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Using new technology to re-construct gender

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Organizing in Action Nets

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Introduction

The relationship between gender and technology has been explored for several decades. Consistently, the field of technology has been described as being permeated by masculine discourses (Cockburn, 1983; Haraway, 1991; Cockburn and Ormrud, 1993; Grint & Gill, 1995; Henwood, 1999; Faulkner, 2000a; 2001; Wajcman, 2004), which find expression in the cultural tendency to treat technological work as an almost exclusively masculine domain. This tendency has been viewed as contributing to gender blindness and has given rise to claims of gender neutrality with regard to job segregation, often resulting in women's exclusion from technical, scientific, and technological education and professions (Wajcman, 1991; Henwood, 1993; Vehviläinen, 2000; Berner, 2003a). A later line of thought claims, however, that both gender and technology are socially constructed, and that gender and technology are mutually constitutive (Ormrud, 1995; Faulkner, 2000b; 2001).

Although there are many attempts to understand technological and social phenomena (Latour, 1987; 1996; 1998), some researchers still claim that the gendered relationships between technology and organizing need to be further scrutinized (Lohan & Faulkner, 2004; Mellström, 2004). In the same spirit, Henwood and Miller (2001) assert that science, technology and gender remain a black box within, for instance, education research. ”Black box” is a metaphor used by researchers within Science and Technology Studies (STS) to refer to the taken-for-granted ”social and cultural practices which constitute science and technology” (Whitley, 1972; Henwood & Miller, 2001:237; Bonner & Chiasson, 2005). As few feminists have peered into the black box of technology, the mutual construction of gender and technology is an area yet to be explored (Sørensen & Berg, 1987, Faulkner, 2000a; 2001).

Technology is part of organizing processes because ”patterns of organizing are inscribed in technology and the ways in which organizations inscribe the technical worlds they produce” (Joerges & Czarniawska, 1998:364). Nevertheless, organizing is mostly interpreted along symbolic and political dimensions, which leaves its material dimensions unexplored. In actual practice, however, technology is an important part of organizing (Knights & Vurdubakis, 2005). Contemporary organizations inscribe institutional order into their products. Being a producer of social relations and of products and services, the modern organization manufactures and diffuses the institutional order, as Joerges and Czarniawska (1998) have pointed out. In the context of this paper, it can be added that, as gender and technology are mutually constitutive, this institutional order of which technology is a part thus becomes a *gendered institutional order*.

In this paper I treat technology and gender as mutually constitutive, and illustrate this assumption with a case in which gender was re-constructed through the use of computers in physics education. Inspired by the ANT methodology (Bonner and Chiasson, 2005; Czarniawska & Hernes, 2005), the study aimed at scrutinized the black box of technology and gender construction. The findings support the initial claim that the construction of technology plays a crucial part in the construction of gender. The same findings further indicate that, under certain circumstances, an attentive and gender-sensitive use of new technology can contribute to changes in the construction of gender. The case also shows that the gender-blind use of new technology actually perpetuates gender inequality. By initiating a discussion about the role of machines in making gender construction in organizations durable, this article is meant as a contribution to the theory as well as to the practice of systems development and gender equality work.

The results of the study also add yet another dimension to the relationship between gender and information systems (Alvarez, 2002) by implying that gender dimensions are built into the system as such, thereafter reproducing and upholding the construction of gender. By the same token, an information system may support changes in the practices (see also Vaast & Walsham, 2005:71), in this case the practice of teaching physics with IS, but also changes in students self-perceptions.

In order to provide the study with a context, the following section contains background information about gender, information technology (IT), and the labour market in Sweden. Then a theoretical framework, based upon literature in gender, technology, and education, is presented, followed by a section on method. The case – the physics project – is then presented in two parts: before and after the reorganization. The results are discussed in relation to the reviewed literature. The article concludes with answering the research question. Based on this answer, follows a discussion of the possibilities of gender re-construction in the context of changes in institutional order.

Background: Gender, IT, and the science labour market in Sweden

Sweden often scores high in international comparisons on gender equality but, in spite such scores, its labour market is not gender balanced (Sundin, 1998). Although both men (82%) and women (78%) take part in working life, the Swedish labour market is gender segregated in the sense that women work primarily in public administration (75% of the labour force) and less in private companies (40% of the labour force). Since the 1970s, various efforts have been made to promote science education for women. Stimulating equal interest in science among boys and girls has been an explicit aim of the Swedish government since the 1990s (Berner, 2003a). Today, women comprise 25% of all students in university science examinations, including computing.[1] Even though women are sought after to work in, for instance, computer companies, the principle of ”last in first out” in downsizing situations strikes women hard, as they comprise a majority of the last employed (Peterson, 2007).

[1] See www.scb.se, accessed 1 March 2007.

Simultaneous to these efforts, there has been effort to diffuse electronic technology inventions, following the development of computers and the Internet. During the past decade, the Swedish Foundation of Knowledge and Competence (SFKC) spent nearly 150 million Euros to build better infrastructure for IT in Swedish elementary and secondary schools. This sum was matched by the participating municipalities, bringing the total to 300 million Euros. The main purpose of these investments was to develop IT as a pedagogical tool in the schools. One of the intermediate goals was to work for increased gender equality. The project, chosen for focus in this paper is called ”Physics for Girls and Boys”, began as an SFKC-financed investment project, thus being one of the attempts to achieve this intermediate goal.

Accordingly, the focus of this article is on gender construction in a specific area: the physics interests of secondary school girls. Politicians and researchers alike have claimed that attitudes towards technology and science influence work opportunities for women and men (Henwood, 1996; Berner, 2003a; Küskü, Özbilgin & Özkale, 2007). Schools provide girls and boys with a basic knowledge of technology and help them to form their attitudes about technology. It has been suggested that if schools can help increase girls' interest in technology, the construction of gender in society may change (Henwood, 1996; Henwood & Miller, 2001; Berner, 2003b). Again, politicians as well as researchers expect that an increased interest in technology and science will motivate girls to apply for scientific education, and that an increased number of women in the sciences will change the institutionalized gender construction in the Swedish society.

Gender construction in science education

The particular black box in focus here is physics education. As science education has been known to be favored by boys, the gender construction in these education programs has been repeatedly scrutinized (Calabrese Barton, 1997; Brickhouse, 2001). Parallels are often drawn between such programs as engineering, technology, and computer science (Siann, 1997), and I follow this categorization here. The research in this area concerned gender aspects of students' choices of programs (Sørensen & Berg, 1987; Turkle, 1988; Rasmussen & Håpnes, 1991; Faulkner, 2000a), gender aspects in the course of technical studies (Robinson and McIlwee, 1991; Henwood, 1996; Siann, 1997; Faulkner, 2000a; Kleif & Faulkner, 2003; Küskü et al., 2007), and even gender aspects of physics programs (Pol, Harskamp & Suhre, 2005; Kiboss & Ogunniyi, 2005).

The studies of students' choices of education have mapped the frequency of choices by sex for engineering, chemistry, and computer studies, and have analyzed explanations given for these choices. Sørensen and Berg (1987) found that women who decided to study engineering preferred chemistry over mechanical engineering or construction – because, as Sørensen and Berg explained, technical artifacts related to chemistry were seen as ”feminine” or

”neutral”, whereas artifacts related to mechanical engineering or construction were seen as ”masculine” (it needs be added that men and women rated the artifacts similarly). Women have refused computing programs because they saw computers as strongly related to the hobbyist hackers (Turkle, 1988); they also rejected the nerd image connected to computers (Rasmussen and Håpnes, 1991). It has also been pointed out that girls ”demonstrate greater potential in precisely those holistic and heterogeneous approaches so necessary to success in technological design (for an example see Calabrese Barton, 1997), as well as a thirst for what educationalists call ”deep understanding”, yet their different ”learning styles” are read by teachers as indicating a lack of confidence or ability” (Faulkner, 2000a:94). Whereas girls identify technological issues in the light of empathy with users, boys are more likely ”to approach technical tasks in isolation and judge the context to be irrelevant” (Faulkner, 2000a:94).

Explanations given for women’s lack of success in engineering included socialization: ”boys are more likely than girls to be socialized into hands-on tinkering with mechanical devices” (Kleif & Faulkner, 2003: 297). It has been noted, however, that even if women lack the experience of hands-on tinkering, when measured by school performance, they are as proficient as men (Robinson & McIlwee, 1991).

There are many negative consequences of the assumption that women have some deficiency that deters them from choosing an education in engineering, and one such consequence is that women are seen as persons who have to be modified (Faulkner, 2000a). As a strategy for modifying the educational preferences of women, women and girls have been targeted with more information about science education and science-based workplaces (Henwood, 1996). As Faulkner (2000a) pointed out, the opposite conclusion – that the teaching content should be changed to fit women – has seldom been reached.

Gerda Siann’s (1997) UK study of factors influencing gender balance in computer science courses revealed a strong under-representation of women in courses on computing, especially in courses with engineering and technology as secondary subjects. Siann suggested some possible psychological reasons for this female under-representation. Subjects such as science and technology have been traditionally sex-stereotyped and thus are preferred by boys; the culture within the computer industry emphasizes masculinity, making women withdraw from the profession; there is a lack of female role models; women lack confidence in computers (an assumption which Siann questioned in light of the ubiquitous use of computers in the late 1990s); and, finally, the subject, ”computer science”, is perceived as lacking social involvement.

In a recent study on gendered prejudice in choice of engineering among Turkish students, male and female students were shown to perceive the profession in the same, positive manner. Both male and female students expected that male engineers would have better career opportunities, however; and male students revealed a gendered prejudice towards women in engineering. In conclusion, Küskü et al. (2007:123) suggested that gender disadvantage in engineering is a result not only of gender imbalance but of ”social, cultural, psychological and economic layers of life”. Siann (1997) suggested the implementation of interventions such as reinforcing positive behavior and attitudes or helping women to develop negotiation and self-promotion skills; in doing so, Siann joined the authors who believe that it is women rather than education programs that need to be changed.

In addition to such general studies scrutinizing gender aspects of science education and workplaces, there are studies investigating physics education in particular. These studies focus on learning outcomes in computer-aided teaching, attitudes among the teachers, gender aspects in simulation, and gender aspects of laboratory work, for instance. It has been shown that students' problem-solving improved when the teachers used software that provided computer-aided instruction (Pol, et al., 2005).

Another study of the learning results of a computer-augmented physics program reveals that the learning outcomes among first-year secondary students increased significantly when computerized teaching aids were introduced (Kiboss & Ogunniyi, 2005). In this study, an instruction program was developed, based on transforming the relevant existing materials for science education (teacher's guide, textbook, syllabus) to a computer that was capable of displaying verbal and non-verbal information. The authors concluded that the use of well designed computer-augmented programs (CAP) create learning environments that can improve students' knowledge of, performance in, and attitude towards physics (Kiboss & Ogunniyi, 2005). In addition, Kiboss and Ogunniyi (2005:324) argue that CAPs are superior to the traditional teaching methods, as the former create ”a rich learning environment, which is non-threatening, enjoyable, and cognitively stimulating while boosting students' academic achievement and performance”.

A specific area of computer aided teaching contains research on the use of simulation in science teaching (van der Meij & de Jong, 2006). Studies of gender differences in science simulations are grounded on the finding that boys tend to dominate the computer in gendered settings (Light, Littleton, Bale, Joiner & Messer, 2000; Scanlon, 2000; Underwood, Underwood & Wood, 2000). Underwood et al. (2000) found that groups using computer-aided tasks have performance gains. Based on this they argue for the benefits of interaction in activities that include working on a computer. Eileen Scanlon (2000) presented a review of research on gender aspects in groups working with computer aided science simulations. These studies focused on the ways the students expressed conflict, perceived the task, and the ways the dialogue evolved during the problem-solving interactions among the students. She concluded her review hypothesizing "that gender influences the ideal conditions in facilitating group work with computers" (2000:478). As the studies reviewed are limited in number, further examination of how gender affects learning settings is called for.

Light et al (2000: 484) reported two experimental studies of "the effects of having a same-sex or opposite-sex partner upon children's problem solving performance". They found out that even if both girls and boys believed that boys handle computers better than girls, this belief was not confirmed in the practice-based experiments. Their results suggest that gender equality concerning computer use in schools can be reached by applying cross-sex collaboration.

Within the subject of physics, there is an ongoing discussion concerning physics teachers. Some authors claim that students do not continue in more advanced classes because their primary-school teachers lack knowledge of physics (Ahtee and Johnston, 2006). One study of physics teachers in Ireland revealed that they believed that students lacked the mathematical knowledge necessary for success in this area. The teachers also believed "that students perceive physics to be a male-dominated subject, a factor that undoubtedly contributes to the imbalance in uptake by girls compared to boys". Finally, teachers reported that it is hard to teach physics because of inadequate technical support in the laboratory (Politis, Killeavy, and Mitchell, 2007).

Politis et al. (2007) described the laboratory as central to physics education. A historical perspective reveals that the laboratory has always been a gendered place, inhabited by lonely and heroic male scientist (Wennerholm, 2005).

The laboratory was – and is – seen as central in the empiricist perspective, which assumes that the senses are the road to knowledge. The laboratory teaches students to use their senses in a systematic way. In addition, the laboratory was an incarnation of a pedagogical idea of "learning by doing", based on the assumed importance of active testing and experimenting. Thus learning in a laboratory would occur through the combined use of hands and sight (Pauly, 1991). Within the empiricist ideal of science, the school's laboratory became an institutionalized space for the practice of science. In a laboratory, students learn observation, order, logic, rationality, and the ability to work to acquire knowledge. By working in a laboratory, students have the opportunity to practice exactitude, orderliness, and patience – all necessary for scientific practice. These modernist ideals of science, transplanted into a male dominated and masculine imprinted environment, and refined through professionalization – resulted in absence of women in research, teaching as well as among the learners (Calabrese Barton, 1997; Wennerholm, 2005; Danielsson, 2007).

The laboratory practices do however reveal different gendering in different disciplines. For instance, women to a larger degree apply for chemistry and biology –subjects also including laboratory practices - than physics (Sørensen and Berg, 1987; Calabrese Barton, 1997). Danielsson (2007) reported that women chose biology over physics as biology was considered "softer" and therefore more suitable for women. Berner (2003b:137) provided a possible answer to this puzzle, suggesting that women's rejection of such subjects as mathematics and physics was not to be seen as a "passive acceptance of gendered roles". Rather, women repudiate subjects that appear irrelevant and are known to include inferior teaching. In order to find out more about the situation where students who are good in a subject and still reject it, a closer investigation of the black box of physics education may be helpful.

If gender and technology are mutually constitutive (Ormrud, 1995; Faulkner, 2000b; 2001), the physics education can be seen as an institution that, while practicing and teaching technology, also constructs gender. Such gendering begins with women's exclusion from educations and professions within the fields of technology, science and technological education (Wajcman, 1991; Henwood, 1993; Vehviläinen, 2000; Berner, 2003a). The technological orientation provides the subject with a masculine hue, corroborated by some of the pedagogical principles inscribed in the laboratory. At the same time, it has been established beyond doubt that women are as successful as men in science classes, even if they tend to choose non-science subjects because of lack of interest (Siann, 1997) or because they reject poor teaching (Berner, 2003b). Thus, gender disadvantages can be seen as the effects of certain ways of organizing education in sciences. In the next section, I describe my attempt to look into the black box of gender and technology – by studying the organizing inscribed in the technologies used in physics teaching.

Method

The starting point for this study is the constructionist approach, which suggests that rather searching for essences, the ways in which reality is socially constructed needs to be studied (Berger & Luckmann, 1966). In a variation of the constructionist approach that is favoured by Karin Knorr Cetina (1981), Bruno Latour (1998; 2005), and Barbara Czarniawska (2003), it is emphasized that representations of reality are created in interactions with others – humans and nonhumans alike. Applied to gender studies, this constructionist stance means that gender is seen as a ”routine, methodical and recurring accomplishment” brought about by everyday actions (West & Zimmerman, 1987:126). Consequently, I consider both technology and gender as performed and processual in character, rather than given and unchanging” (Faulkner, 2001:82).

Donna Haraway (1991), among others, has suggested that an actor-network theory (ANT) may result in a distinctive analysis of technology (for an example see Bonner & Chiasson, 2005). Within this school of thought, the technical is considered to be socially constructed and the social to be technically constructed (Latour, 1987); Law (1991) called this the 'seamless web' of socio-technology. Science and technology are seen as parts of, and dependent upon, relationships among people (Latour, 1993; 1998). Consequently, those who produce technology simultaneously produce society (Latour, 1987; 1998). Even if many of studies with an actor-network approach are gender-blind (Law, 1991), Susan Ormrod (1995:39) has argued that the ANT approach ”allows us to examine how gender relations are enrolled within relations of technology and vice versa:

to specify technology and gender as social processes where their boundaries and content are negotiated rather than pre-existing". Thus, the idea of a mutual constitution informs this text.

The case I have chosen to focus upon was selected from a study of 662 school projects financed by the SFKC. Booth and Booth (2000:10), who reviewed all these cases, discovered that only 20 of these projects "had a clearly identifiable interest in women and/or equity in the IT-society". In this category they included project where women/girls were a focused group (5 projects in total), projects on gender equity (10 projects in total) and projects combining these two focuses (5). Another 25 projects mentioned women but they neither focused on gender nor had any specific measures, Booth and Booth classified them as trying to achieve a veneer of a political correctness. They concluded that the financers of SFKC, as well as the persons applying for money, gave the impression of being gender-blind.

The study on which this article is based focuses on a project called *Physics for Girls and Boys*, in which computing hardware and software were used together with new pedagogical ideas to encourage more women to apply for advanced physics courses. Initially, the project took place in one secondary school in a Swedish municipality, but was later moved to two other secondary schools within the municipality. Given the context of the project, in this paper "technology" refers to computing hardware and software as well as to the institutionalized practices related to the use of the machines (Joerges & Czarniawska, 1998), including pedagogical practices. Technology thus includes computing hardware, computing software, as well as various applications of machines in the practice of teaching physics. In the gendered institutionalized order investigated in this paper, gender is thus inscribed in the computer hardware, the computer software as well as the institutionalized practices of using the technology in question.

Although the project itself has been terminated due to organizational changes, the thoughts and practices that underpinned it still influence the teaching practices in physics in the schools that adopted the equipment that was developed in the project. I used ANT (Latour, 1993; Latour, 2005; Bonner & Chiasson, 2005) as inspiration, and traced various actions and actors back in time in order to construct a picture of the overall project and specific events within it.

Starting with information from the homepages of SFKC and from the IT managers employed by the cooperating municipality, I was able to trace and interview one of the two teachers who had been involved in the project from the beginning (for an overview see Appendix 1). He led me to the second teacher, who meanwhile had retired; and to the person who was vice-principal at the time of the project. The vice-principal, in turn, led me to the Principal, who had been responsible for the physics project and for the computers involved in it. The Principal then helped me to trace the computers and contact the teachers who had taken them over after the reorganization of the schools in this municipality. I asked all of these interviewees to tell me the story of the physics project: how it came to be, how they became engaged in it, and what happened during and after the project. During my ensuing fieldwork, I interviewed yet another eight persons. They told me about other projects in the municipality, and provided information that served as a background to the project, *Physics for Girls and Boys*. The reports from the schools to SFKC were published on the Internet between 2000 and 2006[2].

The material from this case is used to develop a tentative theory (Glaser & Strauss, 1967; Turner, 1983), of the machine as a constructor and therefore also potential re-constructor of gender in organizing. As to generalizability of such a theory, I rely on Lee and Baskerville's (2003:241) statement that "a theory may never be generalized to a setting where it has not yet been empirically tested and confirmed", no matter whether it is produced in a positivist or interpretivist manner. This tentative theory is then an invitation to further testing.

In the next section, I tell the story of the project, *Physics for Girls and Boys*. It begins with the start-up ideas, content, and financing of the project, and the introduction of the project to pupils. The second part describes the changes caused by the reorganization and the results of the project today. Together, the two parts form a story of how gender re-construction was inscribed in technologies.

Case: Physics for Girls and Boys

The idea behind *Physics for Girls and Boys* was born in a school that hosted science programs for 16- to 18-year-old students. For several years no investments had been made in the science laboratories, and the two male physics teachers, Steven and Tim, longed for different working conditions. Due to the financial situation in the municipality, however, they knew that it was unrealistic to hope that their working environment would be a priority. They were concerned that half their students did not take the continuation course in physics. Despite the fact that the science program in Sweden has had a near-equal representation of males and females over the past two decades, girls in their school, whether skilled in physics or not, were particularly unlikely to take the advanced course in physics.

Steven and Tim's explanation of gender differences was that boys grow up exploring things in different ways than girls do (as claimed by Kleif & Faulkner, 2003). They were of the opinion that before their formal education started, boys were more likely to try things out, to test, to tear things apart and put them back together again, to build, and to construct. When the girls began to study more advanced physics, therefore, they had to start from scratch, the teachers reasoned,

[2] All information about the various SFKC projects, including names and sometimes photographs of project participants, has been sent to other schools in Sweden. Although I have changed all proper names in this text as they are of no interest to the general reader, the original project reports from 2000 and 2006 can be found on SFKC's website, linked to the school hosting the projects: http://www.hedbergska.sundsvall.se/projekt/fysik/Projekt.html, accessed 23 May 2005. The reference list contains yet another SKFC report (2000), which is the schools' evaluation of the project.

because they had never done such things before. These differences in experience were most obvious during one of the central activities in physics classes: setting up a laboratory experiment. Boys were more patient and more eager to help the teacher set up the tools, the two teachers reported, whereas most of the girls showed disinterest. Because problems were encountered routinely in setting up experiments, the girls' aversion for physics grew. Steven experienced that, even if girls did not have problems with physics, they usually did ”girls' studying”, an expression he used to refer to what allegedly is a common practice among girls: studying the texts and knowing the theory, but disliking the practical part of physics (see e.g. Katz, Aronis, Albritton, Wilson & Soffa, 2003)**.**

Although Robinson and McIlwee (1991) reported no differences between girls' and boys' interest in science classes, more recent studies (Faulkner, 2001) reported gender differences similar to those described by the teachers. An alternative explanation for girls' lack of interest in studying science, engineering, and technology has been provided by Siann (1997), who discovered that even successful girls made other choices because, pragmatically, they did not foresee a promising work career in such fields. This observation was, however, never made by Steven and Tim. As mentioned before, Berner (2003:b) suggested that women take distance from physics due to inferior teaching. Whether that is the situation in this case or not is hard to tell, but at any rate the teachers' ambition was to improve the teaching of physics.

In 1998 a new vice-principal, Jane, was employed for the science programs. She was experience in applying for SFKC grants and in working with SFKC projects at other schools. The application for the project, *Physics for Girls and Boys,* came into being after the vice-principal had attended a seminar at which a young female student spoke about her experiences studying technical sciences. As Jane told me:

> She [the student] was one of these really bright women... she told us that every morning her [male] teacher in physics entered the classroom saying 'Good morning, boys!', as there were just two girls in the class. This teacher could never accept the fact that she was the best student in physics and chemistry in the class. The girl presented this as an observation, seemingly unmoved by it. For her, it became a challenge. I took this experience with me back to my own work (Jane). [3]

After Jane returned from the seminar, she met with Steven, who headed the entire science program. Steven first complained about old classrooms and bureaucratic organization, and then, as Jane comments, he changed the subject:

> We started discussing the field of physics from a perspective of gender equality. He (Steven) observed that despite the girls being better than boys in physics, they tended to quit physics after the first year. Only the very talented girls stayed, and they were far more talented than the boys.

[3] All quotations have been translated from Swedish to English by the author.

As a result of these discussions, the science teachers and the vice-principal decided to apply for a grant to build a computerized physics laboratory of the type that Steven had seen at other schools, including one in his own municipality. Their plan was to use a computerized updating of the physics equipment and new pedagogical ideas as tools for re-constructing gender. The project description contained an account of the gendered differences among girls and boys taking physics classes, describing the project leaders' experiences of the gender imbalance[4]:

> When girls start upper secondary school, they do not have the same knowledge as boys. The most obvious difference is their perceptions of power/force and movement. It is harder for some students than others to get a feeling for how a body moves within a room [described] in a mathematical expression and this is particularly the case for girls. When girls leave the upper secondary school, they still have not acquired the same knowledge as the boys. In our perception, we have found that context, methods, and processes can be developed to equalize girls' and boys' learning of physics, in order to encourage girls to continue studying in the field of physics.

In line with the teacher's ambition to improve teaching practices, the application specified that the project would involve a new way of performing applied experiments. The traditional pedagogical form used at the school was described in the application as follows[5]:

> Classes in physics have been characterized by a situation in which the teacher performs an experiment, derives a formula and then lets the students count and perform an experiment with instructions about how it should be conducted; and accounts of results are often presented in tables. Mostly, the result is a passive watching of physical events and many students question the utility of learning physics.

According to this model, the students met once a week for a two-hour lecture, and, in addition, half the class spent two to three hours every second week in the physics laboratory performing experiments to test physical theories. Every other week the same amount of time was spent in the chemistry laboratory. In the physics laboratory, the students used a stopwatch to measure at "discrete points" (the force when an object hits the floor or two wagons collide, for instance) and, in this way, they obtained results that could be manually compared to the outcome of the theory. In this respect, the laboratory was superior to the traditional physics classroom. However, the laboratory was ill-equipped for lecturing; in fact every theoretical discussion that arose during the experiments had to be moved from the laboratory to the ordinary classroom.

The goals of the project were to stimulate girls to continue studying physics

[4] http://www.hedbergska.sundsvall.se/projekt/fysik/Projekt.html, accessed 23 May 2005.
[5] http://www.hedbergska.sundsvall.se/projekt/fysik/Projekt.html, accessed 23 May 2005.

by creating new work processes and materials to develop students' meta-cognitive thinking abilities and their knowledge of the subject. In the project, *Physics for Girls and Boys*, the students and teachers were to work together to explore pedagogical methods and materials in physics, following the ideas of computer-supported, problem-oriented teaching. In the new model, the students would be able to conduct various experiments with calculation devices connected to the objects of study, and the results of the movement (e.g. a weight falling, wagons colliding with each other) would be immediately displayed on the computer screen.

Receiving the grant (see Appendix 2 for details) allowed an alternative learning setting to be established. The physics laboratory was refurnished – eight computers and computer desks were installed. In the new model, lectures could be held in the ordinary classroom as well as in the laboratory. Except for a few scheduled times, the laboratory was now always open and the students could visit it whenever and for as long as they wanted. The scheduled laboratory lectures no longer existed. Steven and Tim defined themselves as ”free resources”, providing help to the students in the laboratory whenever they were free of their teaching assignments. Furthermore, the teachers wrote new instructions on conducting experiments with the new equipment. Supported by laboratory experiments and interactive software, including computerized sensors applied to the studied objects, the student groups were asked to do mathematical exercises and to undertake training in problem solving (for an example, see Appendix 3). Instead of being able to take measurements four times a second, the new technology allowed the students to record 100 measurements per second, providing more material and producing graphs. As the experiment could easily be repeated, the students could produce as many results as they wanted, thereby reaching different outcomes of the specific theory. In line with the pedagogical principles of problem-oriented teaching, the students were encouraged to find methods themselves. Up-to-date equipment and simulation programs helped the students ”to conduct experiments in close touch with reality, in order to see the connection between theory and practice”, as Tim put it.

These actions, together with the new technology, changed the organization of physics education in a variety of ways: by acquiring computers and building them into the school desks, by assuming a new pedagogical style, by permitting students to do laboratory exercises whenever they wanted, and by making students responsible for the results, for example. This case thus resembles the program studied by Kiboss and Ogunniyi (2005). In addition, the actions reported from the physics project led to changes in the institutionalized, masculine ways of using the laboratory (Wennerholm, 2005), which were replaced with new, interactive practices.

The project meets the students

Tim explained that when the new approach to learning physics was introduced to the students, it was emphasized that the project was a new way of conducting physics laboratory exercises and of approaching problem-oriented learning. He reported that the students were not particularly interested in the project itself; they focused on the new gadgets. At the first run of the new equipment, a beautiful graph appeared on the screen, which in itself was a success. A week earlier, the class had conducted the same experiment manually, dropping a ball and measuring time with a stopwatch. Upon running the experiment with the new equipment, the teachers were keen to hear what the students thought about it. One girl said, ”Yes it is nice, but we cannot quit doing the manual experiments; they give us an understanding of the course of events”. Tim thought this was a wonderful answer. It summarized the pedagogical intention behind the experiment so well that it became an argument for combining manual calculations with use of the new equipment. As the computer simulation guaranteed the success of the experiment (see van der Meij & de Jong, 2006) , teaching students the physical principles behind an experiment was necessary in order to provide them with an understanding of the phenomenon. A real situation – in industry, for example – would be full of irregularities, and these could only be simulated by manual experiments. Thus it has been concluded that the students needed to conduct both manual- and IT-based experiments in order to learn physics.

The anecdote provided by the female student and its enthusiastic reception indicate that the relationships between the teachers and the students were positive (but also that the teachers did strive to improve the teaching practices). The positive attitude of the students is supported in the final report from the project, containing several pictures of evidently delighted and interested students using the new technology. If these indications are accurate, such a positive climate might have influenced the students' opinions about the new technology, which in turn might have influenced the results of the project. According to Tim, the students taking science were often highly motivated, and the girls received the project well. In the first class where the project was introduced, the majority of the students were girls, and many of them became interested in physics. In the final report to SFKC, the following numbers comparing the outcome of physics applications in schools within the municipality, with or without the project, were reported: 91.7 percent of students who took part in the project applied to enroll in the advanced physics class, compared to 71.7 percent in the reference group (both groups had 60 students). Unfortunately, there is no information at this point regarding gender of the students.

At this point, it is appropriate to comment on the possible influence that the positive climate might have had on girls' achievements. Incorporating intentions into computer design is a risky activity, as its planned use will be affected by the user's construction of the machine. Researchers within the field of social construction of technology have found technologies to be actively created and re-created during their diffusion through the market. When technology reaches the users, new phases of interpretative flexibility[6] begin, leading to unintended consequences (Cockburn &Ormrud, 1993; Lohan, 2000; Vaast & Walsham, 2005). A well known example of unintended consequences is provided by the telephone, which was originally designed for (men in) business life. The development of the telephone systems, however, was directly influenced by women, who used the phone for their social lives (Cockburn & Ormrud, 1993:12; Frissen, 1995).

Berg and Lie (1995) point out that even if certain intentions are inscribed in the technology by design, users may use the machine differently and the intentions will not necessarily lead to the required effects. When the goal of the experiment is explicitly communicated to the students, however, one result may be that they will try to please the experimenter by behaving obediently, rather than by engaging with the technology as such. Although weaker students may learn from encouragement and positive reinforcement (Liaw, 2002; Katz et al., 2003), in the light of the results of the Hawthorne studies[7], one can argue that positive reinforcement cannot alone explain the results reported here. The positive reaction of female students may not have been a response to the intentions inscribed in the technology (both computer and pedagogical technology), but rather an effect of the social climate. Their response might have been a combined result of the introduction given to them, their interest in the use of modern gadgets, and the unintended, more subtle suggestions of the desired result. However, this conclusion must be considered tentative until the later developments in the physics project are described.

Reorganization and after

In the autumn of 1999, after the project had been running for a year, the upper secondary schools in the municipality where reorganized, a process that resulted in three schools becoming two. The school running the physics project was closed, and students, teachers, and computers were split between two other schools, B and C. After many complex negotiations, the project was divided among the schools. Tim, technical equipment, pedagogical ideas, money, students, homepages, responsibility, and management – was moved to school C . As the Principal of school B claimed they had sufficient equipment – a claim which

[6] Steve Woolgar (1991:31-32) explains interpretative flexibility by saying that: "what a technology can do is essentially uncertain; what "we" subsequently take a technology as capable of doing is the result of our adoption of the contingent outcome of a complex definitional process."

[7] In organizational theory, the phenomenon of encouraging people to produce the outcome expected by the researchers is known as the "Hawthorne effect". The original Hawthorne study was conducted in the 1920- 1930s and was aimed at testing the new work organization (Roethlisberger & Dickson, 1939). Later, the critics (e.g. Acker & Van Houten, 1974; Gillespie, 1991) pointed out that the Hawthorne researchers explicitly told the studied women what outcome they expected.

later turned out to be an overestimation of the schools resources - Steven and the same pedagogical ideas were moved to this school to spread the experiences.

In order to continue the project, teachers at the new schools were educated in the use of the equipment and the new pedagogical ideas, but the major goal of the project – equality – was seldom mentioned. Steven, Tim, and the teachers from the schools that took over the project, described how the latter were informed about the proper use of the computerized laboratory and the written instructions accompanying it; the teachers were also introduced to the pedagogical idea of letting the students plan their own time in the laboratory. According to the persons I interviewed, gender was merely mentioned as a side issue.

The final account of the physics project presented to SFKC reported positive results. Some numbers describing the situation are as follows: Prior to the academic year 1998/1999 when the project started, half the students – a majority of whom where girls – did not apply for advanced physics. In 1999/2000, after the project had been running for one academic year, more students passed the basic and advanced courses in physics. The school who was now hosting the project reported that 85 students (44 girls and 41 boys) graduated from the science class. Of these, all but 4 girls and 1 boy chose not to take the advanced physics class. In the 2000/2001 class, of 120 students from both schools, 22 chose not to take the advanced class.

Table 1. Overview of the local statistics describing the applications and examinations in relation to the Physics project.

Year	**Number of students**	**Result**
1999		50% of all students, including a few girls took advanced physics
2000	44 girls and 41 boys graduates	95% of all students (44 girls and 41 boys) took advanced physics
2001	120 students	82% of all students took advanced physics
-		
2003		Most students, girls as well as boys, applied for advanced physics

The school's final report to SFKC claimed that this change was highly significant. It explained that the increase in the number of students not taking the advanced class in the second academic year, 1999/2000, was caused by the reorganization. During the move of the project and the associated equipment, there were problems keeping the laboratory open as planned. The final report assured the sponsors that these problems were about to be solved. According to the Principal who wrote the report, the laboratory was to be open during the entire day to all students taking physics, and a part-time science teacher was to be made available to students.

SFKC officials also saw the project as a success, and the teachers were encouraged to apply for more money to finance the technological solutions for the project. The idea was to develop even better interactive software and computerized laboratory exercises. Tim and Steven agreed with these ideas, but they were both heading for new projects. Also, the Principal of the school that did not host the project regretted the results of the negotiations and started to compete for the project money; the ensuing conflict between the two schools decreased the teachers' interest in continuing the project.

A follow-up of the project in the autumn of 2003 revealed that the physics project was well established in the municipality. Tim, Steven, and the Principal were still extremely positive about the project, both from the teaching of physics and the gender equality points of view, the reorganization notwithstanding. They even claimed that the school B that did not host the project benefited from the expertise of the teachers who were transferred there. Earlier, they pointed out, a majority of the students had found the basic and advanced physics courses to be very difficult. The autumn of 2003 saw more students, including more girls, taking the basic and advanced physics courses than before.

Quite a different account came from another teacher, Theodore. He was not involved in the physics project but worked with the equipment in 2003, claiming that the physics project was simply one part of a larger trend toward computerization in the teaching of physics. According to Theodore, during the past few years, more computer support had been introduced in the physics classes. For example, students conducted various experiments manually, but the results were automatically transferred to the computer for calculation. The important part was the hands-on or manual method, which allowed the students to work with practical laboratory experiments. In the computerized environment, different versions of virtual software programs could have been an alternative, but the teachers found it advantageous to allow the students to work with assignments based on realistic situations – a popular decision among the students.

As to the interest in physics among girls compared to boys, Theodore said that the boys were somewhat more interested in doing the manual assignments in the class. This opinion is consistent with Steven's story about boys being keener than girls to set up experiments; it is also consistent with the UK studies reported by Faulkner (2001). Computerizing laboratory experiments made the experiments easier for girls, but it was not clear to Theodore that it was the physics project that increased the girls' interest. From his point of view, changing attitudes in the society in general, in combination with national efforts to reduce gender inequality may have been more important factors. As Freud (1911) observed, most phenomena in modern societies are over-determined – there are simply too many factors active at any given time to decide on simple causal connections.

When I contacted Tim again in the autumn of 2006, he told me that the success of the first year of the project was due to the project's novelty, and the fact that the investment focused on physics classes in general. Somewhat surprisingly, he also told me that this project was never about gender; the gender issue was used merely as an argument to receive money to update technology. As pointed out by Klein and Myers (1999), the employees, as well as the researchers who study them, continually interpret the context of their actions, and their interpretations alters when the context changes. Storytelling thus changes in time (Czarniawska, 1997), and from the perspective of this text, it does not matter what the project was „originally"[8] about. Tim was by this time working at a new school with a different pedagogical style, and in this new context he credited the *Physics for Girls and Boys* project with the opportunity to re-organize the laboratory classes at his present school in a way that allows students to decide for themselves how much time they needed to spend in the lab in order to learn the principles of physics. Storytelling changes also depending on context: it could have also been the case that Tim, once again asked by the researcher about the gender aspects of the project, did not want the project to be remembered as a "gender re-construction" project but as a project contributing to change in to physics education.) My conclusion was that if the updated technology and a freer organization of laboratories helped create a better balance in the gender ordering – even as an unintended consequence – it is a serious argument for their introduction.

Discussion

Because of unexpected change to the organization of the secondary schools in the municipality, the project turned out to be like a natural experiment – an experiment which was not planned as an experiment but turned out to become one. In the follow-up six years later, it turned out that both schools in the municipality taught physics along the lines established by the project. The teachers in these schools knew nothing about the gender equality goals and did not seem to be interested in finding out about them. From their point of view, the acquisition of the up-to-date equipment was indeed the main purpose of the project. It thus appeared that the reorganization of schools made the project more far-reaching than if it had run as originally planned. If the project had continued in only one school – a school where the teachers were well informed of its aims – all results could have been explained as epiphenomena.

[8] For an example of a project undertaken to explicitly address issues of gender and technology and to "ensure that women are fully represented in the influential world of information technology and computing" see the National Center for Women & Information Technology (NCWIT). In contrast to the case of *Physics for Girls and Boys*, NCWIT use strategies as education, dissemination and a longitudinal plan for national (US) implementation in order to increase for gender equality in areas as IT innovation and professional positions, but also to change the social impact of women in innovation of products and services. http://www.ncwit.org/, accessed 14 January 2008.

To recapitulate: The project was declared successful, at least in terms of the number of students graduating from advanced physics, as reported in the documents produced by the funding organization, SFKC (see Table 1). This successful result was reached in spite of the organizational changes and the forgetting of the initial idea of a more gender-equal pedagogical situation. Such elements of the project as: modern equipment, attractive computers, and popular, committed and knowledgeable personnel were used by the new hosts and later even imitated by a school that did not host the project. It seems that gender equality became inscribed into the computer and pedagogical technologies, so even if the project originators disavowed this goal, the students' gendered perception of physics was subsequently re-constructed. Captivated by the fancy machines and the modern pedagogical ideas, the new users contributed to the continuing re-construction of gender.

Some of the results of this project are corroborated by other studies reporting that the use of computer-aided instruction improves students' problem-solving abilities (Pol, et al. 2005), and has positive effects on their knowledge of, performance in, and attitudes and motivation towards physics (Kiboss & Ogunniyi, 2005). As Faulkner (2000a) noted, a common strategy used to get more women into engineering has been to consider them as person who have to be modified; in case of the physics project focused upon in this paper, the content and forms of the teaching were modified. The open access to the physics laboratory could have helped to remove the advantages due to early socialization that the boys might have had (Politis, et al, 2007). Thus, whether or not it had been the teachers' goal, the new physics laboratory together with the committed teachers appears to have helped achieve a more balanced gender proportion (in the sense that a similar proportion of women and men applied to the advanced physics course) among the graduating students.

Cockburn (1983/1999) has suggested that the only way to achieve gender equality is to introduce (or rather, to re-introduce) women-only schools. ”Provide schoolgirls with separate facilities and the boys won't be able to grab the computer and bully the girls off the console. Provide young women with all-women courses so that they can gain the experience to make an informed choice about an engineering career” (Cockburn, 1983/1999:132). Even if Cockburn observed that this works only in some situations and that it may lead to marginalization of women, this is a suggestion that can be compared to the *Physics for Girls and Boys* project. When the laboratory is open all day long, individual students may come in when it bests suits them, so that there is no need and no opportunity to ”grab the consoles”.

What will happen to these ”re-constructed” students? As Küskü et al. (2007) pointed out, gender inequality, on balance, is not only the result of what happens within the educational setting, but is related to the ”social, cultural, psychological and economic layers of life”. Because of the way in which society and the labour market in Sweden are gendered today, these students are likely to meet with inequality in workplaces and at universities. They will be introduced to new machines, which are inscribed with the present gender-imbalanced institutional norms. It might be expected that the female students will be discouraged in one way or another from choosing and pursuing ”male” careers. The removal of inequality in gender balance would require a re-construction of machines in all layers of life.

A coda: In search of credibility

Following Theodore's suggestion that the same phenomenon happened in the entire whole country and was not influenced by the *Physics for Boys and Girls* project, one could try to compare the number of girls who enrolled and graduated from the physics course after the project was implemented in the schools involved in the study (see table 1) to the same numbers nationally. However, the national data turn out to be incomparable with the local data. There are no available national statistics showing the number of applicants to basic physics versus advanced physics. Nor are there any national data on dropouts, on numbers of students changing programs, or on the amount of time students spend on the science program (the normal period is three years, but sabbatical leave and exchange years can extend the period to four or five years). As the curriculum is planned by each school and program individually, the national data provide no information about the point during the program at which the student took the physics courses. Furthermore, the contents of the annual collection of data and the science program itself have changed during this period.

Let us assume, however, that perfectly comparable data could have been found (which is extremely unlikely, unless they were produced for this very purpose, which would made them questionable). The differences between the national cohort and the local group could be statistically significant – or not. However, does it mean that such a change is not worth trying to achieve? Perhaps, as Deirdre McCloskey points out in her ”The Irrelevance of Statistical Significance” (1996), ”You need to decide whether the one-percentage point change is *important* or not” (p. 18, italics in original). The only numerical counter-argument that I see would be that physics projects exist that have achieved even better results in re-constructing gender. If they exist, no doubt they will be given a green light by everybody concerned.

Conclusions: New technology for re-construction of gender

In this article, physics education is seen as a black box, which, upon inspection, reveals a mutual construction of gender and technology. As both politicians and researchers have high expectations that schools can change the societal gender order (Henwood, 1996; Henwood & Miller, 2001; Berner, 2003b), this case is enlightening. One of the insights concerns the potential impact of new information technology on equality in line with other recent studies in the field (Pol, et al., 2005; Kiboss & Ogunniyi, 2005). Another revealing result is that teachers are aware of the imbalance of gender in physics education, and they tend to explain it by the differential socialization of girls and boys, which is confirmed by research, but which also indicates that teachers see the responsibility for this development as lying outside their direct influence. Still, they actually used this observation as the guide in rebuilding laboratories (or perhaps the way they rebuilt the laboratories incidentally helped to remove the boys' advantage) and applying new ways of using the laboratory. Whichever way, they managed to change the institutionalized forms for both the physics laboratory and physics education.

Technology, it is reported, often creates unintended consequences, usually caused by users interpreting the technology in unintended ways (Lohan, 2000; Lohan & Faulkner, 2004; Vaast & Walsham, 2005). The physics project described in this paper presents a different case: Here, the designers changed their minds as to what their intentions were, while the users proceeded to interpret the technologies according to original plans. Perhaps a new concept, of ”unconsequential intentions” is needed?

A more plausible explanation may be found in the notion of machines as inscriptions of societal norms (Joerges & Czarniawska, 1998). Machines remember better (when ”better” means a recall that is stable in time) what was inscribed in them. In this project, liberated from their designers by the reorganization of the schools in the municipality, the machines carried on the message of equality beyond the reach of the original project.

Is it possible, then, to build equality ideals into a technology? The physics project case is one of many examples supporting the thesis that computer technology can be used to re-construct gender order in organizations. On the opposite side, there are examples that virtual reality tends to reproduce non-virtual reality and its stereotypes and imbalances. It therefore seems to be important to build gender awareness into design and implementation of all new technologies. In this way, the re-construction of gender may continue even when the new technology is detached from its original environment. It needs to be remembered, however, that even if machines carry inscriptions and inscribe the world, they themselves will become unfashionable one day (Latour, 1993). If the people who replace ”gender re-constructing machines” are not aware of their gendered premises, these premises can easily be lost in the programming and ordering of the next fashionable machine.

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Appendix 1

Table describing timeline for Physics project, national statistics and research.

Year	**Event**	**Research**
1995-2001	SFKC finances IT in Swedish schools	
1998	New vice-principal employed	
1998-06-30	National statistics	
1998-09-01	Physics project starts	
1999-06-30	National statistics	
1999-06-30	Closing school – project is moved to new school	
2000-06-30	National statistics	
2000-09-27	Final Evaluation from New Project Owner	
2001-06-30	National statistics	
2002-06-30	National statistics	
2003-06-30	National statistics	
2002-2003		Document studies from SKFC and municipality in question
2003-02-03		First field interview with IT manager
Spring 2003		Interviewing teachers, principals, project initiators
Fall 2003		Interviews with teachers at the receiving school. Interview with vice-principal Marianne
2004-06-30	National statistics	
2005-06-30	National statistics	
Fall 2005		Interview with retired project initiator
2005-2006		Document studies from SKFC and municipality in question
Fall 2006		Follow-up interview with project initiator Lennart

Appendix 2

One example of computerized tasks is the behaviour of colliding wagons. A graph demonstrates the course of events on the screen. The computers can also calculate temperature, pressure, radiation (even though all functions were not available for the students) in the same way it is done in industry.

> Thus the new computer system could solve the following tasks:
> Transformation of energy: Location – movement
> Material: WS 750, 2 photo cells, roller conveyor, wagon, lined plastic board
> Purpose: Verify principle of energy and the laws to decide kinetic energy and potential energy
> Theory: Principle of energy: $E_k = \frac{mv^2}{2}$ and $E_p = mgh$.
> Execution: Assemble the photo cells on the roller conveyer with 60 cm interval. Attach the lined plastic board on the wagon and adjust the photo cells in order to get the black 2.5 cm band to pass through the beam of the photo cell. Connect the photo cells to WS 750 (see manual I-V) and chose Photogate solid with 2.5 cm band length and calculation of speed. The calculated result should be digitally exhibited.
> Set off by deciding the influence of friction by conducting calculations with a totally flat roller conveyer. Set off the calculation (see VIII-XI). Give the wagon an easy push and calculate the energy that is transformed into thermal energy.

Lean the track by raising one of the ends by about 10 cm, and calculate the differences in height by the two photocells.