Is it possible or desirable to change the relationship between science and design and technology in secondary schools?

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Abstract

This paper will consider the findings of 'Interaction', a report commissioned by the Engineering Council and the Engineering Employers' Federation, to explore the relationship between science and design and technology in secondary schools.

The paper begins by summarising the epistemological and other key differences between science and technology, based on a literature review. It will continue with a description of the methods used to investigate the views of the science and design and technology education communities. The paper will then report these views and use them to present a rationale for a closer relationship between the two subjects. Then the paper will describe models whereby a closer relationship may be achieved, taking into account the barriers to progress identified in the report.

Following a list of the recommendations made in the 'Interaction' report, the paper will end with the progress made so far in implementing these recommendations and discuss how this implementation can be seen in terms of robust professional development and the creation of new professional knowledge.

Keywords: science, technology, design and technology, secondary school curriculum

Introduction

'Interaction' is a report commissioned by the Engineering Council and the Engineering Employers' Federation, to explore the relationship between science and design and technology in secondary schools. (Barlex and Pitt, 2000) Pupils often experience science and design and technology as isolated areas, to the detriment of their learning. Yet outside school there is a dynamic, robust and useful interaction between the two disciplines. The aim of the report was to analyse how pupils' learning might be enhanced through a more creative relationship.

The contents and findings of the report

The 'Interaction' report begins by exploring the distinctive natures of science and technology and clearly identifies their unique and distinguishing features. Science provides explanatory knowledge. It deals with hypotheses and empirical laws, concepts, models and theories. It aims to explain and predict, often running counter to common sense (Wolpert, 1993), and occasionally developing new and ground breaking theory that changes the way that people think: Kuhn (1996) speaks of a 'paradigm shift'. Science deals with an ideal and abstracted world (Layton, 1991). Many authors – such as Kline (1985); Staudenmaier (1985); Black and Harrison (1992); Layton (1993); Benne and Birnbaum (1978); Gardner (1994) – have argued that technological knowledge is categorically different from scientific knowledge. Technology, inseparable from design, is concerned with changing the world in response to human demand, rather than explaining it. Technology deals with the particular, the concrete, the contextualised. Technology differs from science in its aims, methods, activities and results. An understanding of these differences must underpin discussion of the two subjects within the school curriculum.

The 'Interaction' report then discusses the nature and purpose of science and design and technology education, as seen in the National Curriculum

Name .... Organisation ....

1 What do you see as the aims of science education in schools?
2 What do you see as the aims of technology education in schools?
3 How might others see the aims of science education in schools?
4 How might others see the aims of technology education in schools?
(Through these questions we want to explore whether there is a national consensus, if so, what is the dominant view? If not, what are the main views?)
5 Paul Gardner has four models of the science-technology relationship which he describes as:
■ TAS or Technology as applied science (in which scientists develop knowledge, and designers/ technologists apply this knowledge)
■ Demarcationist (in which science and technology are seen as independent disciplines or domains)
■ Materialist (technology is seen as historically and ontologically prior to science. Technology precedes science: indeed scientists need the tools, instruments and other artefacts developed by technologists if scientific conceptual development is to take place)
■ Interactionist (Science and technology are seen in a dialectical relationship, with each informing and being challenged by the other)
Which do you think most accurately describes the status quo in :
■ industry ■ academia ■ schools.
Or do you have an alternative model(s), which you consider to be more useful? If so, what?
6 Can you suggest any stories/vignettes which exemplify an interesting relationship between science and technology OUTSIDE schools (following any of the above models)?
7 Which model would you like to see as the basis a developing science – technology relationship in schools? Why?
8 What do you see as the main obstacles to a closer relationship between science and technology education in schools?
9 Can you suggest any examples of good practice in schools where learning in science and design and technology have been linked? What curricular initiatives (linking science and design and technology) do you know about?
10 What likely changes do you see to the science and design and technology curricula in the short/medium term?
11 What likely changes do you see to the curriculum as a whole in the short/medium term?
12 Any other points you wish to make?
13 I am happy to be contacted for further information. Yes/No

Figure 1: Links between science and technology education.

of England, and how this is perceived by leading figures in science and design and technology education. These perceptions using questionnaires and follow-up interviews conducted face to face or elicited by telephone conversations and e-mail. The questionnaire is shown in Figure 1.

In response to the question ‘What do you see as the aims of science education in schools?’ science educators all subscribed to the view that the aim was to provide ‘scientific literacy’ for all and also to prepare some for further study. Only some saw science education as developing transferable problem solving and thinking skills. The views of the experts in design and technology education were more diverse, ranging from a broad acceptance of the National Curriculum definition of science to an emphasis on acquiring specific science knowledge, skill and understanding. In response to the question ‘What do you see as the aims of technology education in schools?’ the science educators expressed a variety of views. Each subscribed to some part of the National Curriculum view. One lamented the demise of craft; another was unsure how studying design and technology related to preparation for further study; another saw understanding how artefacts work as important; another saw establishing a knowledge base for technological applications as important. The views of the design and technology educators were more coherent, subscribing broadly to the National Curriculum view. In response to the question ‘How might others see the aims of science education in schools?’ the science educators saw that there would be a diversity of view, depending on whom you asked, but that many would adopt an instrumentalist view – to produce future scientists. This was echoed by the design and technology educators. In response to the question 'How might others see the aims of technology education in schools?' the science educators were uncertain and views differed widely. An interesting confusion was noted between design and technology and ICT, which was echoed by many of the design and technology education experts, who doubted that many people saw design and technology as an essential part of general education.

Our interviews revealed that design and technology was much misunderstood by the science educators, among whom the substantial gains made in developing a coherent rationale for design and technology and establishing an orthodoxy of practice over the past 10 years has gone largely unnoticed.

Two important points emerge from this snapshot of views about the aims of science and design and technology. Each group holds coherent views about its own subject, but a variety of views about the other subject. Few of these coincide with the view from inside that other group. This indicates that if a useful relationship between science and design and technology in secondary schools is to exist, a first necessary step will be to find ways by which the two communities can begin to understand one another.

The relationship between science and technology in the school curriculum

We next considered experts' perceptions on the relationship that currently exists between science and design and technology in the curriculum, and how this compares with the relationship between science and technology in industry and academia.

Paul Gardner distinguishes between four possible models – *technology as applied science*, (science precedes technology), *demarcationist* (science and technology are distinct domains), *materialist* (technology precedes science), or *interactionist* (science and technology inform and enhance each other) (Gardner, 1994). Using these categories, we asked the experts which they thought most accurately describes the status quo of the science-technology relationship in industry, academia and schools. The science educators described the science-technology relationship in *industry* as highly variable, depending on the industry, with *technology as applied science* figuring largely. Design and technology educators echoed this view. There was, however, little doubt that a dynamic relationship existed, with the *demarcationist* view receiving little credence. Both sets of experts described the science-technology relationship in *academia* as highly variable, with the *interactionist view* figuring largely. Again, both groups gave the *demarcationist* view little credence. But both groups were unanimous in describing the science-technology relationship in *schools* as almost exclusively *demarcationist*. This is in stark contrast to their view of the relationship in industry and academia.

They were also asked which model they would like to see as the basis for developing the science-design and technology relationship in schools. Here the response from both groups was mixed, with most commenting that the exact nature of the relationship would depend on the topics being studied by pupils. But it was quite clear that all condemned a *demarcationist* view and over 80% were strongly in favour of moving towards the *interactionist*. Interviews confirmed that both groups accepted the need for a more appropriate relationship, but all indicated there would need to be clear benefits to teachers in schools if they were to work towards this.

Through the survey we identified restraints that hamper a creative relationship between science and design and technology in schools.

- Science and design and technology teachers have an interest in developing pupils' ability to reflect on their own practice, but as yet do not co-operate in developing pupils' metacognitive skills.
- Mental modelling is an essential component of both science and design and technology, but teachers do not share approaches or expertise.
- Curriculum materials designed to encourage pupils to use science in design and technology lessons appear to have had little impact on classroom practice.
- Curriculum materials designed to enable science teachers to use technological contexts to motivate students and improve learning appear to have had only limited uptake.
- Science and design and technology departments have separate cultures; ignorance of the other's culture is reinforced in teacher training, through examinations and in the structure of the National Curriculum.

The 'Interaction' report identified three possible relationships between science and design and technology in secondary schools:

- Co-ordination
  Teachers in each subject become familiar with the work carried out in the other and plan their curricula so that the timing of topics within each subject is sensitive to each other's needs.
- Collaboration
  Teachers in each subject plan their curricula so that some, but not all, activities within each subject are designed to establish an effective relationship.
- Integration
  This involves forming a single subject called science and technology. The 'Interaction' report concluded that this was an *inappropriate* form of the relationship on two grounds. First, science and design and technology are so significantly different from one another that to subsume them under a 'science and technology' label is illogical. Second, this illogicality leads to misunderstanding and confusion which is highly dangerous in the education of pupils.

The 'Interaction' report clearly states that in developing an appropriate relationship between science and design and technology, schools should limit themselves to co-ordination and collaboration.

Recommendations of the report

The 'Interaction' report made three central recommendations.

Recommendation 1 Concerning the development of good practice

Partnerships should be identified that will release funding to enable teachers in secondary schools to work together to form appropriate relationships between science and design and technology. Initially this will involve developing and providing effective in-service training for some teachers from science and design and technology departments who are receptive to the idea of working together and developing a more productive relationship between the subjects.

Recommendation 2 Concerning the evaluation of good practice

Partnerships should be identified that will release funding to enable the work of the teachers developing a more productive relationship between science and design and technology to be monitored to identify how it can be carried out with maximum benefit to pupils' learning in both subjects.

Recommendation 3 Concerning the dissemination of good practice

Partnerships should be identified that will release funding to enable the models of good practice that have been developed and validated to be widely disseminated to both science and design and technology teachers.

Enacting the recommendations

The Engineering Council is applying for funding from a variety of sources to take the recommendations forward. It has developed a model in which three schools and a department of education from an institution of higher education with a good, established, reputation in either science or design and technology education form a development unit. The role of each school is to provide a head of science and a head of design and technology who are committed to exploring ways of developing a more effective relationship between the two subjects at either or both Key Stage 3 and Key Stage 4. The role of the institution of higher education is to provide a person who can facilitate the developing dialogue within each school and between the schools in the unit. The aim is to have four development units chosen from those who are known to be experts in either science or design and technology education. The three schools for each unit will be chosen so that across the 12 participating schools there are a range of schools, including technology colleges, schools in Education Action Zones, comprehensive schools, selective schools, grant maintained schools, LEA schools. A further role for the higher education institution is to provide a researcher who can work with the teachers to gather data that can be used for evaluation purposes. This development and evaluation of good practice will provide a body of data that can form the basis for a model of evidenced good practice. Much of this will be disseminated through informal networks but dissemination will also include print and web format materials disseminated through the activities of the relevant professional associations, DATA and the Association for Science Education, as well as through the Engineering Council publications. Dissemination to the higher education community will occur through publication of findings in refereed academic journals.

Discussion

In this section we consider the professional development embedded in the enacting of the recommendations and how this can contribute to the creation of new professional knowledge.

For professional development to be effective, i.e. lead to positive change in the classroom, it must involve four crucial elements. First, professional development must provide a challenge to teachers' frames of reference (Carney, 1998). Ball (1996) argues that teachers must use an inquiry and problem solving paradigm that results in their producing new knowledge, rather that a training paradigm that results in their consuming knowledge. The frames of reference within which most teachers operate construe science and design and technology as widely separated: working towards a closer relationship will challenge prevailing frames of reference.

Second, Carney (1998) suggests that new knowledge will not be learned and applied unless it is situated in relevant contexts. Vukelich and Wrenn (1999) believe that professional development should be based on the participants' interests and needs. Cameron (1996) suggests that professional development must be relevant to actual classroom work and to what students need to know and be able to do. Teachers working towards a closer relationship between science and design and technology will be focusing on the four areas identified in the 'Interaction' report as beneficial to students i.e. reflective practice, mental modelling, using science to inform design decisions and using technology to enhance science understanding in order to produce related classroom activities.

Third, research has shown that collaborative support from other teachers greatly increases the likelihood that changes in practice will be sustained (Fullan and Stiegelbauer, 1990). Teachers need colleagues with whom to focus on problems of teaching and learning, to work out how to deal with new subject matter, and to engage in innovative work aimed at curriculum reform (Olson, 1997; Shanker, 1996). The model for exploring ways to move to a closer relationship between science and design and technology requires teachers from the two disciplines to work together collaboratively.

Fourth, professional development must provide opportunities for teachers to form 'communities of practice' (Lave and Wenger, 1991) that encourage them to reflect on the content and contexts of their pedagogy. Schön (1987) demonstrates the importance of *reflection-in-action and reflection-on-action* for the development of professional practice. Louden (1991) argues that reflection is a basic source of learning and change. The model for developing a closer relationship between science and design and technology is predicated on the formation of communities of practice – the teachers in the schools working with each other and together with staff from a department of education at an institution of higher education.

We believe that the model proposed for taking the recommendations forward clearly meets the criteria for robust professional development, likely to result in changed and improved practice. David Hargreaves, the Chief Executive of the Qualifications and Curriculum Authority in England has argued that knowledge creation and dissemination in education must now involve teacher centred knowledge creation through partnerships (Hargreaves, 1998). He argues that teachers involved in such knowledge creation will engage in four activities:

- investigating the state of their intellectual capital
- managing the process of creating new professional knowledge
- validating the professional knowledge created
- disseminating created professional knowledge.

Each of these activities features in the model proposed for taking the recommendations forward. Science and design and technology teachers will undoubtedly discuss their perceptions of their own and each other's subjects with one another. This can be seen as investigating their intellectual capital. The teachers will be intimately involved in developing classroom activities that develop a new and appropriate relationship between the subjects: this can be seen as managing the process of creating new professional knowledge. Through their own reflections and that of staff from the higher education institution on what happens in those classroom activities the teachers will be validating the professional knowledge created. Embedded in the model proposed for taking the recommendations forward are a range of formal and informal dissemination strategies.

Conclusion

The 'Interaction' report has identified areas of the curriculum which science and design and technology can use to develop a closer relationship, described ways in which that relationship can manifest itself and made recommendations for the development, evaluation and dissemination of good practice in improving this relationship. At the present time it appears that the enactment of these recommendations will meet the criteria for robust professional development likely to result in changed and improved practice and the involvement of teachers in the creation of new professional knowledge through partnerships.

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