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Technology in the Rear-View Mirror: How to Better Incorporate the History of Technology into Technology Education

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Abstract The history of technology can play an important role in illuminating the fundamentals of technological change, but it is important that technology teachers, teacher educators, curriculum developers and researchers can be provided with good analytical tools for this purpose. In this article we propose a model of techno-historical interplay, as a help in deciding what historical artefacts and systems should be included in technology curricula and teaching as well as in analyzing and conveying to students the fundamental issues of technological change. We want to emphasize particularly three points of importance in employing the model as a tool of analysis. First of all, it is crucial to decide what one wants the technologically literate student to know about technology and technological change. This should include an awareness of the historical and geographical contingency of any technology. Second, on the basis of this decision one should adapt the model as a tool for selecting relevant technologies. Third, the model should be applied as an instrument of analysis of the history of the selected technological artefacts or systems as well as theories of technological development.

Keywords Technology education, Technological literacy, History of Technology, Social construction of technology

Introduction

A wealth of research within the history and sociology of technology in the last decades suggests that a historical perspective is pivotal in order to understand technological artefacts and systems, their characteristics and place in society and the natural world (see, for instance, Bijker et al. 1987; Hallström 2009a; Hughes 1983, 2004; Ingelstam 2002; Kaijser 2004; Nye 2006). One of the most important policy documents on technological literacy in recent years, *Technically speaking: Why All Americans Need to Know More About Technology* by the Committee on Technological Literacy, also claims that a technologically literate citizen should know the “ways technology shapes human history and people shape technology” (Pearson and Young 2002, p. 4). Technology curriculum documents across the globe have generally included more or less self-sustained items of technological history. Rasinen (2003), who has studied technology curricula in Australia, England, France, The Netherlands, Sweden and the United States, concludes that the “history of technological development” is considered to be “most significant content” in all these countries (Rasinen 2003, p. 45).

Sweden is a country which emphasizes the history of technology, and one can read the following in its technology curriculum: “The history of technology enables us . . . to gain a deeper understanding of the conditions of technology . . .”. Students should in line with this after nine years “be able to describe important factors in technological development, both in the past and present, and give some of the possible driving forces behind this” (Skolverket 2000, p. 1-4).¹ The New Zealand technology curriculum of 2007 also exemplifies a conscious adoption of the history of technology, as can be seen under the Nature of Technology strand:

[Students] learn to critique the impact of technology on societies and the environment and to explore how developments and outcomes are valued by different peoples in different times. As they do so, they come to appreciate the socially embedded nature of technology and become increasingly able to engage with current and historical issues and to explore future scenarios (Ministry of Education, New Zealand 2007, p. 32).

Another example is the South African technology curriculum: “Technology has existed throughout history. People use the combination of knowledge, skills and available resources to develop solutions that meet their daily needs and wants”. The assessment standards for grade three include the criterion that the learner “[f]inds out about the historical context when

¹ The Swedish technology curriculum document is right now being revised, but it is likely that the history of technology will remain an important item even in the new one (Swedish Government Bill, Prop. 2008/09:87).

given a problem, need or opportunity related to structures, processing, or systems and control” (Department of Education, Republic of South Africa 2002, p. 4, 15).

Given the fact that the great majority of technology teachers, teacher educators and curriculum developers are not educated as historians, they need tools for a better incorporation of the history of technology into technology education. The aim of this article, therefore, is to propose an analytical and pedagogical model of techno-historical interplay for the analysis of the development of technology and other issues in technology education that need to be historicized for a full understanding of their complexity. The model is thereby intended as a tool for teachers, teacher educators, curriculum developers and researchers in technology education in developing the historical and societal aspects of the technology curriculum.

The article is divided into three parts: a presentation of the theoretical model of techno-historical interplay, underpinned by theoretical literature as well as empirical examples; an overview of research problems common to the fields of history of technology and technology education which the model could help analyze and resolve; and finally two concrete examples from the Swedish history of technology of how the model could be implemented in full, thereby potentially assisting in developing and clarifying developmental and societal aspects of technological literacy.² The structure and function of the model and its constituent parts are presented below. Suffice it to say here that we adhere to a heuristic definition of models common to historians, for instance, Burke (1992) who defines a model as “an intellectual construct which simplifies reality in order to emphasize the recurrent, the general and the typical, which it presents in the form of clusters of traits or attributes” (Burke 1992 p. 28).

A model of techno-historical interplay

We here propose an analytical and pedagogical *model of techno-historical interplay*, which is designed to analyze various relationships that can exist between technology and society throughout history. Technology is complex and multifaceted, and we therefore believe that the model should be able to harbour a diversity of perspectives in order to make a fair representation of the development of technology. However, a social constructivist meta-perspective permeates the model. In the field of Science and Technology Studies (STS), there

² Both curriculum documents and previous research have been selected mainly to illustrate and construe the argument, not to be entirely complete or conclusive. There is also a slight overemphasis on Western countries, which reflects both language restrictions on the part of the authors and the fact that research in the history of technology and technology education has had such a focus until just recently, but the point of the article should nonetheless be clear (cf., for example, Edgerton 2006).

are many examples of how technology is constructed through negotiations and interpretations by different interest groups. Society influences the direction of technological development in various ways, by regulation, through policies, in designers' ideas, user ideals etc. (Bijker 1995; Galis 2006). These STS studies show with persuasive clarity that technology in the making goes through a process of "interpretative flexibility", where "relevant groups" influence the outcome of technology in different ways before it reaches, at least a relative, "closure" (Bijker 1995). "Interpretative flexibility" highlights the social dimension of technological development. "If no interpretative flexibility could be demonstrated, all properties of an artefact could be argued to be immanent after all. Then there would be no social dimension to design . . ." (Bijker 1995, p. 76).

Solely focusing on the engineer's and technology's desire and potential for improved solutions is commonly referred to as an internalist perspective (Shapin 1992). The problems with this perspective are numerous, since it tends to disregard all the external factors that affect the development of technology – and does not acknowledge that what is considered an "improved solution" is always a matter of context. Was, for example, the wheel plough really better in all situations than the wooden plough or the iron-clad spade (Hansson 2002)?

An externalist perspective, on the other hand, implies that the development of technology is explained first and foremost by the effect of external factors (Shapin 1992). It might be climate changes or social or political factors which constitute the bases for technological change. This perspective also has flaws. Recurrent flooding might be an explanation as to why a population starts developing irrigation systems but it could also explain why people are forced to move, to migrate. How do we know what causes what, and why it leads to irrigation systems in one case and migration in another? Identifying a small number of cause-effect connections becomes quite trivial since one is dealing with extremely complex processes. What was it, for instance, that made it possible to increase production efficiency, thereby enabling industrialization? Was it the steam engine, as one Swedish teacher claimed during a lesson in energy history, documented by Gyberg (2003)? What then, made the development of the steam engine possible? The need for flexible and reliable power? As one can understand, this quiz could continue forever and after having opened one box, there is always another (Gyberg 2003).

This does not mean, however, that it is impossible or futile to isolate single technologies or events and try to understand them in context. The model therefore takes into account both internalist and externalist influences on technology. This is sometimes regarded as a perspective in its own right – contextualism (cf. Staudenmaier 1985). The model of techno-

historical interplay (see Fig. 1) points to the fact that technology always evolves in interaction with various societal actors and factors – inventors, system builders, users and other actors, political and economic driving forces, scientific and technological prerequisites, and formal rules (e.g. laws) and informal rules (such as cultural values). The interplay that the model represents defines technological development, but the model does not specify exactly how the interplay works or how strong the relationships are between the various actors, factors and technology, because they can vary in time and space. In addition, there are other potential influences than those that fall under the different arrows, represented by the question mark. The interplay is always there, but may differ and affect/be affected by technology to varying degrees (Gyberg and Hallström 2009).

Fig. 1 A model of techno-historical interplay

The arrows of the different actors and factors indicate the force and pressure – “pulls and pushes” – on the existing state of technology at a given time. To justify the evolution of technology in the direction indicated, at least some of the arrows must be in the same

direction. However, since the actors and factors aiding or resisting technological change depend on the historical context the model does not specify the exact direction or force of the actors and factors in the interplay. Consequently, this will be the outcome of the application of the model in each historical case.

Elaborating the model: levels of meaning in the techno-historical interplay

It is also important to problematize the different *levels of meaning* of technology, as has been pointed out by Gyberg and Lee (2009). Just as the rest of the model the different levels of meaning will help critically reflect upon the evolution of technology. Yet, if the model as a whole pinpoints actors, factors and influences on technological development, the levels of meaning zoom in on the users and the using of technology in particular, something which has been lacking in history of technology research (Edgerton 2006).

Discourse

The first level is the *discursive*. The discursive level accounts for what people think, know and say about technology. Discourses constitute the knowledge they have about the world and organize the world in. Discourse is a system of rules for different relationships of meaning and they define how people understand and explain the world and their actions (Gyberg 2003; Mills 1997).

The French historian Michel Foucault (1970) shows that how the world is understood is not a natural given, but that the understanding is shaped by socio-cultural factors and discourses prevalent in each society, thereby pointing to the contingency of Western knowledge. There are also very different ways of describing the same thing within the same socio-cultural domain, for example, energy as an area of knowledge in school. Gyberg (2003) shows that energy is dealt with in a variety of ways in school and that some of the ways even conflict with each other. Energy can be about supply and choice of different energy sources (nuclear power, wind power, coal, etc.). But it can also involve, for example, photosynthesis, cellular respiration, chemical processes and the energy principle. In the latter case, this is a more scientifically-oriented discourse with a strong focus on specific, often abstract, concepts. These different discourses lead to completely different knowledge and understanding of energy. The study also identifies a more critical approach to energy where the arguments and knowledge of energy are based on certain ethical positions. Issues and questions that were important in this type of discourse were: Do humans have the right to use resources as we do,

and do we have the right to expose ourselves and future generations to emissions and hazardous waste?

A particular technology can thus be attributed many meanings, and it is consequently crucial to try to understand why certain meanings are dominant. The discursive level is important in understanding technology because it is through discourses we understand and define technology. This means that the discourse around a particular technology also defines the problems that are connected with the technology. If energy is mainly about energy sources, aspects such as how electricity and heat are used, that is, lifestyle issues, may easily be forgotten.

Disposition of the subject

The second level of meaning is the *disposition of the subject*, which has to do with our personal experiences of and thus different ways of relating to technology. Girls and boys, women and men, for example, have very different ways of responding to and acting in relation to technology, which is due to the very different societal expectations that are imposed upon them; boys are expected to be outgoing and active while girls are expected to be cute and passive (Mills 1997). Thus if one is expected to be cute, sweet and passive it is the breaking of social norms for a girl or woman to change tires and get greasy fingers. According to Foucault, the human subject is a "medium" for his or her specific socio-cultural context rather than an entity in itself (Foucault 1972). From this point of view, the individual's actions are always a response to the relation between his or her experience-based disposition and the unique conditions of the surroundings (ibid. p. 64). This is why a certain person, in a specific context, may be interested in electro magnetism, engines or sewing machines. The above argument also goes for other contexts and personal dispositions, such as if one comes from the countryside or the city, or on other grounds such as class, ethnicity, age or sexual orientation.

Interaction

The third level of meaning that should be treated with respect to technological development is *interaction*. This level constitutes the social activities and follows the interactive rules for constructing meaning. It deals with how one encounters the surrounding world and how technology shapes this encounter, that is, how in the process of using technology it *mediates* the surroundings. The written language as a technological tool of communication mediates reality through discourses, but all technological artefacts and systems are mediating tools

(Vygotsky 1994; Säljö 2005). Take, for example, how the cellphone has affected ways of communicating and planning people's daily lives. This could be caricatured by referring to the man who calls his wife to say that he is home while he is driving into the garage.

Interaction does not only mean between people but also interaction with the designed world and the natural environment as a whole. To fly between Amsterdam and New York for seven hours is one, modern kind of interaction that gives a certain feeling of time and space while to go on a cart drawn by an ox between London and Cambridge in two days is quite another. It can also apply to how electricity makes people learn to act in certain ways while they may find it difficult to manage a longer power cut. The technology humans design thus continually creates new conditions for interaction and hence how they should act and what is important to know in relation to technology itself and the surrounding world.

Materiality

The final level to be addressed is *materiality*. Although materiality is dressed with meaning, it is hard to ignore the fact that materiality itself is both an important carrier and maker of meaning, which defines the human conditions for acting. A large stone in the forest forces one to take some extra steps around it instead of simply going straight ahead. The stone has a tangible and significant impact on our actions. The same is true for all technologies that humans use. They affect, limit and facilitate choices and possibilities for action. There is always an interplay between the levels of meaning of technology, but technological development is nevertheless contingent upon the laws (physics, chemistry, mechanics) of materiality to which humans always have to adapt (Callon and Law 1995).

Critical issues and theories concerning the development of technology – applying the model

We will here give some examples of how the model of techno-historical interplay can be employed to analyze historical aspects of technology and thereby to improve technological literacy. The model could help curriculum developers, teacher educators, teachers and researchers in identifying and sorting out important aspects of technological development – actors, driving forces, discourses etc. – and also to disassemble and problematize theories of technological change.

Driving forces of technological change

The classic problematic to be addressed initially is what the *driving forces behind technological change* are. It is sometimes said that “necessity is the mother of invention” but throughout history, and particularly in the modern age, there are many examples of inventions that have instead created a need, for instance, the telephone. In the past hundred years or so it has also been frequently asserted that technology is an application of science (see, for instance, Kline 1995; Layton 1984; Lindqvist 1987; McCulloch et al. 1985), but throughout history there are many examples of technology that has not been merely an application of science. In fact, up until the 19th century it seems that the connections between science and technology were few; technological change was primarily achieved by practical craftsmen and not scientists (de Vries 2005a; Liedman 2001).

So, what are the driving forces behind technological change? Petroski (1992) claims that over the course of history it is the failure of design and human discontent with such failure that have been the driving forces behind technological innovation and change. Hård and Jamison (2005), on the other hand, argue that there is always a certain amount of human hubris, that is, an “attempt to transcend limitations and literally do the impossible” (p. 6), behind technological change. Hughes (1983, 1987) emphasizes the crucial role of human system builders in achieving socio-technical change. Latour (1987, 1999, 2005) points to the importance of collective actor-networks of associated humans and non-humans in accomplishing technological change.

What is important to point out here is that the history of technology and theories developed within this field could be an asset for curriculum developers, teachers etc. when addressing technological literacy and the problematic of technological change. There are several other examples of theories of the driving forces behind technological change, all of them building on examples from the history of technology and spanning from internalist to externalist. The model could help sort out the relevant explanations and perspectives on technological change, given the nature of the learning object.

The notion that technology is merely “applied science”, for example, would seem to be a rather simplified view when using the model as a tool of analysis. The history of science and technology also shows that it is mainly in the past 200 years or so that the idea of technology as being applied science bears any real significance, and often technology and science have been aligned mainly for rhetorical reasons in order to improve their status, get funding etc. (Gieryn 1983; Hansson 2002; Kline 1995). This is not to say that the connections between science and technology have not become more intimate during the last century, what historians, sociologists and philosophers of technology often term the emergence of

technoscience (Hård and Jamison 2005; Scharff and Dusek 2003; Williams 2002). However, the influence has gone in both directions, that is, technology has also affected science, which is often missed. There is the significance of Galilei's modern telescope for our knowledge of the universe, of Harrison's chronometer for determining positions at sea and many modern examples. But even in the modern age we need to rethink the relationship between science and technology. Technology is essentially about human design to solve societal problems – be it by means of artefacts, systems, processes, techniques, knowledge – while science describes the working and laws of nature. These are two distinct fields of knowledge (de Vries 2005a; Hallström 2009b).

Although de Vries (2001) sees science and technology as two separate areas of knowledge, he argues for a nuanced view of the relationship between them, so as to get away from the “technology as applied science” paradigm. He has studied the history of the Philips industrial research laboratory (see also de Vries 2005b) and makes some suggestions on how historical items could be incorporated in science and technology education so as to illuminate the relationship between science and technology in the last century. In his study he identifies three patterns of interaction, as is evident in the history of industrial research laboratories: science as an enabler of technology, science as a forerunner of technology and science as a knowledge resource for technology (de Vries 2001). Consequently, if we see science and technology as historically and culturally contingent practices they should be analyzed individually and neither of them should take the back seat. For our purposes it would mean analysing technology in the interplay between societal factors, actors and the levels of meaning, using the model.

Nature of technological evolution

Another pivotal dilemma to be addressed in technology education is the *nature of technological evolution*. Historians of technology representing an older view of the evolution of technology claim that most modern artefacts have evolved from the oldest and most basic human tools and inventions (see, for example, Eco and Zorzoli 1963). Still others maintain that the evolution of technological artefacts and systems do not follow such a straightforward path. Petroski (1992) argues that there are many artefacts such as paper clips and knives and forks that evolved in a more haphazard manner with frequent detours and failures, and that they mirrored societal changes as much as intentions of innovators (Petroski 1992).

Ihde (2006) is of a similar view and shows convincingly that the evolution of technological design often follows multiple, competitive trajectories through trial and error,

which eventually result in a final design. The ultimate uses of a certain technological design are equally unpredictable. Often, but not always, the intended use of a design is actualized, but the number of actual uses – and misuses – of a technology not originally intended are infinite (Ihde 2006; see also Ferguson 1992). The philosophical reason for the haphazard evolution of technology is to be found in what is often called the “dual nature of technology”. Technology has a physical nature, that is, the physical, chemical and mathematical properties that are intrinsic to an artefact or system. It also has a functional nature, in other words the meaning or intention that designers and users of any artefact or system ascribe to it. Designers and users need to be aware of both these aspects of technology, or else accidental uses, misuses and even failures may be the result (de Vries 2005a, 2006).

The history of technology is very complex because of the very complicated relationship between the physical and functional nature of technology, the designers and the users, the connection between technological and societal factors affecting the evolution of technology. This calls for historical analyses of many different kinds of artefacts and systems in technology education, in order for students to understand both the complexity of design and the variety of technological innovations and their trajectories due to factors internal and external to technology. Our model of techno-historical interplay could be a help in doing such analyses, and, in doing these, problematize and disassemble various actors, factors and levels of meaning.

Technological determinism

The model could also, for example, be used to analyze the question of *technological determinism*, in which technology is considered to develop, expand and become difficult to change by its own internal powers or logic. Various concepts have been developed within the sociology and history of technology to address this problematic, such as *momentum*: technology becomes inert and difficult to change due to investment and other choices made; *path dependence*: through historical choices technology continues to evolve in the well-worn paths; *closure*: technology stabilizes and becomes difficult to change when a particular interpretation of it dominates; or *hubris*: an appetite for expansion and economies of scale make technology difficult to change (Bijker 1995; Ekman 2003; Hughes 1987; Hård and Jamison 2005; Melosi 2000).

But which of these theoretical concepts could resolve the dilemma of technological determinism? Here the model could assist in determining the important actors and factors behind the evolution of a specific technological artefact or system. For instance, Hughes talks

about a technological system getting certain inertia when it has been established for a while. Since so much has been invested technologically, financially, organizationally and socially into the system, it is difficult to get it to stop, or even change its direction. It continues to expand because so many different interests gain from it (Hughes 1983, 1987). The term momentum has received much criticism, since it has been interpreted as a way of turning the systems into actors in themselves. This is close to technological determinism. However, this criticism is undeserved in part, because Hughes several times stated that we are dealing with the choices of human actors, not technology itself. He calls it a *soft determinism*, as the system is, after all, more resistant to change (Hughes 1987; Ingelstam 2002; Sundqvist 2001; Winner 1977).

What makes one think of technological determinism may be the role assigned to the physical infrastructure – materiality. This can be said to apply specifically to strongly connected systems, that is, systems which have an expensive and often built-in infrastructure (cf. Hallström 2009a). Water and sewer systems are a typical example of technology that has received a high degree of momentum. The American historian of technology Martin V. Melosi writes the following:

A commitment to permanence . . . often locked in specific technologies and thus limited choices for future generations. Problems could arise if systems were either too well built or too poorly constructed. In the case of the former, an existing system could prove resistant to change; in the latter case, it might be in desperate need of replacement. As a consequence, decisions made about sanitary systems in the nineteenth century had a profound impact on cities more than 100 years later (Melosi 2000, p. 10).

Since large technological systems are built to last over a long period of time, the technological and other choices made as well as the infrastructure itself influence future generations.

Using categories from the model it is possible to disassemble and sort out the concept of momentum so as to be able to address the issue of technological determinism better. In the case of water and sewer systems momentum mainly depends on the inertia or stability of the physical infrastructure – materiality – but also discourses of hygiene, municipal engineering as well as economic driving forces, in collaboration between actors such as system builders, politicians, users etc. (Bijker 1995; Hallström 2002; Hughes 1987; Ingelstam 2002; Staudenmaier 2001). Applying the model to the historical development of a specific system will reveal more exactly what actors and factors were at work.

The model thus helps us open up what is often called the “black box of technology” since it presupposes the existence of many different contextual influences, not just internal ones. Our reasoning above leads to the need for a definition of technological change in relation to the model presented. The interplay between different actors, factors and levels in certain situations creates zones of interpretative possibilities and restrictions regarding technology (cf. Bijker 1995). The interplay defines the preconditions for technological change, but there is always a certain amount of contingency as well as unique combinations of the interplay. Even if technological change sometimes seems to take sudden leaps, it depends on the characteristics of this zone in a specific time and space.

Two examples from the history of technology

The final step in this article is to present two concrete examples of how the model can be implemented to fully understand complex historical processes concerning technology. The first example deals with the introduction of new technology, namely water supply and sewerage, in two Swedish cities in the 1870s. What triggered the initial construction of modern, pipe-bound water and sewer systems in the cities of Norrköping and Linköping at this particular time in history was a combination of various actors and factors, as suggested by the model. The introduction of these systems was carried out by networks of *actors* linked to the *political* and *economic* elite in the 1870s. Central actors were persons otherwise very powerful in the respective cities. *Economic propelling forces* were predominant factors, particularly in the case of water. For example, the local actors were encouraged by the prospect of lowered fire-insurance fees in both cities and decreased costs for poor relief, especially in Linköping, after an introduction of piped water. In Norrköping, piped water was a patriarchal concern for the workers, but was also indirectly to boost local industrial development. Dumping industrial sewage in the river Motala ström was inexpensive waste management that could continue after providing the residents with clean piped water taken upstream from the city. The Linköping Water Company was also expected to be a profitable business venture (Hallström 2002).

Discourses and *materiality* of public health and environmental issues played a part as well, but here the two cities differed. In Linköping the poor sanitary conditions were attributed to deficient sanitation, drainage and cleanliness, which could be improved through piped water, for example, for flushing the streets. Norrköping’s history of devastating fires made fire protection improved by pressurized piped water crucial. Sewerage came late in the discussion, which implies that, at least in the Norrköping case, the influence of the dreaded

cholera on the introduction of these systems has been exaggerated. A *discourse* of civic pride and *scientific and technological prerequisites* in the form of imported engineering ideas from Great Britain, primarily through Swedish engineers J. G. Richert and Abraham Blix, also played a pivotal part. A change in cultural values – *informal rules* – regarding who was to fetch water, from women in the case of the previous wells to men handling the water standpipes, was necessary, but *interaction* with the new technology also facilitated this cultural change. *Formal rules* such as the 1874 public health law was passed in Parliament when the water and sewer projects in the two cities were well under way, which means that it did not have a direct influence (Hallström 2002).

The second example is borrowed from the historian of technology Arne Kaijser's (1986) dissertation on the establishment of the first public gasworks in Sweden. As a background he read up on the pioneers and the processes leading to the first establishment of public gasworks in London. As far as the handling of gas is concerned, the most important development was in England at the end of the 18th century and beginning of the 19th. His description of this development is, of course, not based on the model presented in this article, but it shows how many different levels of meaning cooperate, as well as how different driving forces affected the establishment process. We use this background to illustrate how the model can explain and problematize the complexity of technological development.

Kaijser discusses a number of driving forces that explain why the introduction of gas was so rapid in London at that specific time: lack of traditional lighting methods due to war in Europe, rapid development within metallurgy, important progress within chemistry (not the least John Dalton's important essays from the beginning of the 19th century), and the growing industry's need for reliable, cheap and simple lighting. Also affecting the development were factors like strong entrepreneurs with resources and knowledge (such as the steam engine firm Boulton & Watt), local political power struggles, rules surrounding responsibilities for street lighting and the significance of fortune seekers such as Philippe Lebon and Fredric Albert Winsor (pp. 37-48). Kaijser's description illustrates a complex interplay between a number of central factors which pertain to *scientific prerequisites* (within chemistry and metallurgy), *technological preconditions* (increased precision, more lasting materials), *politics* (public good, system builders, handling of risks) and *users* (growing industries with a great need for lighting to maximize production but also different users' ideas about the quality and smell of different gases).

We can also identify the different levels of meaning in Kaijser's description of the development of gas in Great Britain and Sweden. Based on Kaijser's study, it is difficult to

say exactly what *discourses* were circulating, but it reveals glimpses of certain discourses. For example, it seems as though there was a growing belief in technology's potential to solve problems, even though machines were seen as a threat, or even something evil, by many groups (Berman 1988). Another example, according to Kaijser, was that people in Sweden were somewhat jealous of the "illuminated" cities down on the continent, and light came to symbolize so much more than just better visibility in dark alleys. This served as one of several motives to introduce gas in Stockholm and other Swedish cities, even though this happened much later. Another example of a discourse that surrounded the introduction of gas was the protectionist idea that one did not want to become dependent on anything other than domestically produced fuel, for example, coal in England and creosote oil in Sweden. One can also see that there were other discourses which supported the introduction of gas or made it difficult, for instance, ideas regarding cleanliness and security. The gasworks also raised questions about, and thereby displayed discourses concerning, the boundaries between private and public. Establishing public gasworks meant new preconditions for the building of large technological systems and other ways of handling, for example, responsibility.

Several studies of technological history are very strongly focused on the role of certain *individuals/subjects and their dispositions* in the development of different technologies and technological systems (Hughes 1986; Strömbäck 1993). To a certain extent, this is also the case in Kaijser's study; certain individuals had significant effects on the introduction of gas. William Murdoch, who later became technical manager at Boulton & Watts facilities in Soho, had experimented with gas manufacturing through dry distillation of different fuels. As technical manager, his experiments were able to continue on a bigger scale. His gas lighting was installed in one of the buildings in the factory area, for example. The son of James Watt, Gregory Watt, travelled to Paris in 1801 and witnessed one of Philip Lebon's displays of his "thermo-lamp", and what he saw made him convince the management of Boulton & Watts to resume testing gas. The tests had been stopped after difficulties with Murdoch's trial facility in Soho. In order to be able to expand public gasworks, a person like Winsor was required to convince London's power elite.

There existed practices and new ones came into being in which technologies developed, but perhaps more importantly, in which it was possible to exchange knowledge between different practices such as between industry and academia, and where new preconditions for *interaction* surrounding gas technology developed. There were many meeting places for new ideas and knowledge about gas and the role of gas. There was also a growing need for new solutions which in several ways came to affect the political arena on different levels, for

example, the view of public good and responsibility. Of greatest interest, in terms of the interactive level concerning gas, was how this more reliable and in many ways less labour intensive lighting method effectively prolonged the workable hours of the day in industries, and how it made streets and buildings more accessible during the dark hours.

At the level of *materiality*, gas has to be produced and stored under special circumstances which often demands high pressure. This meant that adequate gasometers and pipes were required. The transport of gas also entailed new demands, as did measurement and payment of the gas. Gas also has different qualities which can create discomfort through smells, or worse, risk for explosion. All these “qualities” and demands have to be taken into consideration, and the specific society in which the gas is established has to adapt to these conditions. At the same time the ideas and demands in a certain society make certain technological solutions possible and not others. The development process can result in revolutionary changes, but often the interplay entails subtle changes of prevailing structures (Kaijser 1986).

Conclusion

Technology is a powerful tool which is intimately connected with the knowledge of human beings and our ability to process and understand our surroundings (Säljö 2005). In certain cases, technology makes life easier and more comfortable, and in other cases it causes risks, dependencies and direct threats. People are dependent on a number of artefacts and systems in order to carry out their daily activities. The history of technology can play an important role in illuminating the fundamentals of technological change, but it is important that technology teachers, teacher educators, curriculum developers and researchers can be provided with good analytical tools for this purpose. In this article we have proposed a model of techno-historical interplay, as a help in deciding what historical artefacts and systems should be included in technology curricula and teaching as well as in analyzing and conveying to students the fundamental issues of technological change. Our hope is that it could be an aide for the said groups and even others who share our belief that technological change is an important aspect of technological literacy. The history of technology should consequently be consciously adapted and have a self-contained role. Of course history of technology is just one of many aspects of technological literacy and technology education, but if we are to achieve a more clear definition of technological literacy, then philosophical as well as historical aspects need to be treated consciously and with a good foundation. Our model is an attempt to make the developmental aspects of technology visible and well-founded as well as provide a tool to analyze and disassemble theories of the historical driving forces and evolution of technology.

We want to emphasize particularly three points of importance in employing a clearer history of technology perspective on the basis of this model. First of all, it is crucial to decide at the beginning what one wants a technologically literate student to know about technology and technological change. This should include an awareness of the historical and geographical contingency of any technology, and the cultural embeddedness of technology from the dawn of humankind until today. Second, on the basis of this decision one should adapt the model as a tool for selecting relevant technologies. What technologies could epitomize, for example, the collective nature of innovation, obstacles to innovation due to cultural values/informal rules, the effects of users' needs etc.? Third, the model should be applied as an instrument of analysis of the history of the selected technological artefacts or systems as well as theories of technological development. The examples that we have provided in this article are not in any way conclusive, nor can they be. The point of the model is that it is heuristic, that is, it is a help to analyze, sort out and re-think issues, factors and actors related to technological change.

It is obvious that the history of technology can help develop the knowledge base of technology education even concerning other items if we look at, for example, what the Committee on Technological Literacy considers to be central knowledge for a technologically literate person. Not only developmental aspects of technological artefacts and systems but also technology's relation to society and nature can be fruitfully analyzed and discussed in a classroom context with the help of the supporting discipline history of technology and our model. This means that even other facets of technological literacy than the strictly historical can be addressed in the classroom with the help of the model: the role of technology in sustainable development, citizenship, globalization etc. (Pearson and Young 2002).

Previous studies have shown, for instance, that many students expect technology to solve global problems that the world faces (Gyberg 2003), an expectation which can be addressed and problematized together with especially students at the secondary level using the model. The model can help students look beyond the immediately visible functions of technology and see its more subtle and indirect effects on society that in fact change the conditions of our existence at a global level, for example, concerning environmental and sustainability issues.

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