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Discerning technological systems related to everyday objects: mapping the variation in pupils' experience

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Abstract Understanding technology today implies more than being able to use the technological objects present in our everyday lives. Our society is increasingly integrated with technological systems, of which technological objects, and their function, form a part. Technological literacy in that context implies understanding how knowledge is constituted in technology, and in particular how concrete (objects) and abstract levels (systems) are linked. This article has an educational focus concerning systems in technology education. Using a phenomenographic approach, the study explores pupils' experiences of technological systems as embedded in four everyday objects. We identify five qualitatively different ways of understanding systems, ranging from a focus on using the particular objects, over-focussing on the function of objects, seeing objects as part of a process, and seeing objects as system components, to understanding objects as embedded in systems. As a conclusion, we suggest an educational strategy for teaching about systems in technology education.

Keywords Technological systems · Technological objects · Artefacts · Understanding technology · Technological literacy · Teknisk bildning · Technology education · Phenomenography

Introduction

Technological objects tend to be central in definitions of technology, whether you ask people in the street (see for example Rose and Dugger 2002; Rose et al. 2004), or follow the writings of philosophers of technology (such as de Vries 2005, 2006; Dusek 2007; Mitcham 1994). However, there is a broad consensus today that technology encompasses

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much more than simply objects. While de Vries (2005, 2006) and Mitcham (1994) focus on objects and their use, they also make links between knowledge, production, and the use of objects. The relationships between objects and the surroundings have thus emerged as an important facet of technology. This is also a recognition that modern society is permeated by technological systems (Dusek 2007). Technological systems are more abstract and less immediate than objects, and systems are an important way of organising technological objects that give objects several layers of meaning.

On a micro level, individual technological objects may be seen as systems, consisting of components working together to provide the function of that object—for example a car, which may be perceived as a system or as an object. On a macro level, society is permeated by large technological systems (such as societal provision of transport, energy, etc.). As an example, the car is one of many components, which together with humans, infrastructure and traffic regulations make up the whole of the transport system. Grasping the *whole* of such systems is considerably more complex and abstract than grasping its constituents, which typically manifest themselves as single objects. Nevertheless, grasping these systems is an important feature of understanding technology.

Current discussions concerning technology education (Compton and France 2007; McCormick 2006; Skolverket 1994/2001) emphasize the understanding of *both* objects and systems as essential parts of technology. Thus, we see three levels that are important for technology education, in which we can understand (many) individual technological objects:

- The level of the objects themselves, encompassing both their use and function.
- The micro level of objects seen as systems, focussing on the internal functions of objects.
- The macro level of objects seen as parts of systems, where objects are perceived as components in one or several technological systems.

This study aims to understand how pupils approach a multiple of technological objects on these levels. The analysis presented below has focused on capturing the third level, and we have therefore empirically investigated pupils' experience of technological systems, as they are embodied in objects as used in pupils' daily lives. The importance of the study is underscored when seen against the background of its pedagogical implications and the scarcity of research on pupils' knowledge in technology.

Constituting technology through objects and systems

Objects and systems in the field of philosophy of technology

In descriptions of the nature of technology, technological literacy, and philosophy of technology in general, it is clear that objects have a central role (De Vries 2005; Dusek 2007; Mitcham 1994; Pitt 2000). In this study we use the term object to refer to tools, machines, instruments—or more generally, artefacts—that are developed and used by humans in their daily lives. These objects may include both human-made objects and natural objects. We see them as technological objects as they have a specific purpose.

Objects have been a natural starting point in defining and delimiting the multifaceted, extensive, and heterogeneous field of technology. Mitcham (1994) starts his book "Thinking Through Technology" by addressing technology as the making and use of artefacts. The artefacts emerge from reflected ideas and motives, but could be produced and used in an un-reflected manner, as an unthinking activity. It is increasingly important for humans in our technological society to think about technology in a multitude of ways, to see artefacts in context. We argue that thinking about technology involves various perspectives, such as scientific, economic, and psychological ones. Ethical dilemmas are also included in the thinking about technology. Mitcham exemplifies his view of technology with a conceptual framework consisting of four different modes: knowledge, volition, activities and objects.

Dusek (2007) characterizes technology in terms of hardware, rules, and systems. For hardware he argues that "*the understanding of technology as tools or machines is concrete and easily graspable*" (Dusek 2007, p. 31). He describes the rules as the relationships that are involved in technology, they are "*patterns of rule-following behavior or* '*technique*'" (Dusek 2007, p. 32). On this basis he argues that a technological system essentially is hardware in the context of people who use it, maintain it and repair it (the organisation and rules). Dusek stresses that hardware outside of the human context of use and understanding may not really function as technology.

Pitt (2000) takes a different approach and emphasises that technology has long been characterised only as mechanical tools and that it is important to broaden this view of technology. "*Technology is humanity at work*" (Pitt 2000, p. 11) and the tools themselves are not the technology—it is their use that constitutes technology. This description of technology focuses the context as crucial and a model of technology as an input/output transformation.

In the philosophical definitions of technology presented above, connections to objects are central, but other important aspects of technology are brought to the fore; of particular importance here is the link to technological systems. Systems have components with connections and relations that are intertwined in a network, and can be perceived as a whole. By delimiting a system from the surrounding world, the whole becomes discernable (Klasander 2008, pers. comm.). It is important to understand that technological systems are closely related to humans and society and they are sometimes called socio-techno systems (Ingelstam 1994). Kline (1985) has a comparable description of technology as sociotechnical systems of manufacture and use, as systems combining both the production of objects and the people who use it, as well as other elements required to put the object to use. The technology system view has also similarities with Borgmann's (1984) focal things and practice, seeing technology, not as an isolated entity, but as a complicated network of human relationships, and relationships between this network and its surrounding.

It is possible to analyse single objects as confined systems, focusing on how components of the object interact, what we call the micro level of a system. The large technological systems of the macro level have individual objects (and even humans) as components and are bound together by human ways of organising society. Understanding technology—whether from the orientation of objects or systems—presupposes an awareness of the relationship between technology and individuals. Describing technology as starting from objects tends to make technology appear neutral and puts the individual, as the user of objects, outside the object, which has control of the technology. If we start from systems, individuals are encompassed by the technology, taking on roles such as consumers, workers, etc. The individuals are not outside the system, but inside, and technological systems may now appear to control the individual, rather than the other way around (as in the case of objects, see also Dusek 2007). These different ways of seeing the human-technology relationship lead to different perspectives on understanding how technology affects our life and society.

Objects and systems in technology education

Our interest in descriptions of technology is pedagogical in nature. The philosophy of technology is important for shaping the educational context in its contribution to the constitution of the field of technology. In particular, we find philosophical arguments concerning the essence of technology especially useful for describing technological literacy as a goal for technology education (Compton and France 2007; Garmire et al. 2006; Pearson and Young 2002). The American Committee on Technological Literacy[1] describes technological literacy with three dimensions that we find useful for thinking and talking about technological literacy. The *knowledge dimension* includes both factual knowledge and conceptual understanding. The *critical thinking and decision-making dimension*, has to do with your approach to technological issues. The final dimension, the *capabilities dimension,* relates to how well a person can use technology and carry out a process in order to solve a problem (Garmire et al. 2006). One of the general characteristics that describe a technologically literate person is how familiar s/he is with the engineers' way of describing systems: as components that work together to provide a desired function. Systems could be simple with few components, such as a pencil, or they can be complex with thousands of components, such as a computer, or they could be infrastructural, such as, roads etc. However, schools are not oriented towards educating technological specialists such as engineers; technology education aims rather at developing more technological generalists. Striving to understand the world as engineers do would appear incongruent.

The latest revision of the technology curriculum in New Zealand brought together three strands to develop pupils' technological literacy (Compton and France 2007). These strands are: *technological practice*—brief development, planning for practice and outcome development, and evaluation; *nature of technology*—characteristics of technology and characteristics of technological outcomes; *technological knowledge*—technological modelling, technological products, and technological systems. An overall aim in the revision of the technology curriculum was to develop technological literacy in a way that would provide pupils with experience that had depth, breadth, and an informed criticality. Of special interest for this study is the way technological outcomes are described.

> Technological outcomes results from technological practice and are defined by the fact they have been designed by humans to exist as material products or systems to perform an intended function. (Compton and France 2007, p. 264)

In Sweden, the desired outcome of technology education has been discussed using a similar, but in important ways distinct, notion: *technological bildning*. *Bildning* comes from the word Bildung in German and refers to the ongoing processes were humans shape and create themselves and their understanding(s) of the world around them. Bildning is something individuals develop in a lifelong learning process (Blomdahl 2007). Compulsory technology education is an important arena for developing and broadening individuals' technological *bildning*, in addition to more traditional notions of learning about technology. Both objects and systems are important in technological literacy and/or technological *bildning* as goals for technology education.

[1] The Committee on Technological Literacy is a group of experts on diverse subjects under the auspices of the National Academy of Engineering (NAE) and the Center for Education, part of the National Research Council (NRC).

Objects and systems are important concepts in the technology curriculum in many countries. For example, the curricula in Sweden (Skolverket 1994/2001) and New Zealand (Techlink 2007) points to the importance of understanding objects and systems:

> Society and our ways of living are increasingly influenced by the use of technical components, which in their turn are often included in larger technical systems. Making everyday technology as understandable as possible is thus an additional aim. This covers everything from the simplest domestic devices in the home to modern equipment and complicated transport systems. (Skolverket 1994/2001)
>
> Technological products are material in nature and exist in the world as a result of human design. Understanding the relationship between the properties of materials and their performance capability is essential for understanding and developing technological products. (Techlink 2007, p. 58)
>
> Technological systems are a set of interconnected parts (technological products and processes) that serve to transform, store, transport or control materials, energy and/or information. These systems exist in the world as the result of human design and function without further human design input. Understanding how these parts work together is as important as understanding the nature of each individual part. (Techlink 2007, p. 63)

De Vries (2005) suggests that thinking about technology in terms of systems could be an educational tool in teaching about objects. By looking at an object as a part of a system, pupils can get a first impression of the physical and functional nature of the object. Many devices that pupils use, both in everyday life and in technology classrooms, are too complex for them to understand when it comes to the function of every single part. McCormick (2006) proposes that using qualitative reasoning in trying to figure out how components work together, in a context of a system, could yield good learning outcomes.

Objects and systems as manifested in pupils' knowledge

Technology education is still an emerging subject in many countries, each with their own particular emphasis. In some countries design and making is focussed on, while in others, industrial production is central. An international discussion is forming, but it remains somewhat tentative (De Miranda 2004; De Vries 2005; Hagberg and Hultén 2005; Zuga 2004). This notwithstanding, there is a clear focus on philosophically, practically, and historically based arguments about defining technology as such and about defining the content of the technology curriculum in general. In particular, there is a feeling that there is a lack of empirical research concerning pupils' knowledge in, and about, technology. Some studies, as part of the PATT[2] initiative, have investigated pupils' attitudes towards and conceptions of technology. The results have been presented in several reports (Bame et al. 1993; Garmire et al. 2006; Raat and de Vries 1986). These and other empirical studies show that referring to some particular objects (often modern communication equipment) is the most common way of describing technology (Davis et al. 2002; de Vries 2005; Jones 1997). Objects have a direct and concrete connection with technology.

[2] PATT, Pupil's Attitudes Toward Technology, is an international organization based in the Netherlands that promotes research in technology education(?), http://www.iteaconnect.org/Conference/pattproceedings.htm.

> Ask a young child what technology is, and most probably he or she will start listing examples of technical artifacts. (De Vries 2005, p. 13)

Twyford and Järvinen (2000) studied pupils' understanding of some technological principles, such as balance and torque, by using a model of a bridge and asking questions surrounding that. In this study children's technological concepts were expressed using their previous experiences and fantasies. The study reveals that children are constantly analysing factors in order to make decisions about technological problems. To guide them in their analysis work, the children use existing knowledge, direct observations, and practical experience. The conclusion is that this wide array of resources reflect that technology is a multi-dimensional field of inquiry and that in order to work with technological problems or issues a wide range of knowledge, not bound by subject boundaries, is required.

Solomondiou and Tassios (2007) studied pupils' conceptions of technology using photographs of different technologies in everyday life. They tried to figure out pupils' experiences of technological changes and the impact of technology use in their everyday life. Their results indicate that most pupils perceived technology as an object or a process that is modern, "high tech". The majority of the students do not recognize everyday technology processes and technological innovations.

Collier-Reed (2006) has investigated pupils' experiences of technology. His study was based on qualitative interviews with pupils on their experience of technology, both in general and in a number of contexts. In particular, he asked questions about a set of photographs that pupils had beforehand taken of what they considered to be technology in their lives. He describes qualitatively different ways pupils experience technology, ranging from artefacts to processes. Perceiving technology as a process stresses a more multi-disciplinary view of technology and knowledge.

In summary, there is a scarcity of studies on the understandings of technology available. The existing ones focus on pupils' grasp of the subject and the field as a whole, or on understandings of one or a few principles. Our investigation into how pupils perceive object–system relationships may thus provide an important contribution to understanding how knowledge in technology is constituted, and in particular how concrete (objects) and abstract levels (systems) are related.

Methodology and research design

The central aim of the study was to investigate how pupils experience technology in general and technological systems in particular, as present in a multiplicity of everyday technological objects.

Phenomenography as research framework

Phenomenography as a research tradition (see for example Marton and Booth 1997) focuses on the variation in how a phenomenon (in this case technological systems) is experienced by a group of individuals (in this case pupils). The research outcome is a set of categories, which describe qualitatively different ways of experiencing that phenomenon, and which are logically related in structure and meaning. The categories are not descriptive of how individuals perceive the phenomenon, but the categories, as a set, point to potential ways in which the individuals can perceive the phenomenon. Learning in the phenomenographic tradition refers to coming to discern phenomena in new and more powerful ways—here to perceive technological systems as manifested in objects in new ways, which are more powerful in terms of understanding and acting in the technologically mediated world.

Interview design

In this study we used semi-structured interviews with pupils in fifth grade and in ninth (10 and 15 years old) in Swedish compulsory schools to collect our data. The interviews revolved around four everyday objects which were placed in front of the pupil during the interview. To use actual objects in an interview serves to facilitate pupils' understanding of interview questions, to help them to orientate in abstract situations, and to communicate about abstract things (Dovenborg and Pramling 1998; Piaget 1982; Säljö et al. 1999).

Technology as a whole represented by four objects

The objective of each interview was to span some of the whole of technology. The four objects used in these interviews—a mobile phone, an incandescent light bulb/a low-energy light bulb, a pair of side-cutters, and a banana—are a part of everyday life and can be seen as representations of what technology is. Together the objects are entrants to different aspects of technology, providing prepared contexts for the interviewees to grasp. The objects are different in form, purpose, and history. They were in that way part of a purposeful variation to support the constitution of the phenomenon of technology in the experience of the pupils and as means for making that experience concrete. The questions build on the similarities and differences between the objects by thematicising certain features: use, function, system integration, history, and potential for development.

During the interview the objects were put in front of the pupils in a specific order of decreasing visibility of technology: mobile phone, side cutter, incandescent light bulb/low-energy light bulb and banana. In the study on technological systems presented here, we exclude parts of the interviews related to the side cutter, owing to the fact that pupils don't discuss the side cutter as integrated into large societal and technological systems (the macro level).[3] The analysis presented here is thus based on conversations starting from the mobile phone, the light bulb/low-energy light bulb, and the banana.

The mobile phone (shown in Fig. 1) is an object that almost every 10-year-old child in Sweden has today. It is a modern object, used for communication, and common in everyday life. Many people know how to handle it, but knowledge about the inner and outer system is more complicated and largely invisible, and thus harder to understand. The emergence of mobile phones during the last two decades has transformed communication in society. The frequent change in size, function and design is recognisable by most people.

The light bulb and the low-energy light bulb (shown in Fig. 2) are objects present and used in modern everyday life. They are components in the societal energy system. The quality of the dependence of the energy system is less transparent. Light bulbs and low-energy bulbs are natural parts of the environmental discussion in society of today.

The banana (shown in Fig. 3) might appear at first glance to be the "odd man out" in our collection of technological objects. Nevertheless, it is an object that is dependent on technology, for example a system of cultivation and transport in order to be available to us.

[3] In retrospect of the results of the investigation, the discussion concerning the side cutter could have been included as examples of the level of the objects themselves.

Fig. 1 The mobile phone

Fig. 2 The low-energy light bulb and the incandescent light bulb

In particular, agricultural growth, transport complexity, and environmental impact are part of today's technological society.

Interview participants

Twenty-three pupils, 11 in grade nine (15 years old) and 12 in grade five (10 years old), from three compulsory schools on the west coast of Sweden, participated in the study. Data were collected through individual interviews with the pupils. The pupils were selected by their teacher, first asking if they were interested in participating, and after that deliberately selecting pupils considering variation in, for example, gender (Table 1).

The first author conducted all interviews (in Swedish). Each individual interview took place in a separate room, close to the classroom, and lasted for 20–30 min. Before the

Fig. 3 The banana

Table 1 Schools that participated, distribution of pupils among the three schools, and if they have had any formal technology education as part of their curriculum

School	10 years old (G = girl, B = boy)	Technology education (explicit)	15 years old (G = girl, B = boy)	Technology education
Pilot	2 (G)	Yes	1 (G) 1 (B)	Yes
Ada	2 (G) 3 (B)	No	3 (G) 2 (B)	Yes
Beda	3 (G) 2(B)	No	1 (G) 3 (B)	Yes
Total	7 (G) 5 (B)		5 (G) 6 (B)	

interview she visited the class and told them about the study, and that she was going to ask the selected pupils a few questions about some objects.

Interview questions

The questions have a strong connection to the Swedish technology curriculum, and they are intended to cover a wide range of what technology is conceived to be. Questions were divided into four aspects and closely tied to relevant research (for example Compton and France 2007; Mitcham 1994; Skolverket 1994/2000): user, functioning, development and system aspects. The *user aspect* derives from the fact that we are all users of technology from the day we are born to the day we die. The three objects are used in different ways in different contexts. In this aspect it is important to see the effect of using the object. There were four primary meanings for using that we asked about for each object: What is the proper function of the object? How to handle the object (in order to achieve the desired effect)? Who usually handles/uses the object? The *functioning aspect* concerns how different parts are connected and work together to achieve the purpose of the object. The focus in this aspect is to examine the object itself. Function may be explained by principles and/or examples. The *development aspect* focuses on the fact that technological objects have histories, futures, and are as a result of innovations. Their form should not be taken for granted; instead the four objects have changed and developed along different time scales. Finally, the *system aspect* encompasses the complexity of technology where objects, humans, and society are involved. It is a comprehensive way of looking at technology as a network of connections and relations. The system aspect is separate from the function aspect in its level of complexity concerning the different perspectives involved. For function, the perspective in focus is that of making something work or do what it is supposed to do. The system approach includes function but also involves social, ethical, economic, environmental, and other perspectives that build the network around the technology in focus. (Further interview questions are found in Appendix.)

Analysis process

In this article, we focussed on how pupils experience the macro level of system, as this feature of the interviews was particularly interesting. Nevertheless, the analysis began on a general level with the interviews, and their verbatim transcriptions, by repeatedly reading them as a whole and by getting to know them as a collective—following a typical phenomenographic approach to data analysis. The analysis continued with a focus on and systematic identification of the parts of the interviews that thematicised the macro level of the system. The relevant parts of individual interviews were seen as consisting of different meaning units with a natural demarcation between questions concerning different objects (mobile phone, light bulb, and banana). The collection of empirical material was in this way transformed from a set of full-length interviews to a set of focused units of interview extracts. These manageable units could now be compared and contrasted to each other, which consequently offered rich opportunities to delve into how pupils approached the macro level of systems associated with the objects. At this stage, meaningful variation began to emerge between different subsets of interview extracts. These tentative subsets were carefully described in terms of their differences, and subsequently in terms of their defining qualities. The phenomenon that the pupils' experience was directed towards had up to now been understood on a more general level of technological systems. The need arose to describe more of its parts, while still using terms appropriate to the pupils' experience. These subsets were recognised in that process to be three descriptive dimensions constituting the experience of the phenomenon rather than descriptions of different ways of seeing the phenomenon. The dimensions—flow, component and system interaction—were functional in identifying variation with respect to different ways of experiencing the macro level of systems. This, finally, resulted in the first draft for descriptive categories. The first draft of categories was refined to a final form by systematic categorisation of the complete empirical material (of the relevant set of interview extracts) and careful articulation of how parts and wholes of these extracts were interpreted. The whole of the analysis process was carried out in a dialogue between the two authors, where in particular the first author was working closely with the interviews and the empirical material.

Results

The analysis will be described in two structural parts, which we have analytically separated, though they are integrated with each other. The three dimensions—flow, component and system interaction—describe apparent features of systems, as they are described by the interviewees as a collective. The categories describe qualitatively different ways of understanding technological systems in relation to everyday objects.

Dimensions

The three dimensions provide a framework for the categories and organise the interview extracts in terms of the relationships between objects and systems:

Flow—the movement of material, energy or information through the system, which determine the function. Flow could be considered as something special like "this banana" or more general, "bananas".

Component interaction (*intra-system interaction*)—parts that are connected or related by transformation, transport, store or control. This dimension highlights relevant components for a particular system, the richness of components within the system, and the relationship between components within the system.

System interaction (*inter system interaction*)—the limit of the system and the connections with other closely related systems. This dimension puts focus on how the flow, components, connections, and processes interact with the surrounding: society, nature, and humans.

Categories

The analysis resulted in five categories of description, logically related and qualitatively distinct from each other:

A. Using objects
B. The function of objects
C. Objects as part of a process
D. Objects as components in one system
E. Objects embedded in systems

The results show that pupils discern systems in everyday objects in principally five increasingly complex ways. In the least complex, category A, objects are not related to systems at all. In the most complex, category E, objects are naturally seen as part of systems, where their complexity is approaching a system model, describing them as a net of connections (expert description).

The interview can be split into three parts, one for each object (as described above). With 23 interviews, this amounts to 69 units of analysis. To visualise the units of analysis for each category and each object, the resulting categorisations of the units are listed in Table 2. The table also gives an insight of how many boys and girls are represented in each category, and at what age they are.

A. Using objects

Technological objects are taken for granted. Pupils' use them without reflection about connections to other objects or systems in the surrounding. In the interview conversation, it is possible to see traces of knowledge about the function of the object, but they are taken for granted or deemed uninteresting.

Table 2 Summary of the categories in terms of units of analysis (UoA) concerning each object, girls and boys, and age of the pupils

Category	Mobile phone	Light bulb	Banana	Total ($N = 23$)	Girl ($N = 12$)	Boy ($N = 11$)	15 years ($N = 11$)	10 years ($N = 12$)
A	II	II	III	7	3	4	1	6
B	IIIIIIII	IIIIIIII	III	19	14	5	6	13
C	IIIIII	IIIIIIIII	IIIIIIII	23	15	8	12	11
D	IIIIII	III	IIII	13	8	5	4	9
E	I	I	IIIII	7	1	6	7	1
Sum UoA	23	23	23	69				

The total number of interviews are $N = 23$, consisting of $N = 11$ interviews of 15 years old and $N = 12$ interviews of 10 years old and of the 23 interviews $N = 12$ are girls and $N = 11$ are boys

Interviewer What do you think is needed to make this lamp work?
Fenjam Something to light and elect…electricity. (Fenjam, 10 years old, Bedaskolan)

Pupils' don't give the impression that they have had any thoughts about the function of the object. They look upon it as something they have knowledge about how to use in their everyday lives and that's enough (from their point of view).

Interviewer Do you know what is needed in order to put this mobile phone in contact with other mobile phones?
Lana No…
Interviewer What is it that makes it possible to call from this mobile phone to other mobile phones?
Lana Connection
Interviewer Ok and some places you don't have connection with, why is that?
Lana Oh, I don't know (Lana, 15 years old)

The objects are considered only from the user's perspective. The purpose of the object is obvious to them as users. As primarily "consumers of technology" they don't have the possibility of or any interest in influencing technology.

B. The function of objects

In this category, pupils describe the object from a functional perspective. What is needed in order to make the mobile phone and the light bulb work, and to make it possible to eat bananas in Sweden? In expressing the function, some sort of movement is needed—flow—from a source towards a goal. The flow is described as material (bananas), information (signals to the mobile phone), or energy (electricity to the light bulb). The goal for the flow is taken as obvious, since the object is in front of the pupils; the source is less clear. When they talk about the mobile phone, the flow is mentioned but the source is nonexistent.

Interviewer How do two mobile phones get in contact with each other?
Lukas It is some signal…Comviq or Telia [operator companies] or something
Interviewer Some signal then?
Lukas [nodding]

Interviewer	Ok, what happens with the signal, do you know?
Lukas	No
Interviewer	Anything more, to connect two mobile phones?
Lukas	No I don't think so (Lukas, 10 years old)

When it comes to the light bulb and the banana, the sources are more obvious.

Interviewer	What is needed in the surroundings to make the light bulb to work?
Nina	Electricity
Interviewer	Ok and it comes from?
Nina	From…electricity comes out of water and air or wind I think (Nina, 15 years old)

In comparison with category A, extracts in this category have indications of more complex thoughts about the objects as parts in different processes and components in systems. The first signs of thinking of a system as input and output and a flow with source and goal are visible. What happens in between input and output is still a "black box" in this category.

C. Objects as part of a process

Extracts in this category indicate a deeper awareness about flow and its movement through components—for example, wires, satellites and boats—from the source towards the goal. The "black box" mentioned in category B has been opened and some parts in it are identified as components.

Interviewer	What does this, light bulb, need in order to work? As it doesn't work now?
Ronja	Yes, you need some sort of wire, like that [pointing at the wire to the lamp in the room]
Interviewer	Wire, electrical wire?
Ronja	Yes
Interviewer	Anything else?
Ronja	Yes, you could have a round lamp to cover it if you want to….
Interviewer	What are you doing with the wire?
Ronja	You put it in a plug.
Interviewer	What do you get from the plug?
Ronja	Electricity
Interviewer	And from where do you get electricity?
Ronja	A factory
Interviewer	A factory gets the electricity from?
Ronja	Water (Ronja, 10 years old)

The flow is possible to follow and changes in the flow, such as transformation, transportation, and storing is potentially brought to the fore.

Interviewer	What do you think is the history of this banana? Could you tell me?
Nina	Yes, someone picks the banana when it's ripe and then they put it in a box and the box is put on a boat for example And the boat goes to Sweden and then to a house or… (Nina, 15 years old)

An awareness of the fact that the objects (mobile phone, light bulb and banana) have relations to other components to make their function and movement possible begins to emerge. Those components are like a chain, which together makes the system work. It's still looked upon as input and output but now the "black box" is gone and the things inside are beginning to be illuminated.

D. Objects as components in one system

In this category, the main flow is identified, and some components are mentioned explicitly. A crucial difference between categories C and D is that now a connection between components and the flow moving through them is voiced.

Interviewer	Is there anything in the surroundings that lamps need in order to work?
Robert	A plug mm…and lamp to connect it [light bulb] to, and a base station to connect the lamp to, and wires and fuse, controlling that everything is alright, and then an electric box outside the house and finally an energy station which provides the electric box with electricity. (Robert, 15 years old)

Pupils describe what is happening around the object as a process regulated by different factors. In a system one or more processes are taking place and the components are kind of regulators for how the flow moves during the process.

Interviewer	What do you think is the history of this banana? Could you tell me how it ends up here on this table?
Alexandra	Yes, [laughing] first it grows on a tree, then it probably travels with an airplane to Sweden or by boat and there could have been some stops in other countries during the trip. Then it [the banana] is transported to Sweden and to a buyer who buys it and puts it in the store where we can buy it. They are picked from the tree when they are green. (Alexandra, 15 years old)

E. Objects embedded in systems

The flow and the components are both parts of a process that is delimited from the surroundings. One or more systems are distinguished, such as the transport system, cultivation system, information system, and distribution system. Pupils express suggestions about the system delimitation by relating the main system to occurrences, relations to, and influences on the surroundings (humans, society and the environment). The processes and components in this category depend on conditions and occurrences from the surroundings.

Interviewer	What do we need…to have the possibility to eat bananas in Sweden?
Robert	You need transports from other countries, where they have banana plantations, to import the bananas to Sweden. Of course, you could grow the bananas in a greenhouse, but it wouldn't work very well. I think the best to do is to use boats…or airplanes from other continents, that can bring a lot of bananas at the same time. And then of course people that work and control the banana plantations so that they don't go bad. (Robert, 15 years old)

In this extract we see indications that the pupil relates to more than one system, "where they have banana-plantations, to import the bananas to Sweden. Of course, you could grow the bananas in a greenhouse, but it wouldn't work very well"—a cultivating system and "the best to do is to use boats …or airplanes from other continents, that can bring a lot of bananas at the same time"—a transport system. Humans are a part of the system: "people that work and control the banana-plantations", and are not seen as consumers or users outside the system, which is the case in category D.

The next interview extract has connections with category E but is not recognized as a complete category-E extract. There are obvious indications that concern interactions within a whole, seeing the banana plantation as a system in contrast to only considering interactions between single components in one system.

Interviewer Could you tell me the story of this banana? From the beginning until it ends up here on the table.

Bella Yes, it grows and becomes …whole. And then it's transported, a lot of bananas are put into a box, it's possible to transport the banana to different countries, you see it depends on what brand it is to which countries it's transported. (Bella 10 years old)

There is in this extract a connection to more than one system, besides the transport system an economic system is mentioned: "it's possible to transport the banana to different countries, you see it depends on what brand it is to which countries it's transported".

The flow in this category has a general description; it's about signals or bananas in general. Pupils answers show a higher level of abstraction in comparison to the previous categories. The most striking difference compared to previous categories is how humans interact with the system. In category E humans are inside the system as active, having an impact on the system, or as passive, influenced by the system. There are also openings towards other systems, sub-systems, integrated with the main system not only components integrating with each other but larger units with different relationships.

Summary of the analysis of the categories in the three dimensions

In Tables 3, 4, 5, 6 and 7 below, the relationship between each category and the three dimensions is presented. There is one table for each category A to E. The dimensions, flow, component interaction, and system interaction are presented in the three right-hand columns of the table.

A. Using objects—pupils seeing themselves as consumers
B. The function of objects—input and output to make the object work
C. Objects as part of a process—opening the "black box"
D. Objects as components in one system—connections between components in a system
E. Objects embedded in systems—identifying more then one system

Table 3 Presentation of dimensions in category A

Interview extracts	Dimensions		
	Organisation of pupils' answers about the objects in relation to systems		
	Flow—the movement of material, energy or information through the system	Component interaction—parts that are connected or related by transformation, transport, store or control	System interaction—to see the limit of the system and the connections with other closely related systems
Mobile—See extract from Lana, category A above	Missing	Missing	Missing

Table 4 Presentation of dimensions in category B

Interview extracts	Dimensions		
	Organisation of pupils' answers about the objects in relation to systems		
	Flow	Component interaction	System interaction
Mobile See extract from Lukas, category B above	There is a flow—signals from particular companies	Missing	Missing

Table 5 Presentation of dimensions in category C

Interview extracts	Dimensions		
	Organisation of pupils' answers about the objects in relation to systems		
	Flow	Component interaction	System interaction
Banana See extract from Nina, category C above	There is a flow—this specific banana	Components are mentioned such as a boat, "someone picks", and boxes. Vague idea about relations between components, but some sort of process	Missing
Lamp See extract from Ronja, category C above	There is a flow—electricity	Identifying components that are possible to see with your eyes. Some vague relations can be identified	Missing

Table 6 Presentation of dimensions in category D

Interview extracts	Dimensions		
	Organisation of pupils' answers about the objects in relation to systems		
	Flow	Component interaction	System interaction
Lamp See extract from Robert, category D above	There is a flow—electricity, specially expressed for this light bulb	Components are voiced in terms of their function and relations. A transformation process is voiced	A limited system is possible to identify

Discussion

Our results contribute, on the one hand, to an understanding of the way pupils experience the connections between objects and systems, and, on the other, to the ability to inform teaching practice. In this discussion, we will focus on the latter.

The general thrust of the work reported in this article is aimed towards technology education. In particular, the analysis and the results point to ways of, and reasons for, including systems in technology education. It may be inspiring for teachers to have a bank of pupils' experiences and suggested ways of using objects as starting points for learning

Table 7 Presentation of dimensions in category E

Interview extracts	Dimensions		
	Organisation of pupils' answers about the objects in relation to systems		
	Flow	Component interaction	System interaction
Banana See extract from Robert, category E above	There is a flow—bananas in general. Not a single banana, but bananas as a concept	Components are expressed by their function but also described and explained. This indicates an understanding of what is important as far as the interactions are concerned between components	The main system, the transport of bananas, is identified and delimited from the surroundings. Mentioning other related systems, banana plantations, greenhouse. Humans are taking an active part in the system interaction

about technological systems. It may be helpful through the analytical outcomes and through the terms developed (see below for a suggestion as to how to bring this together).

One of the primary outcomes, important for educational practice, of the research we have conducted, is the offered structure of qualitatively different understandings and how these may be discerned in discussions with pupils. Teachers, or more generally educators, may compare their context to ours, looking for the traits we have identified. By being attentive in these teaching situations, a teacher may, for example, become able to discern similar qualitative differences in their own teaching context. Once relevance is established, the knowledge of the qualitative differences may also be used to structure the content of teaching; it may guide pupil–teacher interaction towards supporting the pupils in experiencing technological systems in more complex and powerful ways. This relies on an assumption that the qualitative differences are primary to focus on in teaching in order to support the kind of understanding encapsulated in the latter of the categories we have presented. More general arguments in this vein, as well as examples of how this may be done, can be found in Marton and Booth (1997) and Marton and Tsui (2004).

The results also point to the importance of actively attempting to make technological systems discernable to pupils in "technological" situations inside and outside school, which are not formally during technology education hours. That may result in experiencing technology, as well as the purpose of technology, dramatically differently, and more clearly seeing the links between technological objects, human intentions, the function of technologies, societal contexts and human acts. The results presented in this article indicate thoughts about systems, and objects embedded in systems, that could be a platform for more advanced knowledge about systems and by that deeper understanding of technology in general. The five categories describe how pupils discern systems in everyday objects and open up for a technology content that focuses on the qualitative differences between the categories. De Vries (2005) suggests seeing technological objects as systems, which could be an educational tool for teaching about complex objects. Similarly, we propose objects as educational tools for teaching about systems. By looking at the object as a part of a system, pupils can get first impressions of the relations between objects, humans and society.

We have woven together some of the outcomes of this study into an educational strategy for what a system approach in teaching technology could potentially be. The purpose of this strategy is to help teachers to teach, focusing on what and how to teach about technological systems—and why, while leaving sufficient freedom to contextualise their teaching. Underlying our strategy, are justifications for *why* we should teach about technological systems. These justifications are, as formulated, primarily aimed towards educators. They may be conveyed to pupils, not as direct arguments, but inherent in teaching. Central to the strategy is *what* the content should be. We suggest below a way of structuring the content that is independent of the particular system. Finally, the strategy consists of suggestions of *how* to approach teaching about technological systems.

Why teach about technological systems?

We propose three main educational arguments as to why pupils should learn about technological systems. Learning about technological systems supports pupils in:

- becoming more mature users of technology;
- develop an understanding and consideration of the consequences of using technology; and
- generating an engagement and commitment to technology.

For users, it is important to understand that objects are parts of a greater whole; that using technological objects has an impact on overarching systems. To become a more mature user of technology, you need to recognise some of the opportunities you as an individual have and that your choice makes a difference. If you as an individual are, on reflection, aware of how using an object, for example a washing machine, influences systems such as, energy, water and waste systems, there is a potential to carefully consider your alternative actions, when using or buying that washing machine.

Developing the capability to understand and consider the consequences of using technology in our daily lives is essential for the future of society. We believe that the topic of technological systems is a platform for building such understanding and consideration. In particular the topic of technological systems is suitable to support young people in seeing the network of links between various parts of technology, individuals and society.

One of the "crises" of science and technology in today's western society is the apparent lack of the younger generation's engagement in science and technology. Linking technology to individuals and society, contextualised in pupils' everyday life, may be an important opportunity for generating engagement and commitment—which is essential also for technological literacy and *teknisk bildning*.

What should the content in technological systems be?

Teaching about one or several technological systems may be approached in many different ways. In order to be able to address the justifications we see for teaching about technological systems in general (to teach about particular systems may be justified for quite different reasons), we argue that there must be some recurring structure to how technological systems are described. Such a structure can be a framework that supports an analytical stance towards individual systems in the teaching, offering the students tools for flexibility in delimiting and understanding systems they come in contact with.

We suggest that the three dimensions that were identified as structural components of the pupils' experience of technological systems may provide such a framework. They are

- flow,
- integration of components in a system, and
- integration between systems.

These dimensions were natural delimiters in the interview discussions with pupils. They provide a structure to the content for teaching about systems in general, and what can constitute parts and wholes. The three structural components make it possible to experience a system in its specifics and as an example of a more general phenomenon. In order to grasp technological systems in the way experts do, grasping these three dimensions individually and as a whole is an important building block. Discerning and relating the dimensions to each other imply discerning different levels of systems simultaneously.

How to teach about technological systems?

Teaching about systems requires a variety of educational strategies. In terms of the content, we have found three possible starting points, as a conclusion of our results. We see three levels that lend themselves to linking objects and systems as parts of each other in a reflexive relationship. In that way, one object may be analysed in three directions which together support multiple ways of understanding the same material object. In turn this builds to different kinds of technological potential. These levels, as mentioned in the introduction, can be taken as starting points for introducing systems in technology education:

- the level of the object themselves—objects as objects;
- the micro level inside objects—objects with components as systems; and
- the macro level outside objects—objects as parts of systems, together with humans and society.

The first level takes everyday objects as the starting point, trying to encompass the use and the function of these objects. For example, concerning a mobile phone, this level is about what we want the mobile phone to help us with, such as talking to a friend or listening to music. The second level focuses on opening the "black box" to see what objects are inside. Here we are trying to perceive the micro level of objects, and how its parts co-operate in forming the form and function of the object—what components are necessary in the mobile phone and how they are connected to each other. The third level implies analysing objects as parts of (several) macro system(s), trying to get a grip on how the components in one system—objects and humans—are connected in a network with other systems. Mobile phone satellites, telephone masts and computers are things in the surrounding that are connected to the mobile phone, as well as your friend and yourself.

Appendix: Interview questions to pupils (10 and 15 years old) with four objects; mobile phone, light bulb/low-energy light bulb, side-cutter and banana

The interview questions included, but were not restricted to:
Interview questions related to the *user aspect*:
What do you think of when you see this mobile phone?
How do you use your mobile phone?
What do you think is important to know about mobile phones?
Why do you think it could be hard to understand and use a mobile phone?
What do you think when you see these lamps?
Do you know the difference between the two (light bulb and low-energy light bulb)?
Which one would you choose and why?
How is it possible for us in Sweden to eat bananas? What do we need?

What does ecological or organic certification mean?

Interview questions related to the *functional aspect*:

How would you describe the function of a mobile phone/light bulb/low-energy bulb to someone that has never seen one?

Why do you think it could be hard to understand a mobile phone?

What do you think is important to know about mobile phones?

Interview questions related to the *developmental aspect*:

How long do you think we have had mobile phones/light bulbs/low-energy bulbs?

Do you know what they looked like earlier?

How long do you think we have had bananas in Sweden?

Do you think we will have mobile phones/light bulbs/low-energy bulbs/bananas 10 years from now?

What will they look like? What will they be used for?

Interview questions related to the *systemic aspect*:

What does this mobile phone need to get in contact with other mobile phones?

Is there anything in the surroundings that mobile phones need to work?

Is there anything in the surroundings that lamps need to work?

What do we need to have the possibility of eating bananas in Sweden?

What do you think is the history of this banana? Could you tell me?

Does the mobile phone/light bulb/banana have an influence on the environment? In what way?

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