to 37.7% in 1997. It declined slightly since then, but still remained quite high (see Table 1). The table also shows that the total number of students in the programme – women as well as men – increased during the period of analysis.

The activities of the WCI were diverse. At least three of the theoretical strategies discussed earlier were employed. There were efforts related to recruiting as well as retaining women students. Three main instruments were used to recruit women to the computer science and engineering

programme: an advertising campaign that aimed to convince women to apply; an information day for applicants who were admitted; and the allocation of a quota for women.

The strategies used to retain women students included curriculum changes, efforts to improve teaching quality and technical facilities, and various activities designed to improve the social environment for women students. The latter included hiring teaching assistants to organize social events. Overall, the initiative comprised a wide variety of activities (for a more detailed presentation, see Berg, 2002).

It was the newly elected Vice-Rector Professor A who in autumn 1996 proposed actions to recruit more women to the computer science programme. Soon after the WCI was formally launched in February 1997, NTNU's Board passed a resolution of an annual quota of extra places (30 for the first year and 45 for the next) exclusively for women, allowing up to a 10% reduction in credit points to be admitted. The resolution and the preceding process received much criticism and induced a debate about the use of quotas for women. The critique came primarily from students outside the computer science programme. Many were against quotas in principle and argued that admission should be based on merit alone. Some expressed a fear that women admitted by a quota would not be qualified, or would become a 'B-team' within computer science, and some considered them unfair (Teigen, 2003).

It was further argued that the women who were recruited to computer science would otherwise have chosen other engineering programmes, so that the quota simply redistributed women who were badly wanted in other programmes. However, this argument was dismissed when the initiative team showed that the number of women applicants to the other engineering programmes had also increased. They argued that the other programmes probably had benefited from the campaign through a kind of rub-off effect. The B-team prediction was also proved wrong, since all of the women applicants were very well qualified.

Table 1 suggests that the quota greatly increased the number and percentage of women students. I will return to the issue of whether this increase constituted a critical mass.

The team behind the WCI was established in April 1997. They initiated an extensive information campaign immediately. They hired an advertising agency, which worked closely with the initiative manager and

Table 1.
Share of women in the CSE programme at NTNU.

Year	1996	1997	1998	1999	2000
Women students (%)	6	38	34	33	28
Women students (%)	6	50	67	96	107
Total students (*N*)	100	132	203	290	382

Source: http://datajenter.ntnu.no/resultat.php

one of the IDI faculty staff. The campaign consisted of a screen advertisement shown at cinemas, a website and information brochures. The campaign was funded by the Confederation of Norwegian Business and Industry and some large Norwegian companies. It consisted of a brochure and a screen advert. The brochure was sent to girls, science teachers and advisors at 326 different upper secondary schools, while the screen advertisement was shown at all cinemas in Norway for one month.

Following the success of the first year, an expanded, national advertising campaign was carried out for the following year, which sought to motivate women to apply to computer science at *all* of the Norwegian universities. That campaign was funded by the Research Council of Norway and the ICT industry. The advertising material was widely distributed, and it also received a lot of attention from the news media. A third campaign was undertaken by the WCI as part of the university's general advertising efforts to recruit new students from 2002.

Another local action was the 'Women's Day', organized by the WCI in collaboration with the Student and Academic Division at NTNU. All admitted women applicants were invited to visit NTNU and offered a comprehensive presentation of the Department and the University. They heard talks from women working in the ICT industry (who were supposed to serve as role models), attended popular science lectures, and participated in an Internet course and other activities. The idea was to make the programme visible and to demonstrate the good social environment among the students. In spring 1997, 52 women participated. All expenses were covered by NTNU. Approximately 80% of those who took part in the 'Women's Day' accepted the offer and began to study computer science.

The advertising campaigns deserve particular scrutiny because they represent conspicuous and direct efforts to change the image of computer science in order to make it more attractive to women. In addition, the high profile of the campaigns shows that the WCI spent a lot of money on an effort to symbolically redefine computer science. In fact, Professor A told us how impressed she was with the agency's ability to transform the WCI's ideas into catchy slogans.

To give an impression of this strategy of symbolic redefinition, I will briefly describe two of the campaigns (see Lagesen [2003a] for a thorough analysis of all three campaigns). The first was a brief film advert about a young man (Tom) and a young woman (Linda). The picture of a young man appears on the screen. The text says: 'This is Tom. When Tom started the computer science programme he took one hour to get into the database of the Pentagon. Today it takes him only ten minutes. Well done, Tom!' Then the picture of a young woman appears on the screen and the text says: 'And this is Linda. Linda knew nothing about computers. Today she talks to people, analyses problems and solves them. Besides, she can get into the database of Pentagon – if she wants to.' The punch line of the third and final picture is: 'The computer science programme is more about human beings than about machines. NTNU wants more women in computer science.'

The second campaign featured a brochure. Its front page carried a striking image: in the foreground the figure of a young girl stands behind a circle, looking outwards; and in the background, a young man stands behind a square looking outwards. The text reads: 'Women make circles, men make squares. The universities want more computer science students that make circles.' The brochure claims that it had been made by young women who have studied computer science. The text is narrated as the voice of these women, addressing young women readers directly, telling them why they should choose computer science. In between, there are portraits of young women who study or have studied computer science, quoting them on how successful their choice has been. The brochure was printed on glossy paper, and in a fashionable design.

In the text, two main arguments were presented to persuade women to study computer science: first, that the social consequences of the work done by computer scientists are too important to be done by men alone; and second, that computer systems will be better adjusted to users if women make them, because women are more attuned to utility. Men often become too occupied with technical aspects and details, the text argues. Women, on the other hand, are perceived differently:

> Women listen. Women talk to each other. Our experience is that women ask 'why'-questions, like: What is the point of this button? Who will benefit from this function? How will the user understand how she begins? 'Listen!' women say. 'This is too difficult! We must make the system easier!' ... This is why we want women. This is why the skilled staff of a department are ready to welcome you. Because it seeks what you've got: femininity.

In earlier work (Lagesen, 2003a) I presented an extended critique of the gender politics of the advertising campaigns, focusing on how they created highly stereotyped and dichotomous images of men and women and their relation to computer science. As a part of the re-gendering effort, the campaigns attempted to redefine computer science from a technicist, 'masculine' stereotype into a communication-oriented, 'feminine' stereotype by arguing for the superior importance of human communication and relationship skills. We recognize the familiar binary of technology skills versus people skills (Faulkner, 2000b), but in the campaigns the latter were given priority (see Woodfield [2000] on a similar effort). Thus, the WCI produced an image of computer science where computers had been moved backstage. Assumed 'feminine' qualities, such as communication skills, orientation toward users and empathy, were used to provide new metaphors for the profession. In the same move, women were attributed presumed progressive qualities based on gender stereotypes.

Consequently, women were invited to take part in the computer science profession, not because they really were interested in computer science, but rather because of the essential 'feminine' qualities they were presumed to have. Men, on the other hand, were denounced as hackers, perhaps as a way to invalidate a potent assumption in the symbolic

masculinity–technology constellation. Hence, a dualist split between a 'feminine' and a 'masculine' way of dealing with computer science was constructed, reinforcing a link between, on the one hand, 'femininity' and people skills, and on the other, 'masculinity' and technical skills. In turn, these two sets of qualities were hierarchized, but in reverse to the normal hierarchy. 'Femininity' and people skills were ranked above 'masculinity' and technical skills.

The redefinition strategy of the WCI may be viewed as a way to position women in the ICT field as carriers of competence really needed by the industry. Thus, it was an effort to create a space for women in the computer science profession as particularly useful people. It also provided arguments alternative to those of equal opportunity, to legitimize their presence within the profession. In this sense it might be viewed as highly effective to focus upon stereotypical 'feminine' features as important and valuable resources for becoming a competent computer professional. On the other hand, the naturalization of this version of femininity reinforces traditional figures in gendered politics (Keller, 1985; see also Woodfield, 2000).

The Shaping of the Initiative

The attempts to reform computer science education through the WCI were less prominent. The curricular changes instigated by the initiative were minor. Some adjustments in one of the introductory courses were made, and a module aimed at contextualizing computer science was developed, called 'Know your subject'. The students visited companies and were required to learn to use electronic meeting rooms and to design web pages in which they wrote about what they learned from the visit. Further, teaching capacity was improved by increasing the number of teaching assistants and by making sure that there were as many women teaching assistants as possible.

Thus, there was a limited effort to improve the learning environment and even less was done to change the content of the discipline. The relatively low priority given to educational reform raises the issue of the way in which the WCI was shaped through stakeholders' ideas about the problems at hand and how they interacted. To pursue these questions, I shall analyse the stakeholders' accounts about the background of the WCI, what they perceived the problem to be and how they considered the outcome. This provides an interesting glimpse into the way WCI stakeholders defined their challenges and set their priorities. In particular, I shall analyse their ideas about the teaching and curriculum reforms.

As mentioned above, Professor A, the newly elected Vice-Rector, initiated the WCI. She told us that she did it because of her concern about the low number of women in a very important technological field. But that was just one part of her argument. She also saw the initiative as a way to 'heal' what she perceived as an incipient harmful culture at IDI. According to her, the male-dominated environment at the department had facilitated the

hegemony of a hacker culture, which marginalized the women students and also discouraged other men and women from applying.

Further, Professor A said she had received signals from people in the Norwegian ICT industry that they were not really satisfied with the graduates they received from NTNU. The industry wanted more women 'because they wanted computer engineers who could communicate, who could grasp the customer's needs and who could do more than just sit in a dark room and program'. In order to be able to attract women, NTNU had to do something different:

> We could not just shout to society: 'Please girls, enrol in computer science!!', because there were no reasons to enter computer science! It was a hacker culture there, right? So the women with good grades would rather go to Technical Design or Medicine. So, in order to get women to computer science we had to do something completely different. We had to advertise, we had to change the programme and to make certain arrangements so that it was guaranteed that we got some attention from young women.

This was how the idea of a quota for women as well as the advertising campaign emerged.

Among the faculty at IDI, the young Professor Y was part of a group that was highly motivated to change the educational strategies of IDI. He, as well as others among the committed younger people, including Professor Z, had also worked hard to develop a so-called 'quality reform'. This aimed to apply a more critical perspective in their teaching. Professor Y wanted to make the programme more applied and to enhance teaching quality and the level of information about the discipline given to students during their first year of study. He and the others also wanted to include some new elements into the programme, such as history of technology and social science.

As previously noted, when Professor A brought forward the idea of the WCI, IDI was very receptive. According to Professor Y, IDI had 'the motivation, the consciousness and the wish to reform ... The quota was just a part of a larger plan ... We wanted to use the quota to bring about changes in the study programme.'

This was Professor Y's vision, and the WCI fitted into it. In a way, he was offered the opportunity to use an argument about gender to legitimize changes in the study programme and, to some extent, in the content of the discipline. The need for a better programme was thus linked to the problem of enrolling women students, because this looked like an argument that would help realize the other goals:

> The nerd-like sub-groups dominated more and more. Not only had the women disappeared, but also the sensible boys. We were left with people who were unfit in a programme that was about making things for people. The candidates did not fit with the profile of the programme. Before, the programme used to be gender neutral, and there were a lot of women and a very different environment.

In this regard, Professor Y shared Professor A's concerns about the hacker culture. He was of the opinion that the pre-WCI change in the student body had been threatening the development of the programme.

However, not all of the staff at IDI shared Professor Y and Professor A's view that there was a hacker culture at the department, or that the programme had to change. For Professor B, the head of department, the call for more women students was mainly a resource argument:

> We thought that our programme did fit women, and we also wanted more women in the programme. We had professional reasons for wanting more women. You see, we do not only follow the laws of nature here. Computer systems are the work of human beings more than most other things, and we wanted women to contribute in the process as well. Because, even if we work with technology, we also deal with many other things. We interact with values, languages, communication and visual design. And all this made us want to include the reservoir of ideas, knowledge, values and attitudes that women possess into the discipline. It was very 'deep-rooted'. We wanted more women in order to develop the *discipline*.

Professor B emphasized that the hackers or nerds were not important to the department or representative of the men students. The hacker culture, he said, was a myth created by outsiders, especially sociologists ('who wanted to make themselves interesting'). Therefore, he also admitted that the advertising campaigns had been unfair towards the men students:

> Yes, it is unfair! It is unfair to the men students because I think they more or less have the same values as the women, actually. A bit modified ... That brochure was maybe ... perhaps it was the price we had to pay ... in order to push things to extremes. I think the men students coped, but it has not been fair to them ... the world isn't fair.

He interpreted the fact that relatively few of the women who entered the IDI programme had dropped out as proof that they were satisfied with the programme, both socially and professionally. He did admit, though, that the programme had made some adjustments in the teaching capacity and the technical equipment. However, he argued that this was basically because of the responsibility towards the women who had been 'specially invited'.

As we see, Professor B's interpretation of the initiative, as well as that of the previous Head of Department, Professor C, was different from those of Professor Y and Professor A. They did not see a need for a change in the curricula for computer science, but rather assumed that women students would learn to appreciate the programme as soon as they were admitted. Professor B saw the low number of dropouts among the women students as proof of this assumption.

The alliances made through the initiative were interesting. Professor A made clear her feminist motives. Professor Y showed a great commitment to the need for a revised curriculum, and he saw the WCI as an opportunity to achieve change. The argument to support curricular reform referred

to the hacker culture as well as the problem of recruiting women. Professors B and C mainly wanted to expand the department by raising the number of students. For them, the WCI was a great opportunity to do that (and at the same time to be perceived as a woman-friendly department). In addition, Professor B argued that more women might have a positive impact on the discipline. Thus, the stakeholders had complex and varied motives for their engagement. Nevertheless, these motives meshed sufficiently for WCI to be effectively anchored among all stakeholders. However, as discussed earlier, the initiative did meet with strong opposition and received a lot of criticism, especially from students at NTNU outside IDI. According to stakeholders, this contributed to uniting IDI. Professor B put it this way:

> There was no disagreement among the faculty, as far as I remember. Everyone supported this, we had a general meeting among the computer science students and mathematics students. The students, who were most involved, were most positive ... The majority of lecturers, research fellows, students and the administration have been positive toward the initiative. It does expose the whole environment, right? It is a very good way to reach out.

It also united the Rectorate and IDI in their common struggle. Professor A emphasized how the support of the faculty at IDI had been invaluable in the most turbulent stages of the WCI.

Despite the critique (or perhaps as a response to it), the WCI has been regarded as very successful by all stakeholders. Professor Y was an exception, because he had hoped for more far-reaching educational changes, with a greater focus on recruitment of younger women to science subjects in general, and above all more extensive curricular reforms in the programme's first two years. As mentioned earlier, Professor A was also satisfied with the initiative, even though she too stated that she had wanted more changes in the curriculum.

From a gender and technoscience perspective, it is interesting to note that the leadership of the department went quite a long way in accepting Professor A's feminist-inspired reform strategy. They consented to a quite radical advertising campaign that provided a symbolic link between computer science and 'femininity' and ridiculed men. They agreed to a quota for women students. Several of the stakeholders, also within the department, thought educational and curricular reform would have been beneficial. But the department leadership did not see this as necessary. In fact, they argued from the success of the WCI that such changes were not needed to attract women students. They came anyway, through the quota and the information efforts.

One could have anticipated that the inconsistency between on the one hand, the symbolic redefinition efforts of the advertising campaigns to make computer science appear 'feminine', and on the other, the lack of change in a programme (that the same campaigns had rendered problematically 'masculine') would create problems for the women students who

entered the programme. They could be expected to experience frustration emerging from this discrepancy: the promise of a 'feminine' education versus a 'masculine' reality. How did the recruited women students account for this situation? More generally, how did they react to the campaign itself and its efforts to redefine computer science as 'feminine'? To what extent did they appreciate this strategy?

Finding a Place: Experiences of Women Students

As we have seen, the stakeholders considered the WCI successful. However, the women students provided more critical descriptions of their choices to study computer science/engineering and their perceptions of the inclusion activities.

In the following, I will present some of their stories, particularly those that give insights into which features of the WCI they appreciated and how they had become motivated to study computer science. As noted previously, the advertising campaigns put great emphasis on producing an image of computer science that was less technical and more concerned with people. Accordingly, I assumed that at least this would motivate some of the women, and that their alternative education option would have been non-technical.

However, Katrine, like most of the other women I interviewed, told me that she initially wanted to become a graduate engineer. She decided that after studying mathematics for one year at the University of Oslo. Here, she found that she preferred an education where teaching was more structured than she had experienced during that year. She also wanted to study in a new place so she could meet new people. She thought it would be easier to take part in and enjoy student activities if she moved to Trondheim (where NTNU is located). Her main preference was to study something where mathematics and physics were important. An engineering programme at NTNU seemed a good choice, because of its status and prestige. She had not really thought of computer science previously. However, when she saw the WCI advertising campaign and since she had always 'done some computing', she thought 'why not?'.

Katrine's account of her motives and reasoning contained many elements that were typical of most of my informants in this group: they were interested in science and mathematics, they were motivated by future career opportunities, and they had some, but not a strong, interest in computers. Their route to computer science was through a more general interest in 'some kind of' engineering programme.

In addition, almost all of these women were influenced by the WCI, but the impact was mainly to make them choose computer science rather than some other form of science or engineering education. They were not persuaded by appeals to interests in people or communication. This point was emphasized by Karen. She told us that she entered at the programme because of the WCI advertisements. She was quite sure that she wanted to get a master's degree in engineering, but she did not know which

programme to choose. Then she saw the Circles and Squares brochure, where it said: female qualities, we want women, big words like that. So she swallowed the bait, as she said. In addition, Kristel said that she wanted to get a master's degree in engineering. She had originally put mathematics and physics as her first priority. But she changed her mind, and then she read about the quota and saw an opportunity to be admitted to computer science.

A few of my informants, such as Kamilla, gave the impression that they were motivated by a specific interest in computer science. Kamilla could not remember what she had thought about the quota when she applied. She said she believed she knew about the WCI, or perhaps she just heard that they were trying to recruit a lot of women. But it was not vital for her whether there were many other women in the programme.

Kristin also emphasized an interest in computer science. Initiallyshe studied physics and mathematics at the University of Oslo. Then, by chance, she took a course in programming, which she enjoyed very much. From that experience, she decided to enter the computer science and engineering programme at NTNU. She had not seen the advertisements when she applied.

These women attributed variable significance to the fact that there were many women in the computer science and engineering programme. Some were positive, some quite indifferent and one was negative because she was used to being in a male-dominated environment, which suited her well, she said.

To summarize, the recruitment campaigns seem to have had a substantial impact on these women's choices, but mainly by making them choose computer science rather than some other science or engineering degree program. This is evident from the fact that many of the women started out with the wish to become a master of technology, mainly because of the prestigious title and, in turn, good job prospects. They combined this with an interest in mathematics and science subjects. The campaigns do not appear to have succeeded in recruiting women who were not already interested in pursuing a career in science and engineering.

The WCI made my informants aware of the computer science and engineering programme. They reacted positively to the message that computer science had good career prospects, and that this was a programme that particularly invited women. Not everyone recalled having seen the actual brochures, but most seemed to have been in touch with the WCI, directly or indirectly through hearing about it from friends. Kaja said she was recruited by a women friend, who relayed one of the campaign's main messages that previous knowledge of computers was not needed. Substantial media coverage of the WCI also appeared to be important for enhancing recruitment (see also Berg & Kvaløy, 1998).

However, none of the informants remembered being attracted by the effort to redefine the gendered meaning of computer science, arguably the major message of the advertisements. Their main interpretation of the campaigns was as an invitation or reminder that it would be a good idea for women to study computer science. The effort to redefine computer science

as people-oriented rather than as technology-focused did not 'speak' directly to their motivation. Karen was the exception, saying she was attracted by the campaign's message about women being good communicators.

Some informants viewed the advertisements' play on gender and computer science dualisms as catchy and entertaining, but they did not really approve of such messages. They also appear to have overlooked the message that women were particularly suited to study computer science, perhaps translating it to mean that 'we want women to apply'. When questioned about this, they said that they would avoid the kind of dualistic gender stereotypes used in the advertisements. This may have been because they wanted to be valued for their individual qualities, not because they were women. To the extent that they saw gender to be relevant to the culture of the department, they did so reluctantly and even paradoxically.

This may explain why women students in the programme did not report the frustration I expected about computer science education not being the 'feminine' option they were promised. Mainly, they did not really appropriate the message of computer science as particularly fitting for women. One exception was Karen, who expressed disappointment about the programme because she experienced it as more technically oriented than she had expected from the campaign.

Activities to Retain Women: Changing the Experience of being a Woman Computer Science Student?

The WCI aimed to retain women students by, among other efforts, establishing a computer laboratory exclusively for women, called 'Cybele', assigning a woman lecturer to the introductory course, establishing a course on future jobs for graduates and scheduling lectures by women practitioners who were supposed to serve as role models. Additional efforts were made to improve the social environment of the programme.

Generally, all the women computer science students I interviewed expressed favourable views of the programme and the environment. They were positive toward many of the efforts that had been made to increase the number of women, and said they thought the situation of women students must have been improved over previous years when there were only 5–10 women in a class of 100 students. Even if they felt that they had received particular attention from the 'outside' because of the WCI, they believed that the men students favoured the initiative and the quota, because the increased number of women resulted in a better atmosphere:

> I think it [the quota] is positive for both boys and girls. I think the boys are very happy that there are not just boys in the class. That would be like being back in the army ... the culture becomes much better. (Kari)

> They know ... that it is not such a big difference in the marks from school between those admitted on the quota and the others. So, they know that we are not inferior to them. (Kaja)

Kaja's comment even dismisses a concern, mentioned earlier, that the women's qualifications might be devalued. She and others also complained that they became tired of all the focus on women. Kaja had worked as a teaching assistant for 2 or 3 years, where she and others had tried to organize activities such as social events and courses for women in the programme. When I asked her whether these things had worked out, she said:

> I don't know if I can comment on it now, because I really have it up to my throat at the moment ... I have been so intensively engaged with all this women, women, women for three years. So, this last year and six months, I did it primarily because I could use the money. So, it became a little bit too much. But it works fine for those in their first year of study. They are very happy that there is a community there, and that they can participate in courses, lectures and such.

However, the women students I interviewed expressed ambivalent views of the Cybele laboratory. Some said it was okay, while many deemed it unfair to the men students. None of the women said they used the laboratory very much, except to check mail or use the scanner. They would normally employ other computer laboratories for their work, because they usually collaborated with other (men) students, who were not allowed to use the laboratory.

Overall, the effects of the retention efforts seem to have been limited, but the women students appeared to be reasonably satisfied both with the culture and the education offered in the programme. The dropout rate remained low, and there were not many outspoken complaints among our interviewees. Rather, it seems as if the women students very much appreciated the fact that they were no longer a small minority. Thus, one could argue that they had reached a kind of critical mass that facilitated a peer-supportive community. Accordingly, it appears that the main reason that the WCI should be considered a success was their quota strategy and the efforts to make women feel wanted. How may we understand this in relation to the theoretical assumptions introduced earlier?

Changing the Image of Computer Science or Benefiting from the Strength of Numbers?

I began this paper by outlining four interrelated ways to address the problem of getting more women to pursue and receive degrees in computer science. These also represented four different strategies for achieving inclusion. The first addressed problematic aspects of the hacker culture and weaknesses in teaching, by arguing for educational reform. The second was concerned with the lack of a critical mass of women students. The third argued the need to alter the 'masculine' image of computer science. The fourth took its point of departure from feminist critiques of technoscience and addressed the need to change the content of computer science to accommodate women's interests.

Clearly, the WCI was initially designed to pursue all four strategies, even if stakeholders held different priorities. However, the main efforts drew on the second and third strategies: they tried to create a critical mass (through the quota and the Women's Day) and, through the advertising campaigns, to change the image of computer science to become less technical ('masculine') and more relying on social skills ('feminine'). The need for improving the learning environment was agreed upon by most of the actors behind the initiative, but the efforts were modest, since strong actors in WCI believed that changes in the content of the discipline were not needed. Consequently, the fourth strategy was not pursued, except for smaller adjustments.

The WCI included some efforts to improve the learning environment for women students. It seems as if the teaching assistants and the work performed, such as setting-up extra courses and arranging social events, supported community building among the women students, and thereby reduced the number of dropouts. As mentioned, the women students offered positive comments about improvements in the learning environment, strongly related to the fact that there were more women. This may be interpreted as if the quota was also important to improve the learning environment.

What about the advertising campaigns and their attempt to change the image of computer science? No doubt the WCI helped to recruit many women, and in this regard it was a success. But was the success due to the advertisements? Most of the women I interviewed had noticed them, and many who actually entered the programme told me that they had been influenced by the advertisements when they chose computer science and engineering, rather than other programmes at NTNU. However, they were mainly attracted by the career prospects and relatively high status of the degree. It also was important that the advertisements signalled that women were welcome in the programme and implied that there already were many women computer science students. Many also appreciated the message that they did not need to have extensive knowledge of computers to succeed in the field.

The advertisements used a people-oriented rather than technical approach to make computer science attractive to women. The students I interviewed did not seem to appreciate this effort either. The women students' choice to study computer science was generally grounded in a prior strong interest in mathematics and science. Consequently, to construct campaigns with the assumption that women are not really interested in science and technology, and that they prefer to work only with people, may actually perform a disservice to some women. First, such campaigns do not provide interested women with the motivation and information they feel they need. Second, they reinforce traditional images of women that may not apply to many potential applicants. Why should traditional women make untraditional choices?

The women students emphasized that the advertisements made them feel welcome as computer science students, and they remained generally positive about the initiative. It is tempting to interpret the success of the WCI also to be strongly influenced by the mere attention given to women in computer science. The highly visible initiative to recruit more women to computer science seems to have persuaded many to choose that programme, probably also because it implied that there already was a considerable number of women in the programme. Perhaps, in the end, the most successful inclusion effort was to raise the number of women?

However, the high percentage of women students was not self-sustaining, nor was there any sign that a critical mass had an accelerating effect for recruiting even more women. Professor B told me that at one point the WCI had tried to reduce the inclusion efforts, but promptly experienced a downturn in applications. He meant there was no reason to think that they could manage to recruit women without such extra efforts.

Conclusion

The analysis of the WCI did not support the assumption that computer science as a discipline had to change in a fundamental way in order to recruit women students. In addition, the efforts to redefine computer science as symbolically 'feminine' appeared not to have been particularly successful as a recruitment strategy. The increase in the number of women students was mainly achieved through the use of a quota, combined with efforts that aimed to make them feel welcome and appreciated.

However, the observed effects did not support the theory of critical mass, since the fairly large number of women was not self-increasing or even self-sustaining. While the theory predicts that there may be threshold effects, the main issue is what is achieved when this threshold is reached. My analysis suggests two such achievements. First, when the number of women is sufficiently high, they no longer see themselves or are seen by others as a small minority that risks being marginalized or becoming token (Kanter, 1977). This is also commonly observed in the literature about critical mass. Second, when the number of women is high, the symbolic image of the field changes from 'masculine' to more neutral or gender diverse.

The second observation points to the importance of the symbolic properties of numbers. It is commonplace to describe computer science as 'masculine' and to use the apparent symbolic identity between computers and 'masculinity' to explain why women shy away from the field. However, my analysis of the WCI shows that a sudden influx of a relatively large number of women computer science students affected the symbolic interpretation of that field, at least among the students. They apparently did not consider studying computer science to be 'masculine'. This suggests that the gender symbolism is much more dynamic and fluid than held in the literature on computers and 'masculinity' and is related in a

straightforward way to the relative numbers of men and women. Another example of this is a study that shows how computer science was considered a typical female subject among computer science students in Malaysia, where women generally outnumber men (Lagesen, 2005; see also Sørensen & Berg, 1987).

Consequently, it may be more accurate to characterize the threshold effect as a *degendering mass* – the proportion of women in a technoscientific field that changes its symbolic interpretation from 'masculine' to a more open gender coding. However, this concept implies no assumption about accelerating effects or of a stable redefinition. Such a point may seem prosaic, but true; when men dominate a field numerically, the field is coded as 'masculine'; when women dominate, the coding becomes 'feminine'.

However, this argument should not be confused with a liberal (and reductionist) point of view that gender inequality is only a matter of numbers, which may easily be changed. In fact, the achievements of the WCI demanded large efforts and the consistent use of radical instruments, such as the quota for women. An important feature of the WCI was also that it was positively received among all involved parties, not least the men students. This ensured that the women students felt welcome and appreciated, which is important (Etzkowitz et al., 2000).

Still, the point is that a numerically weak position of women frequently seems to produce a symbolic image of the discipline as 'masculine', which in turn may reinforce the minority position of women. Thus, increasing the numbers will facilitate changes in the gendered symbolic image of objects or fields, at least by obscuring the gender-related images. In turn, this seems to produce more space and freedom for the minority group, in this case women.

We also saw that a large increase in the number of women students in computer science at NTNU brought about a fundamental change in the social environment. When women were no longer a minority, they found the learning environment more positive. The 'nerds', previously observed to be a problem for women students at NTNU (Rasmussen & Håpnes, 1991; Berg, 2000), were no longer considered troubling (for details see Lagesen, 2003b). Thus, the positive impact of the large increase in the number of women resulted from the way numerical change works through other phenomena, such as those discussed in this paper. Apparently, this is true both for the gender image and for the learning environment.

Perhaps the main lesson to be learnt from the WCI is that the so-called image problem in computer science cannot be changed only through efforts to critique and redefine the gendered image of the discipline. It seems that such change may best be obtained through measures, such as quotas, that more directly recruit women, or through actions that directly change manifest appearances of gender, such as providing more role models. It is certainly also important to enhance teaching quality, since this eases entry into the field (Margolis & Fisher, 2002; Roberts et al., 2002). Finally, one should never underestimate the importance of actively demonstrating a positive concern to include more women in fields where they are underrepresented.

Notes

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