# The Concept of Technology and the Gendering of Engineering Education

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## Abstract

This article considers the concept of technology, which forms the basis for engineering education and the engineering profession. Two distinctive features of this concept are close ties with natural science and also with economic rationality and economic growth. These features are seen as limiting the concept and are discussed as gendered. The criticism female engineering students express about their education in different studies is viewed through the lenses of feminist science criticism and Ve's theory of two different rationalities. To a certain degree, this criticism by female engineering students can be seen as a reaction against the limits of the underlying concept of technology in education. If engineering should be a more gender balanced profession, the gender of the concept itself should change and exceed its current limits.


Two personal experiences have inspired this article. After having studied engineering education and gender for a number of years, I received two different impulses in close succession to each other: these were evaluating a county technology school and hearing a lecture about the changed meaning of the concept 'friendship'. Both led me to reflect on the underlying concept of technology in engineering education. The county technology school provided me with other concepts of technology than the one I had unconsciously adopted in studying engineering education, and the lecture on friendship reminded me of how concepts can change gender.

The county technology schools are a new and still a rare phenomenon in Sweden. They are established to increase the interest of children and young people, particularly girls, in choosing technical education and technical professions. They work with a new pedagogy and start from the basic assumption that girls do not have the same opportunities to try their hands on tools and technical equipment in their upbringing and leisure time



activities as boys do. Another assumption is that girls are more interested in other aspects of technology than boys, these being most importantly the aesthetic aspects and design. Accordingly, at a county technology school, technology is primarily associated with creativity and practical, hands-on solutions. Artistic aspects are being taken into consideration. When talking about inventions, everyday inventions are encouraged. At least four conceptions of technology are in use: technology as an application of scientific laws to create functional artefacts; technology as a creative means to create aesthetically appealing artefacts; technology as something which makes everyday life easier; and technology as a basis of inventions which can be economically exploited.

Undoubtedly county technology schools encourage an interest in technology. However, 'technology' at a county technology school seems to be very different from the 'technology' these young people will encounter should they choose to enrol in engineering education. In my studies of engineering education only two conceptions of technology seemed to stand out: technology as an application of scientific principles, and technology as creating economically exploitable artefacts, i.e. technology as a driving force in economic development.

The idea of looking at the concept of technology in itself as one important factor in the gendering of engineering education came about when I learnt about the gendering of the concept of friendship. Nardi (1992) has described how the concept of 'friendship' has changed genders during the last two hundred years in Western culture. In the early nineteenth century, friendship was a concept with a masculine connotation; that is, it was primarily men who were seen as capable of friendship. Today, 'friendship' denotes something feminine (there are other concepts —like 'buddies'—to denote friendly relationships between men). The change in the gender of the concept has come about because of developments in society. But in the process the concept also changed meanings. A masculine friendship, in its time, had connotations to 'bravery, loyalty, duty and heroism', according to Nardi. Today the concept of friendship is associated with 'intimacy, trust, caring and nurturing'. This is an extreme example of how changing the gender of a concept also changes its meaning.

Technology in today's world is a concept laden with masculinity (Mellström 2001; Wajcman 1991). While the dictionary definitions are formulated in gender neutral terms, in practice, technology is associated with what men do, on different levels in the gendered society: The overall cultural image is masculine; on the institutional level, for example in working life, men are found in technical occupations more often than women (and even when women work with technology, their occupations are not defined as technical); on the individual level, many relationships between men have technology as a common denominator. This also means that women are kept and keep themselves outside this area.

If the efforts to make engineering education more attractive to women are to succeed, then perhaps something similar must happen with 'technology' to what has happened with 'friendship'. And if these efforts succeed, something similar certainly *will* happen with 'technology'? As long as we have a gender structure in the society, technology done by men will not be quite the same as technology done by women. One effect would be revolutionary changes in engineering education, which has remained astonishingly unchanged during the whole of the 20th century.

The concept of technology in engineering education can be compared by the definition in the Swedish National Encyclopaedia: 'The creation and use of artefacts to satisfy human needs'. This definition covers all the different practical definitions which are in use, for example, in county technology schools, better than, for example, the definition in the Encyclopaedia Britannica: 'The application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment'. While many dictionary definitions (though not all of them) associate technology with science, Sjögren (1997) has shown, that this is less often the case among ordinary citizens, at least not in Sweden. Thus, the definition in the Swedish National Encyclopaedia leaves the definition more open (and thus more susceptible to change) and may reflect the everyday definition of the concept more accurately.

My aim in this article is to reflect on the implications of the concept of technology prevalent in engineering education and the way they affect the gendering of the education. In this I look at two basic features of the concept: one feature of engineering education and the engineering profession



which appeared around the end of the 19th century and which has been prevalent ever since, is the scientification of the creation of artefacts. The other important feature is the close ties between engineers and the economic-technical rationalism, which has been significant for the societal development of the Western world during the past hundred years. Both features are unquestioned elements of engineering education: engineering education is built on a scientific basis and should produce engineers who can forward the technical development (preferably of their own nation in international competition).

I refer most often to engineering education in Sweden. Engineering education and its ethos, however, are international to the degree that the basic characteristics of the dominance of natural science, and the connection to economic development, are prevalent, with some variations, in most European engineering education, and engineering education in the USA.

As a starting point for my reflections I look at what feminist critics of science have had to say about natural science, because so much of engineering education is based on science. I also look at what female and male engineering students say about their education in various empirical studies, and reflect on to what degree the gender differences (which appear in basically all studies) relate to the concept of technology inherent in engineering education.

One such interview study, which nicely confirms the gender component in both the scientification and the economic rationality of engineering education, is that of Stonyer (2002) at an engineering education institute in New Zealand. In describing the situation of female engineering students she distinguishes three discourses, 'the scientific discourse' (a discourse limited by the inherent limitations of natural science), 'the managerial discourse' (stressing the economic rationality when talking about workers) and the 'liberal education discourse' (trying to broaden the concept of technology, partly a counter discourse to the first two). These discourses had clear gendered aspects, in that women were more uncomfortable with all of them, especially the first two. But even the liberal education discourse was problematic, in that it was seen as countering the inherent ideals of the education provided, and the women who supported this discourse were easily marginalised. Thus, female students were uncomfortable with the discursive limitations of what technology was supposed to be, but they were not in a position to change the situation.

## Engineering education based on natural science

The scientification of technology has separated graduate engineers with training on a post-secondary level from ordinary technicians or hands-on engineers on the factory floor. In the first part of the 20th century an engineering degree was not only reserved for men, it was often practically reserved for men from the higher spheres of society, a signifier of both gender and class. Being scientific was, in the beginning of the 'engineering era' of the 20th century, regarded as the qualifier making engineers suitable for taking responsibility of the management of big projects. After WW II, the scientific basis of engineering education was stressed even more, at least in the USA (Lyman 2002). However, even if technical institutes have described themselves as scientific since the beginning of the 20th century, there have also been discussions on the value of science in what can be regarded as practical engineering work. This was more marked in the beginning of the period, but even today, as Lindqvist (1998) states, tension exists about the balance between basic scientific subjects and more applied technical subjects in engineering education.

Feminist science criticism has developed into a flourishing and broad field of study, with many internal discussions (for example, Harding 2001; Sprague 2001; Walby 2001). The point of departure, however, has been the realisation of the fact that in Western science for centuries men have formulated the questions, worked out the methods and interpreted the results. Feminist science criticism claims that this fact has influenced science; that scientific questions, methods and results are gender biased. The most serious effect of the masculinity of science is that it has determined scientific and technical development in general (in a way that many feminist critics of science see largely in negative terms). However, this masculinity of science is also seen as one reason why many women today are not attracted by science and engineering. Those aspects, which feminist science criticism has brought up as masculine and problematic in science, on a theoretical level, can often be observed on a practical level when female engineering students criticise their education. It is not that they directly criticise the concept of technology—most of the



subject matter of engineering education is taken for granted by the students. But the aspects they discuss can often be seen to originate in the underlying concept of science.

One limitation that the natural science basis introduces in engineering education is the role of the human being. The original positivist science sees the scientist as being separated from the object of study, the objective observer. As an object of study, humans can only be regarded and taken into consideration as biological creatures. In engineering education this means that

> With a focus on science and technology follows a focus on things, i.e. a focus on the inanimate. The world of pure physical science and the world of pure technology is accordingly not populated by humans for whom life has a meaning (Danielsson 1998, 123).

A focus on the inanimate and disregarding human factors is problematic enough in science. It is even more problematic, however, when the aim is to apply scientific principles to satisfy human needs and wishes. There is a gap between natural science and social science, science about things and science about humans. Engineering science has taken a position on the natural science side of the gap. It is not the bridge between natural science and social science it could be expected to be, in the satisfying of human needs by the creation and use of artefacts.

The separation between scientific principles and human concerns, and the primacy of scientific principles, can be seen, for example, in the curriculum. Engineering education comprises basic courses in mathematics and science, courses in technical subjects and a small amount of what can be called 'non-technical subjects' or 'humanities and social sciences'. These are subjects that are not grounded in the natural sciences and most often deal with human beings, as subordinates, users, colleagues, customers, citizens or economic actors (subjects like management, communication, psychology, economics, history of technology, ethics, etc.—the composition has varied according to how different decades in different countries have viewed the role of an engineer).

The first problem with the curriculum is the separation of these subjects. While technology is the interaction of artefacts and humans, in engineering education knowledge of these two components is separated.

The second problem is the marginality of the subjects dealing with humans. All through the 20th century there have been discussions on the percentage of non-technical subjects in engineering education. In general the need of such subjects has been acknowledged, but they have been regarded as marginal compared with scientific/technical subjects. In the USA, the stated goal has been 20% of the curriculum, but according to Lyman (2002) this aim has not often been achieved. In Sweden there has been no national goal and the amount of non-technical courses at the individual institutes of technology has often been 10% or even less. The situation is quite similar in other European countries. Even if an engineering student were to be interested in building bridges across the gap between natural laws and human needs, the resultant structure would necessarily be askew, with the abutment on the human side being so very much weaker.

Toulmin (1998) makes a comparison between engineering education and medical education. Both strove to become more 'scientific' at the beginning of the 20th century. Both professions had their bases in natural science, and in the process of scientification both experienced a reductionism, in that aspects which were not directly connected to human concerns gained importance. Engineering science turned towards physics and medical science towards biology. The difference, according to Toulmin, was that medical education, parallel to scientific education, also preserved long periods of clinical training, which developed the more complex abilities of human concern and judgement among the students than the narrowly scientific ones. Engineering education has not had a similar amount of on-the-job training in how the scientific principles have to be adapted to practical situations, considering the human aspects of the context. This makes it more difficult for graduate engineers to realise the complexity of their work tasks and makes it natural for them to concentrate on those aspects of the task which can be handled by scientific knowledge, even when this disregards important factors for reaching a solution which is practical and usable for those concerned.

The idea of the detached, objective observer and the separation between nature and humans is one of the fundamental points in the criticism delivered by feminist science critics towards positivist science. The way



technology is presented without its human context in engineering education is also a common criticism of female engineering students. 'Women want the whole picture' and 'women want to see the societal consequences of technology' are opinions that are commonly uttered when gender reforms in engineering education are discussed. They have appeared after the first studies among female engineering students, where the women more often than the men said that purely technical subject matter was heavy and meaningless. These results have been verified time and time again in new studies, where female students say that they want more 'human' subject matter in their engineering education (Copeland 1995; Göransson 1995; Lewis et al. 1999 and Srivastava 1997 can be compared about the differences between male and female students).

One example of this is teaching in ethics. A view based on positivist science, that engineers do not have responsibility for what they create, but responsibility only appears when things are put in use and thus is a concern of the users, is still quite common in engineering education. Thus, professional ethics is a marginalised detail in the curriculum (Zandvoort, van de Poel & Brumsen 2000). Female students, more often than male students, say that they want more teaching and reflection on ethical matters during their education.

Danielsson (1998) points out that the theoretical point of departure also presents the creation of technology as something that is done in a certain succession of steps, from the first idea to the completed product. The fact that creating technology involves trial and error, backlashes and new directions is not stressed. Those who have been the cleverest students, mastering all the steps in theory, do not always become the best engineers in the industry. The solutions that are excellent in the educational context can be less adequate in the complex human practices where the technology is to be integrated. After having studied science and construction of artefacts with defined technical constraints, having to think about a human context in an educational task can be perceived as an irritating complication of the problem, rather than an inherent part of it.

The original ambition of scientific research, to dominate nature, also affects the underlying idea in engineering education about how technical problems should be solved. Engineering education builds on the primacy of technology: problems that can be solved by technology should be solved by technology, and it is the task of the engineer to find these solutions. Looking at other kinds of solutions, possibly on an equal basis with those concerned, is not something that is taught in engineering education.

Teaching the privilege of engineers to define users' problems is further evident in the way 'elegant' solutions often are appreciated in engineering education. This is also an inheritance from natural science, where it is common to talk about the beauty and elegance of different scientific phenomena. In engineering, however, achieving elegant solutions often requires that not only scientific complexities, but also the complexities of human practices are reduced to the point that the solutions do not cater for all the different aspects of processes and situations these practices normally address.

Grundy (1996) describes how male computer engineers seemed to find this much easier than female computer engineers did. The women more often wanted the systems they designed to fit closely to the practices and different problem situations of the users, which meant that the preparatory and even the programming phase easily became quite time-consuming. For the male engineers the creation of a computer system was an easier task, once they had understood the main tasks it would need to perform. This sometimes resulted in the implementing phase taking much time, as there were many adaptations to be made to get the system to function in the 'messiness' of real work situations. Promoting elegance rather than functionality means teaching the engineering students that it is their right to redefine other people's (the users') reality and try to adapt it to their models—which is also a way to dominate rather than to start a dialogue with users and their material reality.

One further influence of positivist science on engineering education can be observed in the impact of concepts like competition and excellence. In part, the claims of science for respect, authority and money are grounded in the image of science being something difficult, which only extremely gifted and intelligent people can work with and understand. The concept of technology in engineering education has a similar image: technology is presented as something that can only be created and understood by an elite (that is, those who have been gifted enough to be accepted by an



institute of technology and who have successfully completed the tough education). Tonso (1996) and Seymour & Hewitt (1997) reflect on the frequent use of the concept of 'challenge' in engineering education and the problems it causes for many female students who seem to be less clear about its role in their education. The goal of becoming part of an elite seems clearer to many of the men.

Feminist science criticism does not only say that women do not find the questions and methods of traditional positivist science as attractive as the men do who have designed them. The main message is that the questions, methods and results of science are much more limited than they are claimed to be. The same applies to the criticism of female students of engineering education. It does not only say that female students do not find their studies as interesting and enjoyable as men do. What these students are often reacting against is the underlying concept of technology and its limitations. This is not only interesting from a gender perspective, but also points at the fact that there are limitations, which carry over to the technology creation done by engineers educated according to this concept.

## Engineering education and technical limited rationality

The second limiting factor in the technology concept of engineering education are the strong ties between engineering and the fact that technical development has been motivated by economic or status-related reasons. As Freund states: 'It can be argued that engineering research is *the* vehicle by which wealth is added to a society' (Freund 1998, 213, my italics). The main task of engineers, both according to themselves and other stakeholders, is to keep up or advance their society's position in the economic and military competition of the Western world. Lyman (2002) points out the importance of status competition, especially with the Soviet Union during the Cold War, for the education of American engineers. The ambitions as to status and salaries of engineers are grounded on such expectations. For example, the magazine of the engineering union in Sweden, *Civilingenjören*, subtly transmits the message that other professions naturally are important in society, but that the welfare of the Swedish state is dependent of the ability of its engineers to maintain the position of Sweden against international competition.

Combining scientific positivism and economic rationalism easily makes humans 'human material', as is stated in a Swedish report on engineering education from 1943:

> Just as an engineer must not be foreign to the properties of dead material and machines, may he as a supervisor not be foreign to the properties of human material (SOU 1943:34, 108).

This means that when engineering education leaves the pure sciences and considers the human being, for example as a worker or as a user, the perspective adopted is very instrumental. The connection between engineering and industrialism has taught the engineers-to-be to view their work and the artefacts they produce in economic terms. When creating artefacts to satisfy human needs, engineers are taught to view humans as economically rational beings. 'Humans' as users of technology are regarded as abstract entities, who use economic rationality when they relate to technology. The fact that artefacts can fulfil many different kinds of human needs —not only practical but also, for example, aesthetic ones—is normally not interesting for engineering education, except when there is a possibility to use this fact in making a product more competitive on the consumer market. The strong association to economic gain is also something that limits the concept of technology in engineering education.

When discussing the gender aspects of the connection between engineering education and economic rationalism the theory of the different rationalities by Ve (1994) offers a frame of interpretation. The basic assumption of this theory is that the two sexes are socialised for their different tasks in a gendered society, and as a result they also develop different rationalities. (The Anglo-Saxon theory of caring rationality is similar to Ve's theory, but is to a higher degree based on the socialisation and psychological development during early childhood than the societal gender division of tasks.) Ve refers to Weber and writes about 'technical



limited rationality', which is the prevailing form of rationality in a capitalist society, a combination of technical, economic and bureaucratic rationality and which has economic effectiveness as its rationale. This rationality is only useful in the productive sphere, however, while another kind of rationality is needed in the reproductive sphere, taking care of other people, which women are socialised into to a higher degree than men. To denote this rationality, Ve uses the concept of responsible rationality (created by Sörensen 1982). It is based on a conception of personal responsibility for the welfare of other people one is interacting with.

The technical limited rationality views human beings as cogs in a production-consumption system. Responsible rationality views human beings and their needs as primary. Engineering with technical limited rationality implies producing goods for a market (of individuals or of societal institutions). Engineering with responsible rationality implies improving the quality of life for people one feels connected to, in one way or another, by inventing or improving material objects. This also means that technological development is not seen as positive in itself, but is seen as positive only to the degree that it fulfils real human needs and to the degree that it does not create new problems, for example for the environment, or by increasing gaps between different groups of people.

Of course, the different rationalities are not exclusively gendered—there is nothing essentially masculine about technical limited rationality and nothing essentially feminine about responsible rationality. However, when looking at the criticism female and male students express about engineering education, there are clear connections both to gender and to the two forms of rationality. It is visible, for example, when talking about human beings, or about the importance and the consequences of technological development or about the importance and the definition of effectiveness (Copeland 1995; Srivastava 1997; Tonso 1997). It can be expected that socialisation to responsible rationality, with its origins in care work, is not as strong among women who choose engineering education as in women who choose more traditional care-oriented professions. But even these women do forward opinions and attitudes associated with responsible rationality to a higher degree than their male fellow students.

Srivastava (1997) writes about how building engineering students learn to view a person (for example a building worker) as a component in a system, the effectiveness of which should be maximised. She concludes that this suits male students much better than it suits women:

> Male Building students identify with instrumental views of Building rather than the social, problem solving approaches preferred by women Building students. The authoritarian, conservative, emotionally reticent characteristics of science discussed by Head (1980) can be seen in the Building process and are seen to be attractive to male Building students who enjoy the hierarchy, the primacy of time and money, controlling people and production (Srivastava 1997).

When asked about technological determinism and technology optimism, female students have been more hesitant than men about the belief that technological development will result in increased prosperity. Göransson's (1995) study is a case in point: women agreed more often than men with the statements 'technological development should be guided by environmental considerations', 'technology should be steered according to human needs', 'the wrong kind of technology has destroyed our environment'. Men more often than women agreed with the statements 'money used for technology is well-used money', 'technological development raises our standard of living'. Similar results can be seen in other studies. The connection between technological development and economic growth thus seems to be more self-evident and less complicated in the eyes of male than female students.

## Conclusion

To summarise: In engineering education 'technology' is applied natural science, it is something abstract with relatively few sensual experiences, it is aimed at creating economic profit (or at least status or security—such as space technology and military technology), it is something between an engineer and a user but does not unite them, and it is separate from its consequences. Technology is something that engineers do, because it is their (important and well-paid) job and, ideally, it is something that engineers experience as challenging and fun.



And what is technology *not* in engineering education? Technology is not practical handling of artefacts and free use of creativity and trial and error to solve practical problems. Technology is not something done on a small scale, for one's own needs or for the needs of one's immediate environment. Technology is not a way to communicate a message between a designer and a user, and not a way to care about other people. Technology is not an inseparable part of its context (context of creation and context of use), with inherent possibilities and obstacles, suggestions and imperatives. Technology is not something that is done by men and women, children and old people when they make, use and remake artefacts to satisfy their daily wishes and needs. Technology could be all this, and for many people it is—but in engineering education these aspects hardly exist. In engineering education the concept is limited, and has hardly changed over the past hundred years.

Historically, engineers have had the right to define technology, and, naturally, they use this right in defining technology in engineering education. In Sweden, for example, all evaluation reports (those initiated by the state as well as those initiated by the profession) of engineering education during the 20th century have been written almost solely by engineers (and, naturally, by male engineers). Regarding the strongly socialising effect of engineering education, it is not really surprising that these reports have not questioned aspects which have been taken as givens in the examiners' own education and their professional lives, such as the limited concept of technology the education is based on. Besides, these examiners of engineering education also know that they and their colleagues base their status and their power on promoting a concept of technology which builds on the masculine aspects of science—such as reductionism, objectification and claims of dominance. Being more sensitive to contexts and starting dialogues with users and citizens (in both productive and reproductive spheres of the society) on a truly equal basis would in itself lead to the privilege of engineers in evaluating and deciding on technology being diminished.

The interests of engineers and engineering educators also coincide with the political interests in keeping engineering education relatively unchanged. Society needs its engineers in promoting technological development, which is seen as the primary means of increasing economic (and thus general) welfare. Diminishing the privilege of engineers in directing technical development would also change the political scene around the development of technology. As long as societal development is evaluated basically by means of technical limited rationality and the society needs its engineers to lead it towards more and more sophisticated technology, there are no big incentives to change engineering education to make it correspond to the preferences of students in whom responsible rationality is more prevalent.

Thus, to base engineering education on a more diversified concept of technology would not only change the knowledge possessed by the newly examined engineers. It would probably also direct the engineering profession away from its privileged position. That is why it is difficult to see which of the present stakeholders in engineering education—students, teachers, employers, the state—would be interested in working on a development towards a radically different concept of technology. If the concepts of technology and engineering education are to be feminised the same way as the concept of friendship (and possibly in a similar time perspective) their context will be changed, too—other actors and agents will relate to them in a different way and they will play a different role both practically and symbolically. This is a very long process, however, and the change in the concept of technology has to happen in interaction with the surrounding society.

A man at the end of the 18th century would probably not agree that what is conceived as friendship today could describe his relations to those he calls his friends. And it might be quite as difficult for the engineers of today to feel at home in a work environment which would be based on a more practical and aesthetic, less pretentious and more human-centred concept of technology, not associated with large technical systems, consumerism and exploitation of natural resources in the same way as technology is today. If the gender of the concept of technology should be changed, also the engineering profession would experience changes that are inconceivable today. On the basis of how female engineers-to-be talk about technology and their education, it is reasonable to conclude that women would find those changes more positive than men do and that those changes may, actually, be inevitable if engineering should become a gender balanced profession.



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