"A sufficiently complex construction" and other conceptions of technology held by engineering students: A case study from Sweden

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***Abstract**: Engineering has been described as a particular community of practice with its own tacit assumptions about the nature and purpose of engineering and technology. In this paper we investigate how engineering students conceptualise technology. Data was collected through ten interviews and the data was analysed using a phenomenographic approach, leading to six different conceptions of technology. Interestingly, the social dimension of technology was almost invisible in all conceptions. We discuss how these results can be used as an educational intervention to help engineering students to develop a more complex understanding of technology. We also outline the structure of a course aiming to increase students' understanding of engineering as well as the relationship between science, technology and society.*

Introduction

Engineers have come to play an increasingly important role in society. In our technology-dependent and technology-filled society, the impact of decisions made by engineers is amplified, especially in light of challenges such as poverty and environmental sustainability. In addition, engineering students graduate and work in an increasingly global context, with and for a diverse group of people. As a consequence, the stakes for the decisions engineers make have increased.

Kabo and Baillie (2010) have suggested that engineering can be considered as a particular *community of practice* (Wenger, 1998), with an associated *common sense* (Gramsci, 1971). They argue that this common sense could restrict problem solving and act as a barrier toward approaching social justice. If anyone is to move beyond the tacit assumptions and common sense of a particular community of practice then these assumptions need to be made explicit and members of the community made aware of their existence and (socially) constructed nature (Fleck, 1979; Freire, 2003).

In the area of STS (Science & Technology Studies) there is a long tradition of making assumptions that are tied to a particular context or phenomenon, such as engineering (Sismondo, 2004), explicit. We suggest that a fruitful contribution to this "deconstruction" (i.e., making assumptions explicit and critically question these) of engineering is to investigate how both engineering *students* and *faculty* conceptualise fundamental aspects of engineering common sense, such as the nature and purpose of engineering/technology. A similar point was recently made by Pawley (2009). There has, however, been very little research in this area (e.g., Dunsmore, Turns & Yellin, 2011; Pawley, 2009).

In this paper we first investigate how engineering students conceptualise the notion technology. We also discuss how our findings can be used as an educational intervention to help engineering students to deconstruct and reconstruct (i.e., rethink) the notion of technology. Finally, we outline the thematic structure of a new course with the overall aim to increase engineering students' understanding of what engineers do and the relationship between science, technology and society.

Method and methodology

Ten interviews were conducted with students enrolled in Engineering Physics at Chalmers University of Technology in Gothenburg, Sweden. The students were in the latter stages of, or had just finished, their education and thus had little or no professional experience as engineers.

Since the aim of the study was to identify and describe different conceptions of technology, the notion of technology was discussed from different angles without leading the interviewees to certain answers. To help the interviewees to explore and articulate their conceptions of technology, the interviews were based on a series of "exercises" in which various "props" were used. For example, early in the interview the interviewees were asked to reflect on what technology means to them and to write down a few examples. Later the interviewees were shown three pictures – an aerial photograph of a cityscape, a cave painting of a hunting scene, and a photograph of a protest march – and asked what technology they saw in the pictures. Toward the end the interviewees were asked to discuss how they view the relationship between technology and science.

The interviews were carried out in a semi-structured, dialogical manner. Follow-up questions were used when something was unclear or to explore interesting thoughts that came up. The interviews were carried out in Swedish and lasted between 20 minutes and one hour. All interviews were audio taped and transcribed verbatim.

The interviews were analysed using a phenomenographic approach (see, for example, Sjöström & Dahlgren, 2002, for an overview). Phenomenography is based on the assumption that it is possible to describe the ways in which people conceptualise a certain concept in a limited number of qualitatively different categories of description. The categories of description are distinguished from one another in terms of the presence or absence of certain critical aspects of the concept. The resulting set of logically related and empirically grounded categories of description is called the *outcome space* for the concept.

The interview transcripts were read through several times and when relevant quotes relating to technology were found these were highlighted and collected to form a *pool of meaning*. The selected quotes were then in turn read through several times and the data was organised according to the various themes that emerged. This iterative process continued until the emerging themes could be formalised into categories of description.

In the study the interviews were analysed with respect to the following issues: the *nature* of technology, the *purpose* of technology, the role of *people* in technology, and the type of *knowledge* needed in technology.

Results

Six different categories of description corresponding to an increasingly more complex understanding of technology were found. In this section, the categories are described in terms of critical aspects and illustrated by student quotes. The quotes have been translated into English. The notation "I#" refers to the student being interviewed.

Category 1 – Technology as artefacts with certain characteristics

In this category technology is seen as artefacts with certain characteristics. These characteristics are quite vague or general in their nature. Technology has no clearly stated purpose. The focus is on the artefacts themselves and their characteristics. Common characteristics of a technical artefact appear to be: complex construction, requires a power-source, constructed/manufactured, or modern.

Humans have passive roles in relation to technology, mainly as observers of the technical artefacts. As observers humans have a quite limited and shallow understanding technology. Technological knowledge is limited to the characteristics of technical artefacts.

> A sufficiently complex construction. (I6)
>
> [In response to a picture of a cityscape:] I see a number of combustion engines, for example in buses and cars. Trams that are powered by electricity. (I1)

> Trams, buses, cars, bridges, everything like that – that is the technology I see. Everything that we see is constructed by humans, essentially. (I2)
>
> I mean for it to be technology today in some way it feels that it has to be something that is a modern invention. It feels that technology many years ago could have been to invent a fork because it was practical… Well, it is an expression that has to do with the present time in some way. (I9)

Category 2 – Technology as artefacts with a purpose to satisfy certain needs

In this category technology is seen as artefacts with a purpose to satisfy certain needs. Now technology has a clearly stated purpose, e.g., to accomplish a specific task or to solve a particular problem. The focus has now shifted from the characteristics of an artefact to its purpose or functions. Common purposes of technical artefacts seem to be: to facilitate life/certain tasks or to entertain.

Humans now have more active roles and are now users and consumers of technical artefacts. As users humans still has a limited and shallow understanding of technology. Technical knowledge is limited to how technical artefacts are utilized.

> If you look at applications and such, I feel that they in most cases have been created to satisfy a certain need or something … technology is very concrete to why it has been created and what it is utilized for. (I3)
>
> A water tower… that is a technical development to solve a specific problem. (I1)
>
> For me technology very much is gadgets, devices, things that humanity has invented to make everyday life easier. (I9)
>
> Or to amuse us, entertain us. I mean TV-sets don't exist first and foremost for facilitating our daily life, but they might make our daily life a little bit nicer. (I8)

Category 3 – Technology as how artefacts work and are constructed

In this category technology is seen as the inner workings and the actual construction of an artefact. In other words how artefacts work. The purpose of technology is vague.

In this category humans also have more active roles and are consumers of knowledge of technical artefacts. Thus humans have a deeper, but still limited understanding of technology. Technical knowledge includes how technical artefacts work and are constructed as well as how activities are carried out, i.e., methods. This knowledge is something that has to be learnt.

> How things actually work. (I3)
>
> Technology is for example how an engine works… and the technology is exactly how it is constructed and how it works. (I3)
>
> How a lever is used or really anything, a jack. (I3)
>
> [Technology] is something that involves many complicated steps, which require knowledge humanity has accumulated and that is not included in our basic repertoire of behaviours. (I5)

Category 4 – Technology as an independent discipline

In this category technology is seen as an independent craft/discipline with the purpose to satisfy the needs of humans through the creation of new technology or improvement of existing technology. Technology is here a process where the outcome is the products of the previous categories.

In this category humans have active roles in relation to technology. Here they are the creators and developers of technology. Technology has its own "body of knowledge" which is used to create products and to develop new technology. The basis of this knowledge is what is known to work. The "body of knowledge" can be expanded through systematic trial-and-error.

As I see technology is that the need of society … or the individual is solved by developing new technology… well if you look at it from a techno-historical point of view … it is the needs that in most cases force you to develop new technologies and such. (I3)

Maybe because it is to put existing things together to something new and better, something new and more useful in someway. (I9)

You do as you know that this has worked earlier and then we do the same. (I2)

In these canals and bridges and such it isn't that much science. It is older structures from before science really gained momentum and started to influence ordinary life. (I2)

Category 5 – Technology as applied science

In this category technology is seen as applied science. The purpose of technology is to use science to satisfy the needs of humans through the creation of new technology or improvement of existing technology. Technology is here a process where the outcome is (new) artefacts (products).

In this category humans have active roles in relation to technology. Here they are the creators and developers of technology. Science is seen as the basis for technology. Technology is dependent on principles and knowledge from science. To create new technology scientific knowledge is needed.

We have the sciences and then with what we get from science we create technology. (I8)

The purpose and goal of technology is to… to perform things for humans in some way. Yes, to use the science that we have been given in some way to produce more things, better things, or to make it easier, more flexible, more fun… to facilitate our lives. (I9)

To construct the electric power lines they have been required to use electromagnetic field theory or more precise circuit theory. To create the clock they have been required to use knowledge of mechanics and things. So to make the components they have been required to use techniques that science has developed. Not technology in its meaning but techniques, that is to say methodology and such. (I1)

Category 6 – Technology as reciprocal to science

In this category technology is seen as reciprocal to science. The purpose is similar to that of the two previous categories, i.e., to satisfy the needs of humans through the creation of new technology or improvement of existing technology. However, the focus might have shifted more to the actual technical development. Here technology is a process.

In this category humans have active roles in relation to technology. Here they are the creators and developers of technology. There is a reciprocal dependence between technology and science. Each helps to drive the development of the other. This might lead to a cyclic process of development. A consequence of this is that technology becomes very dynamic in nature.

There is an interplay where new technical applications give birth to, make it possible to explore science, but at the same time in most cases the theories is the basis to which applications you can come up with… Well, the atomic bomb is a fun example (laughter) where the theory definitively came before the application. They knew that this should work, so now we try if it works, and then they did. (I6)

Through development of new technical things you can see, make pictures of, things you never have seen before … and thus discovering new things and thus new theories and therefore, hopefully, continuing to discover things and then new theories so it adds onto itself. That science needs the technical development of its measuring tools, its thoughts and such to continue its own development which it then feeds back to technology. So it is a very symbiotic relationship. (I1)

In Figure 1, we have illustrated the logical relationships between the six categories in terms of their critical aspects. In this outcome space the categories are distributed over four hierarchical levels. At the second and third level two complementary pairs are situated (category 2 & 3 and category 4 & 5).

In addition, the six categories form two groups of three. In the first group technology is described as a product whereas in the second group technology is described as a process.

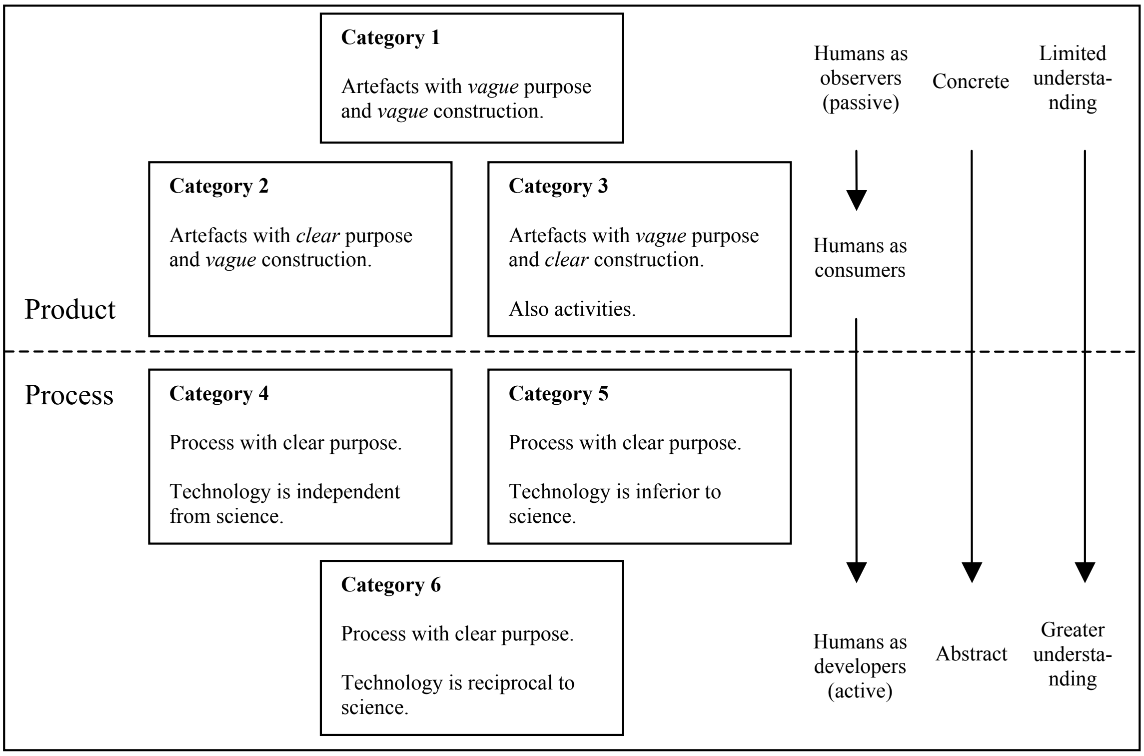

Figure 1: The logical relationships between the six categories in terms of critical aspects.

Discussion

The engineering students in this study expressed a broad range of conceptions of technology – even after several years of engineering studies. From a constructivist perspective this is not surprising since learning is an active process of constructing personal meaning (Bransford, Brown & Cocking, 2000). Moreover, engineering students at Chalmers learn many different things about technology in different courses, but there is little or no explicit discussion about the nature and purpose of technology today. We believe, however, that this type of discussion and reflection might benefit and prepare engineering students for a professional career after graduation (Tahan et al., 2006).

McRobbie, Ginns and Stein (2000) conducted an extensive literature review of different definitions of technology and identified five dimensions of technology: 1) technology has a human dimension (it is a purposeful activity); 2) technology has a social dimension (it has effects on society and it is influenced by value judgements); 3) technology is a process; 4) technology is situated (it is conducted within contexts and constraints); and 5) technology leads to the development of products, or artefacts.

An interesting and important observation regarding the three latter categories in the outcome space (the process categories, representing a more complex understanding of technology) is that they mainly focus on the relation between technology and science while the social dimension of technology is almost invisible or taken for granted. To some extent this might be a consequence of the focus chosen in the interviews. Nevertheless, even if the purpose of technology in these categories is to satisfy human needs, the question remains: Whose needs? Who benefits and who bears the burden? This kind of assessment is an important part of engineering practice and should be made when new technology is introduced into society (Budinger & Budinger, 2006).

One strategy we consider for increasing engineering students' awareness of the social dimension of engineering – and potentially how social justice intersects with their future professional practice – is to devise a course around the idea of deconstructing and reconstructing engineering. A somewhat similar course has been described by Kabo, Day and Baillie (2009). The course will comprise five thematic units: “Why am I in engineering?”, “What is technology?”, “What is it engineers do?”, “Engineering and sustainability” and “What is engineering?”. The idea is to start with the students’ own experiences (such as “Why am I in engineering?”) and aspects that students might have a more concrete notion of (such as “What is technology?”) and move toward the more abstract and complex (such as “What is engineering?”).

The results of this study can be used as input when discussing the second theme of the course: “What is technology?” The idea, drawing on variation theory (Marton & Tsui, 2004), is to expose students to variation in how technology is conceptualised by someone in a similar context. This would make them more aware of what the critical aspects of technology are and help them to develop a more complex understanding of technology. Combined with suitable readings this approach can help students reconsider what technology is and leads on to a discussion about what it is that engineers do.

The fourth theme, “Engineering and sustainability”, is well suited for opening up the social dimension of engineering practice. The popular concept of the triple bottom line – social (people), environmental (planet), and economic (profit) – can be used to open up a discussion about social responsibility and social justice, which can be expanded on when discussing what engineering is. And what it can be.

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