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Public understanding of science: using technology to enhance school science in everyday life

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In this paper, one aspect of public understanding of science is discussed: the use of school science in students' everyday lives. Given the difficulties of using traditional school science in everyday life, the author discusses the possibility of introducing aspects of technology into the science curriculum. It is shown that technology, as curricular content, provides pragmatic models that can be used to connect school science with students' everyday lives. It is argued that the goal of connecting school science to students' everyday lives moves the discussion of public understanding of science to public understanding of technology. The implications and limitations of this movement are also examined.

Introduction

The intensification of the debates on the public understanding of science reflects a renewed concern for the role of science in society. This is evident when one reviews the literature of the 1980s and 1990s in which the relationship between science and its public is widely studied (e.g. AAAS 1990, Arons 1983, Miller 1983, Shamos 1995, Bybee 1997, Fensham 1997, Jenkins 1997).

Given the diversity of publics and sciences as well as the different methodological commitments of researchers, it is not surprising that discussions and research on public understanding of science have been analysed from several perspectives. Wynne (1995: 364), has identified three generic methodological approaches that researchers have used to study levels of public understanding of science:

- large-scale quantitative surveys;
- cognitive psychology or the reconstruction of the 'mental models' that people appear to have; and
- qualitative field research observing how people use science in their everyday lives.

In science education, each of these approaches has its parallel. Particularly, quantitative surveys can be identified using multiple-choice tests, which are still widely used. Cognitive psychology is perhaps the dominant paradigm in contemporary research on teaching and learning science. From this perspective, students

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develop their own unique mental models of natural phenomena. Research on naive conceptions (Novak 1987, Smith 1990), e.g. is based on this assumption.

The third approach identified by Wynne (1995), research on how people may use science in their everyday lives, is relatively new in formal science education. In fact, there are not many studies dealing with how students use school science in daily life.[1] This concern has only recently become important because of a renewed conception of the meaning of 'public understanding of science'. For example, one important American science education reform proposal, the National Science Education Standards, assumes that 'Understanding science and being able to use it in everyday life affairs are hallmarks of scientific literacy' (Collins 1997: 300). In this paper, I have studied the complexities of this statement, i.e. the goal of connecting school science to students' everyday lives.

Difficulties in connecting school science to students' everyday lives

The connection of school science with students' everyday lives is an educational goal which looks simple, plausible and desirable. However, this goal is complex, difficult and rarely studied. Of course, there are several interpretations of this connection. For example, in teaching my own classes, particularly topics, such as forces, energy and momentum, like many science teachers I frame 'real-world' problems with common examples like climbing a rope, accelerating a car, pushing a box along the floor, filling the tyres of the car with air, etc.

The picture is different when one realizes that educational reformers are asking for meaningful applications of science in relation to students' everyday lives. This assumes that scientific knowledge can be used in meaningful ways in everyday life. Here the starting point is the use of science in everyday life rather than solving specific academic problems. One intriguing point is that in formal science education there have been only a few studies on this topic. One systematic work on school science and students' out-of-school experiences is the recently published paper of Mayoh and Knutton (1997). They reported the way in which 12 science teachers were using students' out-of-school experiences in their science lessons. My interpretation of this study is that few teachers from this sample were able to connect school science to students' out-of-school experiences (Cajas 1998). In other words, connecting school science to students' everyday lives seems to be very difficult for teachers.[2] Why?

One immediate answer, regarding the difficulties teachers have in connecting school science with students' out-of-school experiences, may be that teachers simply do not know how to do so (e.g. they do not have the specific pedagogical knowledge). This requires a better understanding of what it takes to connect science to everyday life. One reference can be the same study by Mayoh and Knutton (1997: 865), who report that for the few episodes in which teachers made attempts to connect out-of-school experiences with science lessons they:

> appeared to possess some knowledge-in-action concerning the importance of linking everyday experiences to scientific knowledge. However, their awareness of the role of out-of-school experience within their teaching seemed largely to be tacit. Rarely were teachers explicit about the potential relationships of out-of-school experiences to their science learning.

The questions are: What is this 'knowledge-in-action' teachers need to help students connect everyday experiences with science lessons? and Why is it difficult for science teachers to be explicit with the connection between students' everyday lives and school science? One specific example may serve to clarify this point.

Consider the case of the 'Episodes developing skills of use in everyday life' section of Mayoh and Knutton's (1997) paper, which is related to the topic of electricity. Electricity is accepted as a topic that presents meaningful contexts for the use of science in everyday life because it has several practical applications (McDermott and Shaffer 1992). However, such applications tend to be difficult because science teachers normally work with very simple circuits (e.g. closed circuits constructed with flashlight bulbs, wires and batteries) while real-world circuits tend to be different (Black and Harlen 1993). More importantly, classroom work with bulbs, wires and batteries is designed for developing models to understand how electricity works rather than skills to be used in everyday life. This becomes clearer when one reads the specific episode reported by Mayoh and Knutton (1997: 859) on the electricity unit:

> This was rarely observed but one episode which could be interpreted as deliberate skills training involved wiring an electrical plug. However, for safety reasons, pupils were not allowed to test their wired plug in a socket . . . Pupils also carried out a range of classroom-based skills such as plotting graphs and recording numerical data in tables as well as open-ended problem-solving investigations. However, the extent to which these skills might be transferable to other problems and issues in their lives is not clear.

There are at least two different episodes in this quotation. One is an attempt to do practical things (e.g. wiring an electrical plug). As the authors state, problems of safety did not allow students to fully develop the task. But, perhaps science teachers do not have the kind of practical knowledge needed to help students with these tasks. Or possibly science teachers are not interested in this kind of knowledge.

Certainly, one can see that in order to wire an electrical plug, teachers need to draw from practical knowledge that is rarely integrated into their own formal education. Given the low status of practical knowledge, its integration into the science curriculum has been a persistent problem (Layton 1973). This has been explained in terms of the high social status of disciplinary knowledge as opposed to the low status of practical knowledge (Goodson 1994). My explanation also includes the need for clarifying what it takes to connect school science with students' everyday lives.

The problems of connecting school science and everyday life

It is important to note that the problem I am approaching is not the difficulty of developing students' scientific understanding. Rather, it is the potential connection between scientific understanding and students' everyday lives. I suggest that part of this problem is the general assumption that it is possible to use science in everyday life without changing its meaning or without integrating other kinds of knowledge (e.g. practical knowledge). Here research on how people may use science in everyday life becomes an important reference.

Kempton (1987) studied residential heat control using data from 12 residents of Michigan. The study examined how people explain their home heating control, particularly the in-home thermostat control. In the United States, according to Kempton, heating accounts for approximately half of residential energy. Kempton's concern was the possibility of saving energy. It was estimated that efficient management of thermostats might save billions of dollars.

The thesis of the study is that people have some guiding theories for adjusting their thermostats. In fact, Kempton identified two different kinds of explanations. The first was called the 'feedback theory' in which the thermostat measures the temperature, contrasts it with a set of desirable outcomes and turns itself on or off to maintain the desirable temperature. The second was the 'valve theory' in which heat flows throughout the thermostat (valve) and it produces a higher or lower temperature.

From the perspective of heat transfer, experts view the 'feedback' theory as a simplified version of the 'correct' theory. It is assumed that if the public knew the 'feedback' theory they would save energy. On the other hand, people who hold the 'valve' theory believe that they control the temperature by adjusting the setting of the thermostat which, according to them, controls the flow of heat. From this perspective, thermostat devices are analogous to the accelerator (gas) pedal of an automobile. This theory does not correspond to the expert explanation. However, Kempton's study shows that in some respects the 'valve' theory is valid enough to compete with the 'feedback' theory because the predictive validity of the feedback theory depends on other factors, e.g. the existence of marginal rooms, asymmetries, etc. When these factors are included, the 'feedback' theory becomes so complicated that the 'valve' theory (the incorrect theory) may be simpler to provide some approximations (Kempton 1987: 233).

The lesson one can learn from this study is that an incorrect theory may even be used in explaining the role of the thermostat in everyday life. Of course, one should not interpret that all theories are equally valid. What is important is that in everyday life even 'incorrect' theories may have a role (they are useful rather than valid). The problem is much more complex when one takes into consideration other factors, e.g. personal views of heat and temperature that may determine how people reconstruct scientific knowledge in specific contexts (Layton *et al.* 1993). However, school science does not usually consider these contextual situations. For example, the topic of heat and temperature in science education tends to be based on atomic and molecular models.

Few science education researchers have studied the relevance of atomic and molecular models of heat in relation to students' everyday lives. For example, Marcia Linn and her colleagues at the University of California, Berkeley, have developed a curriculum on the topic of thermodynamics that explicitly attempts to connect school science with students' everyday lives. Since earlier works, Linn and her team have criticized the uses of atomic and molecular models of thermodynamics in K-12 education (Linn and Songer 1991). They have argued that these models lack relevance in students' everyday lives (Linn and Muilenburg 1995: 19). In contrast, they suggest models that can be used in more relevant ways. Particularly they found '... alternatives to the abstract, elegant models in the relatively concrete, pragmatic models used by experts in heat transfer' (Linn and Muilenburg 1995: 21).

From the perspective of Linn and her colleagues, the problem of connecting school science with students' everyday life experiences is an epistemological problem. What she suggests is to reduce the abstractness of school knowledge by introducing more concrete and pragmatic models. Certainly, when one examines the knowledge upon which the curriculum suggested by Linn and her colleagues is based, one finds that they have drawn from epistemological territories different from, yet perhaps complementary to, science. In the case of Linn's curriculum, these models come from technology. Linn and her colleagues have used engineering models of heat transfer (see examples in Kreith 1973). Therefore, one would defend the idea that technological knowledge can increase the connection between school science and students' out-of-school experiences (Jenkins 1992).

School science in everyday life: technology

After a long history of separation from the science curriculum, technology emerges as part of the leading contemporary America science education reforms (AAAS 1990, National Research Council 1996). The introduction of technology into the K-12 curriculum can be seen as a process of intensification of the uses of science in everyday life. It is possible that this kind of knowledge can reduce the distance between expert scientific knowledge and school knowledge. A wave of research has called our attention to the importance of technology in science education (e.g. Raizen *et al.* 1995, Roth 1996). In addition, recent works from the philosophy of engineering have shown how engineering communities have a particular world-view that transforms scientific knowledge into specific applications (Goldman 1984, Layton 1993, Bucciarelli 1994). This research also suggests that there is the emergence of specific knowledge to deal with specific artifacts, technological knowledge (Vicenti 1990). One example would be helpful.

In designing a typical solar collector (a box containing a fluid), engineers do not use atomic models. They do not even use classic thermodynamics because '. . . it simply prescribes how much heat to supply to, or reject from, a system during a process between specified end states without taking care of whether or how this could be accomplished' (Kreith 1973: 2). What engineers use, or construct, is a specific kind of knowledge developed by the demands of the specific design and the constraints of reality (e.g. kind of materials, costs, engineering standards). In the specific case of a solar collector, '. . . the determination of the rate of heat transfer at a specified temperature difference is the key problem' (Kreith 1973: 2).

This example suggests that engineers use science for their specific needs. Their 'use' of science is not the simple application of universal knowledge to particular problems. Rather, they construct knowledge for specific situations illuminated by practical and mundane information. Although science may play an important role in their designs, they integrate several kinds of knowledge in a very utilitarian way. A similar approach is needed in facing everyday life problems.

The suggestion that technology may be a key in connecting school science with everyday life is very important to any consequences of this paper. However, we still need to learn many things about the role of technology, as curricular content, in general education. For example: is there something that engineers know (which science teachers do not) that can be used to help students use science in their daily lives? Can technology increase public understanding of science? If so, how may technology actually be influencing this understanding?

Public understanding of science – public understanding of technology

For many science educators, the goal of using science in everyday life has motivational value. In light of this approach, using everyday experiences helps teachers to build upon students' prior knowledge. In contrast, some educators see the uses of science in everyday life from a different position. For example, the science, technology and society movement, usually called STS, advocates for the use of science to deal with social problems, e.g. global warming, nuclear waste, local problems of contamination, etc. (Solomon and Aikenhead 1994, Yager 1996). However, at least in the US this movement has not had real impact in general education. Part of the problem, I argue, is that the STS movement has not clarified what students ultimately learn from their social projects.

Technology, as curricular content, can play a connecting role between academic knowledge and students' everyday lives, given the nature of the pragmatic models on which technology is usually based. The introduction of this knowledge in general education has important implications for the ideal of public understanding of science.

It is important to clarify that what is being argued here is not the advocation of the introduction of the generic ideology of engineering into science education. This is a different problem (see Layton 1971 for a review of this ideology). Although some aspects of technology seem to be useful for connecting science to everyday life, this does not mean that the science that society needs should be 'engineering science'. What I mean is that technological knowledge is an important element that can help us to connect school science with students' everyday life. For example, key ideas from technology are important to understand contemporary society. Think of basic ideas related to the emergent epistemology of engineering, e.g. design, failures, constraints, trade-offs, unintended consequences and negotiations (Petrosky 1982, Vicenti 1990, AAAS 1993, Bucciarelli 1994). By designing their own artifacts, students can learn that technology is governed by trade-offs and constraints that do not allow the production of perfect outcomes (artifacts, designs). These key ideas are part of an emergent notion of technology that is just making its way through general education (AAAS 1993).

The introduction of technology into the curriculum is in many ways the introduction of a specific world-view quite different from the traditional science education view. In fact, technology challenges the basic assumptions of the ideal of public understanding of science. The first assumption to be challenged is the notion of understanding. Technology can be seen as a complex interaction between understanding and doing. However, the kind of understanding in the context of technology differs from the analytical understanding endorsed by science. In science, the deeper the theory the better the understanding (this explains why atomic and molecular models are preferred over macroscopic and phenomenological models). In technology, like in everyday life, understanding is a means rather than an end. This utilitarian position contrasts with the ideal of public understanding of science. In fact, the goal of using science in everyday life moves the ideal of public understanding of science to the option of public understanding of technology.

The public understanding of technology will require the inclusion in general education of pragmatic models that can be used in everyday life as well as the clarification of key aspects of the technological thinking needed to be able to function in contemporary society. This will also require some kind of scientific knowledge. However, one can infer from work on the epistemology of engineering (Goldman 1984, Petrosky 1982) and sociology of technology (Bucciarelli 1994) that this will not be a simplistic addition of scientific plus technological knowledge. Rather, one can expect an intrinsic creation of knowledge for local purposes.

Introducing technology into the science curriculum is not a new idea (Lewis 1991). Technology and engineering are old activities. However, research on sociology and the epistemology of technology, particularly on engineering knowledge, is new (Goldman 1984). In fact, technologists have spent most of their time doing rather than clarifying what they know. The goal of connecting school science to everyday life is forcing us to explore the potential technology has in general education. We know, that technology is not the simple application of universal knowledge to specific problems (Layton 1993). We also know about technology's low-status history, relative to science (Lewis 1991). Now we should ask, what are the aspects of technology that can provide elements to integrate relevant science into everyday life? How does the introduction of technology change the ideal of public understanding of science?

Notes

1. There have been some works about the relevance of science education, e.g. the reports of Lewis (1972) and also Newton (1988). The problem with these studies is that they tend to be general recommendations (opinions), rather than research based on actual observations of everyday life activities. Nagel (1996) is an exception, but her work is still general.
2. The connection between school science and real-world problems is not an impossible task. See examples of successful cases in the Blueprints for Reforms of Project 2061 (AAAS 1998: 127–134). The demands of these projects on science teacher knowledge are enormous because they require interdisciplinary approaches.

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