On Young People's Experience of Systems in Technology

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Abstract

Immersed in a technologically complex world, young people make sense of a multi-faceted set of events in everyday life. This article investigates the variation in how Swedish young people experience technological systems and is based on interviews focusing three systems concerning transport, energy and communication – contextualised in relation to bananas, electricity, and mobile phones. A phenomenographic analysis results in five qualitatively distinct categories, describing different ways of understanding technological systems: *Using single components, Using the system output, Influencing the system, Interacting with the system, and Integrating the system*. The results support that different ways of understanding technological systems implies different ways of understanding the complex nature of technology. The results also point to possible ways of developing teaching for technological citizenship.

Key words

technological system, technology education, phenomenography, citizenship

Technology, humans and systems

The internationally emergent theme of technology in compulsory education emphasizes active citizenship, understanding of the nature of technological artefacts and activities and the interdependency between technology and humans. The purpose of this study is to contribute to the understanding of the development and the qualities of knowledge in such technology education. Our focus concerns how young people experience and conceptualise (socio)technological systems.

We live in a world interwoven with technology, and life in today's society presupposes integration with technology – physically in terms of objects and the outcomes of technological processes; intellectually in terms of the knowledge needed to make use of technological objects and processes, as well as the knowledge manifest in their development and function – to the extent that much participation in societal life presupposes a 'technological citizenship'. Latour (1999) even argues that "*…the relations of humans and nonhumans are so intimate, the transactions so many, the mediations so convoluted, that there is no plausible sense in which artifacts, corporate body, and subject can be distinguished*" (p. 197).

Thus, having an interest in understanding how people can relate to technology in their daily lives, we cannot do so with the starting point that technology and human are separate. Neither is it meaningful to talk only about individuals' relationship to technology since the manufacturing of technological objects today is no longer one individual's work, a whole collective of humans is involved. Latour says:

> One finds, of course, longer chains of action in "modern" collectives, a greater number of nonhumans (machines, automatons, devices) associated with one and another, but one must not overlook the size of markets, the number of people in their orbits, the amplitude of mobilization: more objects, yes, but many more subjects as well (Latour, 1999, p. 195).

In the same vein Mesthene (2003) talks about technology of our age as a social phenomenon that implies new possibilities:

> Technology, in short, has come of age, not merely as technical capability, but as a social phenomenon. We have the power to create new possibilities, and the will to do so. By creating new possibilities, we give ourselves more choices. With more choices, we have more opportunities. With more opportunities, we can have more freedom, and with more freedom we can be more human. That I think is new about our age (p. 619).

This view of technology, as complex, collective and integrated with humans, is closely related to definitions of sociotechnical systems[1], or technological systems as we will refer to them. Thus understanding technological systems offers a powerful way of understanding technology in modern life.

Technological systems can be described in different ways: as an object with parts working together – a car with steering wheel, brakes, engine and so on making the car move; as a process with input and output – when you put fuel in the car it is by a process transformed into motion, heat and exhaust; as a network of relations – roads, traffic rules, drivers, cars, petrol stations and so on making it possible to move from one place to an other.

In this article, a technological system is defined in terms of an *ascribed function* (cf. how DeVries (2005:14) uses

[1] In sociotechnological systems technical, social, economic, and political components are interconnected in a "seamless web" (Bijker, W., Huges, T., & Pinch, T., 1989).

ascribed function to denote what technological objects are expected to achieve), *components* that may have either technical or human agency, or *rules* (Dusek, 2006; Kline, 2003). The system has internal network connections between components, as well as external relations to the surrounding world, e.g. society, nature, and other (technological) systems (Ingelstam, 2009; Joerges, 1996). A technological system understood in this way may also describe the long chains of action, the large collection of nonhumans, and the association to large numbers of people, that Latour (1999) points to (see above). Kline (2003) argues that sociotechnological systems also are central in the extension of human capacities.

Seeing technology from a system approach encompasses humans, whether they are seen as consumers in terms of the system function, or as contributors to sustaining the system in terms of function, rules, and structure (Dusek, 2006).

In summary, we perceive technology in today's society as a network of relationships within and between technological systems, where humans are important parts, agents and actants on all levels. Knowledge about this is a crucial part of technological citizenship in modern society.

Knowledge about technological systems

Chen and Stroup (1993) point to the possibilities of using a system approach in technology education. The authors use General System Theory[2] as a framework for education in science and technology, arguing that this framework gives the pupil possibilities of understanding how different areas, such as engineering, nature, and society, are integrated; that the framework stresses the complexity of the environment and tries to bridge the gap between the world of the learner and the world of science and technology education. According to Chen and Stroup (ibid), General System Theory also offers an intellectual tool to understand changes in the environment. In a later study Barak and Williams (2007) present an instructional framework to help teachers and curriculum developers to focus on essential aspects to support system thinking: contextual and interdisciplinary learning, use of models and modelling, and learning experiences of different systems. Barak and Williams (ibid) admit that their framework needs further empirical investigation of pupils' understanding of technological systems and further discussions about what possible pedagogical implications the framework enhances.

Ginns, Norton and McRobbie (2005) focus on pupils' knowledge about systems encapsulated in technological objects, by investigating grade 6 pupils' understanding of bicycles and steam-powered model boats. One part of the investigation entailed designing, constructing, and developing a Lego robot, where the authors found that pupils in the study were able to identify components in the systems, to explain interactions between components, and to speculate on inputs and outputs, and also on how feedback in the system might work. The results point at the possibility of developing pupils' knowledge about systems, focussing on the internal function of simple systems in objects.

A recent study by Svensson and Ingerman (2010) focus on pupils' understanding of technological systems as connected to everyday objects. The study is based on interviews with 10 and 15 year old pupils with some objects (mobile phone, light bulb, and banana) as a starting point, and the analysis indicates five qualitatively distinct ways of understanding objects in relation to systems. The set of categories ranged from focusing objects for (personal) use over seeing them as parts of a system to experiencing them as embedded in a set of systems. Even though most of these imply discerning a system aspect, what is experienced as the specific nature of systems is not clear from the results.

When we investigate the research about learning complex systems more generally we find that there are relatively few studies concerning pupils understanding and learning possibilities of complex systems. One crucial problem according to some researchers (Abrahamsson & Wilensky, 2005; Jacobson & Wilensky, 2006) is that pupils have a linear system approach resulting in not understanding the complexity of systems. Jacobson and Wilensky (2006) emphasize that it is important to make the pupils aware of the fact that they are participants in systems not only observers or users of systems.

When we look at these studies in the light of the complex nature of technological systems in everyday life, it is clear to us that the understanding of the role of humans and the "whole" are aspects of technological systems that need further attention. This is emphasized by the turn towards technological literacy as an educational goal, when understood in relation to possibilities of fully participating in society, that is, possibilities of enacting citizenship.

The Swedish national curriculum, which is our context, offers interpretive opportunities and is designed to establish what all pupils should learn through setting goals, while at the same time providing great scope for teachers

[2] General System Theory was established by Ludwig Bertalanffy in 1955.

and pupils to choose their own content focus, materials, and working methods. In the general part about education, citizenship as "participation" is emphasised, but in the specific text that concerns technological systems this approach is not evident. There is also a tension between the parts describing goals for learning about technological systems and goals discussing technological literacy as an overarching goal. Technological systems are discussed mainly in terms of structure and function, and the general descriptions of technology and technological literacy include humans, but do not in any explicit way link humans to technological systems:

> Society and our ways of living are increasingly influenced by the use of technical components, which in turn are often included in larger technical systems. […] Examples of large systems are networks transporting goods, energy or information, whilst carriages, power cables, and computers are components in these systems. […] By studying individual technological solutions and their incorporation into larger systems, pupils can obtain important insights into the special character and conditions of technology (Skolverket, 1994/2000).

Similar writings about technological systems are found in the New Zealand national curriculum (Techlink, 2007) and in a policy document about technology education from the National Academy of Engineering in USA (Pearson & Young, 2002).

> When engineers speak of a system, for instance they mean components that work together to provide a desired function. Systems appear everywhere in technology, from a simple system, such as the half-dozen components in a click and write ballpoint pen, to complex systems with millions of components, assembled in hundreds of subsystems, such as commercial jetliners (Pearson & Young, 2002:17).

In the above quote, technological systems encapsulated in objects are focused. Doing so, humans are specifically seen as outside the system. With the broad view of technology we embrace, the technological systems of interest include objects as well as humans and rules.
Even though technological systems are an explicit part of several national curricula, research about knowledge of technological systems is almost non-existent. Such research is important, for example, to inform developers of technology education. One first step could be to understand how such knowledge is constituted by learners, in order for teachers to be able to support young people in critical parts of their learning about technological systems, as a part of developing their technological citizenship. Later steps may include, for example, investigating knowledge about technological systems among young people nationally.

In summary, our analysis of previous research (mainly Barak & Williams, 2007; Ginns et al., 2005; Svensson & Ingerman, 2010) and philosophical descriptions of technological systems (mainly De Vries, 2005; Dusek, 2006; Ingelstam, 2002; Kline, 2003), can be synthesized in a framework of technological systems with four interconnected parts that are linked and related in different ways:

- The *structure* of the system – how the components form a system as well as their interaction through transportation, transformation, and control, as well as different inputs and outputs such as information, energy, or matter;
- The *function* of the system – the ascribed function in terms of what the system achieves;
- How the system *interacts with humans and society* – how society and humans, individually and collectively, maintain, control, interface, affect, and are affected by the system;
- How the system *interacts with other technological systems and nature* – the net of relations between different technological systems and between technology and nature, which together points to a larger whole.

Consequently, the overall aim of this study is to investigate young people's experience of technological systems. The research questions are:

- How do young people experience the function and the structure of technological systems?
- How do young people delimit the technological systems vis-à-vis their surroundings?
- How do young people experience the role of humans in technological systems?

These research questions are to be understood broadly in relation to school and society, and not primarily as functions of schooling.

Design and methodology

Phenomenography

Phenomenography as a qualitative research approach offers opportunities to investigate research questions concerning ways of understanding specific phenomena, such as technological systems. One fundamental assumption in the phenomenographic approach is that there are always a number of qualitatively different understandings of a particular phenomenon or aspect of the world (Marton & Booth, 1997). Some of these ways to understand can be argued to be more powerful than others when acting in the world. The focus in a phenomenographic investigation is the empirical search for qualitative differences in the collective experience of the phenomenon. Thus, ”*…the aim is not to capture any individual's understanding but to capture the range of understandings within a particular group*” (Åkerlind, 2005:331). This is possible if the informants are describing experiences of aspects of the same phenomenon. Thus, ultimately what the investigated phenomenon is, must be answered in relation to the empirical material. In practice, the design includes doing semi-structured interviews where young people are prompted to expound in relation to situations where technological systems are central, whereupon differences in their reasoning emerge. The design of the interview was determined by our pre-analysis, as described above, while still remaining open. The analysis, however, did not take the pre-analysis as a starting point; instead we attempted to see technological systems as they made sense to our interviewees, in line with seeing the investigated phenomenon as “emergent” from the empirical material. The analysis process entailed the synthesis of differences between two or several interviewee's reasoning into differences of importance or qualitative differences with respect to the phenomenon. Less important differences, such as phrasing or how the phenomenon is contextualised, are allowed to recede into the background, and the qualitative differences are brought to the fore through the construction of a set of categories. In these categories, the structure and meaning of the qualitative differences are articulated, commonly as logical relationships between the categories. Marton and Booth (1997) describe the phenomenographic research tradition in considerably more detail.

Data generation

Data was generated through semi-structured interviews with eighteen Swedish young people, all 15 years old, during their last semester in compulsory school. Youths from five different schools, located in Gothenburg and in the surrounding suburbs, participated in the study. The first author in this article contacted the technology teacher at each school asking him/her to select four youths. The rationale for selection included a confirmation of interest, and consideration of what the teachers knew about the youths, for example, their knowledge of technology, with the aim of ensuring productive variation across the interviews. The interviews were done individually in the school during a school day and lasted for 30 to 40 minutes.

The investigation does not focus on the extent to which the interviewees have reached the goals in the national curriculum. Further, Klasander (2010) concludes that teaching technological systems is unusual, even though it is an explicit part of the Swedish curriculum.

The three systems concerned transport, energy, and communication, contextualised in relation to bananas, electricity, and mobile phones. These three kinds of systems span the primary system aspects of societal ways of handling material, energy, and information, which are the three main kinds of “objects” transformed in technological processes, according to the Swedish curriculum; cf. also Van Der Vleuten (2009). We find it especially important that the interviewees were familiar with the context that the systems were presented in – bananas, electricity, and mobile phones – and that they interact with those systems in their everyday life. Further, aspects that have been taken in account are that the flow differs in these systems – material, information, and energy – that the ways of transporting the material, information, and energy vary – for example in vehicles, in the air, or in wires – and that the aim(s) of the systems could be recognised on different levels – for individuals, humans, and societies[3].

When trialling the questions for all three systems, we found that the attention of the interviewees decreased towards the end. Thus we adopted an interview scheme where each interviewee was asked about only two of the systems, systematically combined to span all combinations. All in all this resulted in 12 youths interviewed about each system. The banana or electricity systems were always introduced first, followed by the electricity or mobile phone system. They were presented in an order of complexity. The interviews started with introductions, a picture or a description, in order to contextualise the technological system in focus (see Table 1).

The interviewees were also asked to make a sketch of the system to visualize and communicate their ideas of the system. The questions following the introduction of the system were designed around the different themes mentioned above:

- *Structure and function of the system* – with questions revolving around young people's experiences of the aim of the system, how the system is structured, what the limitations of the system are, and relations within the system.

[3] Here *individual* concerns one specific person, *humans* concerns a number of individuals, and *society* concerns humans in general, living together in communities.

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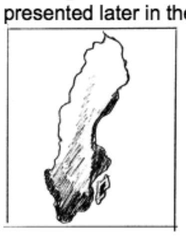
System	Oral introduction	Pictures * The pictures/photos are here replaced with sketches for copyright reasons
The banana system	In Sweden we eat 184 000 tons of bananas each year. I would like to talk with you about the system that provides us with bananas.	
The electricity system	What do you think we see in the photo? Why do you think that some parts are brighter than others? I would like us to talk about the system that provides us with electricity.	
The mobile phone system	When I was in northern Sweden this summer I realised that it was impossible to make a call or a text from my mobile phone and the rest of family’s phones. But my friend’s mobile phone worked well. What do you think was the reason for this? When we climbed the highest mountain in northern Sweden my mobile phone suddenly started to sound and I received a lot of missed calls and texts. How could this happen?	A map of a mobile phone network coverage in Sweden was presented later in the interview 

Table 1. A presentation of the system introductions used in the interviews

- *System interaction with humans and society* – with questions emphasising the impact that individuals, people, and society could have on the system and vice versa.
- *System interaction with technological and natural systems* – with questions focusing on related systems, how the system interacts with nature, and if nature could have any impact on the system.

Data analysis

The interviews were transcribed, and the whole transcripts were repeatedly read, for the purpose of getting to know them as a collective. Different interesting aspects were found in the transcripts, but since the aim of the study was to understand how young people experience the structure, function, and interaction of the technological system, this was the focus in the continuing analysis. The interviews were in this way transformed from a full-length interview to a set of focused units of interview extracts related to the research questions. In the process the sketches were used as an additional context to the interview extracts.

In the analysis the distinct differences were sought across the units of interview extracts and as a first result tentative categories emerged. The tentative categories were delimited in a more elaborated and explicit way from each other by using the analytic tools of structural and referential aspects. The structural aspects refer to “*the way in which the whole is discerned, how its parts are discerned and are related to one another and to the whole*” (Marton & Booth, 1997:100) and can be divided into the internal horizon— the parts or in this case the components in a system and how they are related to each other, and the external horizon—what surrounds the system and makes a system demarcation. The referential aspect refers to the understanding of the meaning of the phenomenon—the meaning of the technology system to them as humans and for the society.

The categories are presented as subsections in the Results section, while the fine-grained delimitation of the categories is presented in Table 2.

The phenomenographic research approach is an interpretive process, and to ensure the trustworthiness of the outcome and impact of the study, three kinds of credibility are important: content-related credibility, credibility of method, and communicative credibility (Booth, 1992; Collier-Reed, Ingerman, & Berglund, 2009). The content-related credibility concerns the researcher's insight into the topic related to the phenomenon and the researcher's open attitude during the whole research process so that he/she is open to different ways of understanding the phenomenon. In respect to this we prepared questions around three different themes related to our synthesised description of technological systems and at the same time remained open to different experiences stemming from these themes. To fulfil the credibility of method– the relationship between the research question and the design of the study, a relevant sample selection and a shared interview context are important. To frame the interview situation so that there are shared experiences between the participants and the researcher, we use a prepared context (Collier-Reed et al., 2009)–a picture and a description as an introduction of the interview situation. In relation to the communicative credibility–the presentation of the results and conclusions in an open way that it was possible to scrutinise, we have presented units of interview extracts, an open description of the method, analysis, and the qualities and hierarchy of the categories.

Results

The analysis resulted in a set of five categories qualitatively distinct from each other. A list of the five categories is presented below, followed by a description of each category with extracts from the interviews. Since no single extract fully captures one category, the extracts have been chosen to illuminate the main thrust of the categories, especially in terms of the meaning and structure of the understanding of technological systems that the different categories signify.

Categories

- Using single components
- Using the system output
- Influencing the system
- Interacting with the system
- Integrating the system

Using single components

In this category the focus is on single components, such as a lamp or a mobile phone, and how to use them. This may be linked to the internal structural aspect with components as an important part but here without internal connections. The system aspects and situations are ignored and, despite the system approach presented in the introduction and recurrent questions concerning this during the interview, there is no connection between components and something discerned as a whole, such as a technological system.

Interviewer – Are you part of this system?
Youth 14 – Yes, I am the one switching the lamp [bedside lamp or pendant] on and off, in that way I am a part.
Interviewer – Is the system important to you?
Youth 14 – Of course it is important, I need light, that's important.
Interviewer – Could you have any influence on the system?
Youth 14 – Yes, I can in some way. Maybe…I am the one buying the lamp. You buy them in a special shop.

In this extract, Youth 14 points out that using and buying single components affects the system, thus limiting the discussion to a user interface with components, which could indicate an underlying assumption that the meaning of the system is for their own use of components.

Using the system output

The focus in this category is on the necessity of the output of the system for human use and the impact that individuals, humans, or society could have on the system to maintain it by using the output. In this category there are humans using the output of the system: the energy, banana, or information of the system. This contrasts to the *Using single components category* where the interviewees emphasise their own use of single components belonging to the system, for example, a lamp. The referential aspect in the *Using the system output* category is described in terms of what the system delivers; the output and the structure of the system are described as components, without any special relation to each other, which means that a developed system approach is not present. Both *Using single components* and *Using the system output* can thus be described as emphasising a user interface approach to technology, in the former regarding single components and in the latter also regarding systems.

Interviewer – If we look at society, what impact does this system have on society?
Youth 4 – Yes it makes light, everyone has the possibility of seeing things, and then there is electricity for all devices

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and for the computer. It makes it possible for people to go out in the evening and you could talk to people on the telephone, you get closer to each other.
Interviewer – Does society have any impact on the system?
Youth 4 – Yes, if there were no humans using the electricity the system wouldn't exist.

Youth 4 exemplifies the need of the output of the system for humans, in this case the electricity, and the system is characterized in terms of its components: *devices, computers,* and *telephones*, without any internal connection. Youth 4 also points out that the general purpose of the system is to deliver the output, *electricity*, for human use and that the system wouldn't exist without humans.

Interviewer- And what impact does the humans have on the system [mobile phone system]?
Youth 12 – They are the one using the system. Without humans the system isn't needed.
Interviewer – All right…does this system have any impact on society?
Youth 12 – Yes, it is important. Especially the mobile phone has become something very important nowadays, so that you have the possibility of reaching each other wherever you are.
Interviewer – Does society have any impact on the system?
Youth 12 – Society…humans using the system, that's the way society has an impact on it [the system].

Youth 12 also expresses that human use is the meaning in general terms and that it is the case on all levels – individual, human, and societal – and associates the system with single components such as the mobile phone and with the output of the system – *the possibility of reaching each other*.

Influencing the system

In this category the focus is on how humans influence the system from a structural point of view by working with the components in the system and using the output of the system. The structure of the system is described here as components with relations and with specific functions. In comparison with the *Using the system output* category, where the components have no relations or only weak ones, here the internal structural aspect includes components and their connections.

In the *Influencing the system* category it is clear that humans have an impact on the system since they are working within it and in that way affect the output of it. Humans influencing the system are referred to as experts working with the system and humans in general using the system. In relation to the *Using the system output* category, where humans are seen only as users of the system, this category emphasizes that humans have a greater significance in the system, because of the influence that the system has on their life, both as users and as workers.

Interviewer – Are there other people in the system [mobile phone]?
Youth 11 – Yes, there is someone that takes the call and then there are people that work with the mast, however it [the mast] works, but anyway making the mast work all right. Then there are people making the operating system, making it possible to make a call. And people making the mobile phone and people developing the system together, I mean the people making the different parts in the system. All of them affect it. There are a lot of people involved.
Youth 11 gives some examples of components in the system that people work with, …work with the mast, …making the operating system, …making the mobile phone. Youth 11 also notes that humans working within the system affect it.
Interviewer – Does the system [banana system] have any impact on humans?
Youth 6 – Yes it is their job and they make money on it so they can pay the rent and so on…
Interviewer – Do humans have any impact on the system?
Youth 6 – Yes, we have to buy bananas so that they survive…the wholesalers. They order bananas and pay for the transport so that we can buy bananas here.
Interviewer – Does the system have any impact on society?
Youth 6 – Yes, society?...or we need bananas, maybe we'll try to cultivate bananas here I have no idea.
Interviewer – No, but does society have any impact on this system?
Youth 6 – They [bananas] are transported in society…I don't know

First youth 6 exemplifies how humans influence the system by working in it and how this affects human daily life, *…so they can pay the rent…*. Then youth 6 highlights that the impact on society is associated with humans, *…we need bananas*, and this view, that humans are not distinguished from society, is significant for this category. However, we can see a link to the next category, as youth 6 develops the answer, *…They [bananas] are transported in society*, and this indicates that society can be something more than humans.

Interviewer – Do humans have any impact on the system?

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Youth 8 – Yes, …otherwise this connection here [pointing at his drawing of the structure of the system] between the nuclear power station and the generator, the transformation, wouldn’t work. Although they are largely self-sufficient…

Youth 8 exemplifies how the components are related to each other, here by transformation, and that the components have specific functions and in that way they are not only a number of components.

Interacting with the system

In this category descriptions concern human interaction with the system, controlling or managing it, and the system’s interaction with the surroundings. In comparison with the *Using the system output and Influencing the system* categories, the system does not exist just because humans are using or working within it; there are also factors in society that are important for the maintenance of the system, such as natural resources and related systems. In this category, society encompasses more than humans, in contrast to the *Influencing the system* category, where society equals humans. In this category the structure of the system is described as related components that humans interact with and that have connections to the surroundings.

Interviewer – Can something happen in this system that makes it go wrong?

Youth 16 – Sometimes the mast doesn’t work, that is something that can go wrong. It is in the same way as in the electrical system that, someone can direct something wrong and then the system doesn’t work. Or when a cable is cut off in a storm, the system doesn’t work.

Youth 16 describes how humans interact with the system by controlling components in it… *someone can direct something wrong*, and also focuses on how the surrounding, such as a natural phenomenon …*a storm*, can affect the system. These two ways of disrupting the system distinguish how humans and society (and the world) interact with the system and point towards a more highly developed system perspective.

Interviewer – Does the system have any impact on society?

Youth 7 – Yes, without electricity, society would have been something totally different, because we use electricity all the time…and if we hadn’t come up with this [wind energy system] more people would have used systems that are not environmentally friendly, such as the nuclear power systems, and that would have had an impact on the next generation…

In this extract youth 7 stresses that society would have looked different if the system didn’t exist. It is not merely linked to human involvement in the system as in the *Using the system output* and *Influencing the system* category. Also related or alternative systems are focused on… *such as the nuclear power systems*.

Integrating the system

The focus in this category is that the system is integrated in society and with humans. The meaning of the system is described on different levels – individual, human, and societal – which may be problematized by the impact the system can have on these levels. The way of seeing the system from different levels distinguishes this category from the *Interacting with system* category. The main reason for the system’s existence appears to be linked to society, building up the economy, welfare, and infrastructure in different countries. Related systems, nature and society, are described, which places the system into a more elaborated context.

The system is viewed from an overall system structure view that includes relations to components, humans, and society. There are thus connections to some components, but since the questions in this part of the interview do not specifically concern the structure of the system, each component does not need to be described and in that way it is possible to “black box” them. This differs from the *Interacting with system* category, where the focus is on components in the system.

Interviewer – Are there other people than you in this system? [Banana transport system]

Youth 9 – Oh yes, if we look at the developing country here [pointing at the drawing made] there are a lot of people that are unemployed and they want a job, so they are the winners if they start a banana plantation in the country… they have the possibility of making money. It’s possible for the economy in the country to expand. Then there are people working every day, for example, in the harbour in Gothenburg where the bananas are distributed. A lot of job opportunities are connected to this system.

Youth 9 gives an example of how the system affects the economy in different countries, the country where they start a banana plantation and in the harbour of Gothenburg, and youth 9 also points to the impact the system could have on humans *…there are a lot of people*

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	Structural aspect		Referential aspect
Category	Internal horizon	External horizon	
Using single components	Single components	User interface of component for interviewee	Usage of components. The intentions with the system – for themselves (the interviewees)
Using the system output	Components that are part of a process	User interface of system for users	Using the output of components in the system. Looking at the system from the outside. The intentions with the system—for individuals
Influencing the system	Components with specific functions and system structure	System	Using the output and working in the system. The intentions behind the system – for individuals
Interacting with the system	Components with connections and relations that humans control and manage	Related systems	Taking part in the system looking at the system from the inside. The individuals are not important but humans are for the system as whole. The intentions behind the system – for humans in society
Integrating the system	Overall system structure, including relations to components, humans, and society	The society, environment and other systems	Differentiating the role of humans and individuals and how they are part of the system The system is described as important for society as well as for human's economy and jobs. The intentions behind the system—for society

Table 2. Analysis of the categories in relations to structural and referential aspects

that are unemployed and they want a job. What we see in this example is an illustration of the impact on different levels.

Youth 9 – …There are of course very many jobs in Sweden, where we use mobile phones in our work for example to communicate with different companies and it might affect them a lot if their mobile phones didn't work and if they couldn't communicate with each other. So it affects many businesses and individuals.

From the extract above we can see how youth 9 expresses that the system has an impact on things that are not really part of the system but that can be found in related systems or as part of society, *…we use mobile phones in our work for example to communicate with different companies*.

Interviewer – What impact does society has on the system?

Youth 7 – The priorities that are made in society affect how we design this system. If we are totally against boat transports, then another system would have been necessary to transport [the bananas] or if we in the North of Europe don't want any bananas then the whole system has to change. So everything is dependent on everything else in a way.

Youth 7 exemplifies that the system is part of society and how different decisions or choices that are made in society can affect the system. An awareness of other alternative systems is also described…*If we are totally against boat transport, then another system would have been necessary*.

Interviewer – Thus you need to be part of the system [electricity system] to make it work?

Youth 16 – No, I don't think I am necessary. Individuals are not needed because it is a society thing.
Interviewer – Would you get by without the system?
Youth 16 – I would but society wouldn't. Of course you survive but society can't exist without it [electricity].

Youth 16 gives a good example of how one can distinguish between different levels – individual and society – when talking about the system, *…I would but society wouldn't*.

Summary of results

The different experiences of technological system were generally found to be related in a hierarchy based on logical inclusiveness. Category *Integrated with system*, for example, presents a broad view of technological systems both with respect to structural aspects and meaning, and in contrast category *Using single components* technological systems are omitted.

In Table 2 we summarise the results and describe how the categories are related to the structural and referential aspects. We also clarify the internal and external horizon of the structural aspect.

We want to point at some important leaps in terms of complexity in the set of categories.

In the internal horizon of the structural aspect between the categories *Interacting with the system* and *Integrating the system*, there is a leap in complexity in the way of describing the system as components, or as an overall system structure.

Another important leap in complexity is in the external horizon of the structural aspect between the categories *Using single components* and *Using the system* output concerning awareness of system as a phenomenon among the youths. In the first category the system aspect is overlooked but in the other four categories the system is in some sense visible and essential. There is also a leap in complexity between *Influencing the system* and *Interacting with the system* from not relating the system in focus to other systems, to clearly referring to other systems.

When it comes to the referential aspect there is a leap in complexity between the categories *Influencing the system* and *Interacting with the system* from placing humans outside the system and using the system without being a part of it to placing humans inside the system and being part of it.

Discussion

In line with the overall aim in this study the results contribute to a deeper understanding of young people's knowledge about technological systems. Beyond this we claim that the results also suggest a possible way of understanding technology generally by focusing on technological systems.

We start with a discussion of the results, structured by the three research questions, in the light of previous research, followed by some implications of the results.

How do young people experience the function and the structure of technological systems?

The results show a variation and increasing complexity on young people's experience of the structure of technological systems, from focusing on single components without relating them to any system perspective to primarily describing systems with components, and including humans and society in interaction. Similar results, with respect to the structural aspect, are reported in the study by Svensson and Ingerman (2010) where, in the most complex category, objects are described as embedded in systems where components are characterised by their function and internal interaction, and where humans are part of the system. An important contribution from the present study is that, if the system components are obvious for young people at a particular time in the interview, they "black box" them and focus on the function and the system as a whole instead of the components, which is in line with Latour's (1999) reasoning. We think this may be an essential step to develop a more complex understanding of technological systems where systems as such can be taken as the starting point.

Young people's experience of the function – the aim of the system, which, for example, may be producing electricity and purveying it to individuals and society – varies from using single components for individual benefit to understanding and describing the aim of the system on different levels: individual, human, and societal. The aims or intentions of the system are a referential aspect that seems to be crucial for young people in experiencing the system as a whole in all its complexity. This complex understanding of technological systems is in line with the descriptions of technology by Latour (1999) and Mesthene (2003) as complex, collective, and integrated with humans.

How do young people delimit the technological systems vis-à-vis their surroundings?

Following the external horizon in the resulting set of categories in Table 2, the variation in "what" surroundings are delimited is apparent, ranging from focusing on the user interface of the component itself, not talking about the system, to describing the system of interest as delimited by and related to other technological systems, nature, and society. Parallel to this variation in character of the delimited surroundings, there is a corresponding variation in the character of the whole and parts of the system, ranging from expressions where the components are pointed to primarily in their own respect as independent parts (or small entities in themselves), to expressions where the components are discussed in terms of their part-whole relationship, and as such also as representatives of other components in "classes" of parts, sharing some characteristic in terms of their meaning and function in the whole.

The conclusion we draw from this is that learning to see this "generality" of parts, and seeing the corresponding complexity of the whole – the technological system – is potent towards experiencing complex nets of events and objects in a technological society as parts of the same

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meaningful whole. We understand the latter as an important part of developing technological literacy.

How do young people experience the role of humans in technological systems?

The first and second category implies seeing humans as basically taking a "consumer position" in relation to the technological system (and components within it), not being a part of the system and only influencing it by using or not using it. The most complex category implies seeing humans as part of and integrated with the system, having the possibility of affecting the system in several ways, e.g. using, sustaining, and controlling. According to Dusek (2006) and Kline (2003), a system approach is essential for understanding technology as an activity where humans have multifaceted roles, which is in line with our results. We conclude that using a system approach in technology education may be fruitful in supporting citizens in developing their awareness of the possibility of an "active" citizen role in technological society, rather than being limited to the "passive" consumer role.

Concluding remarks

The thrust of this article is to illuminate in what ways understanding technological systems may be a ground for understanding technology in contemporary society. The results show indeed that different ways of understanding technological systems imply different ways of understanding technology and its complex nature in relation to humans as individuals and society, and in that way what possibilities are open in technological citizenship. Thus, we conclude that technology education would benefit by developing technological systems as a goal and vehicle for developing the opportunities of the young generation to understand technology and participate, engage with, and influence the development of technology. This means strengthening their preparation for a future citizenship. In order to develop strategies for teaching about systems further investigations of how and what to teach are required. In an article by Svensson (2011) a first step for such an investigation is presented drawing on the variation theory (Marton & Booth 1997; Marton & Pang 2006), and using the ways that young people understand systems as a starting point. Furthermore it remains to be determined how teaching technological systems might impact young peoples understanding and the learning possibilities of technology more generally.

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