No wonder kids are confused: the relevance of science education to science

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Abstract

My experiences in science have left me wondering if we know what we want to achieve when educating students in science. An important question for science educators is: how authentic is the science presented in science classrooms? To answer this, science educators need a clear idea of what is they believe to be the purpose of science and then how they can portray that in their classrooms. This paper represents my journey in thinking about and researching of these ideas. It is my belief that, if we are to engage students in science, then science education has to be far more authentic than it has been in the past. In this sense, the title is apt – it is no wonder students are confused as I believe that, as educators, we have not been successful in creating the bridge between science and science education.

Introduction

My experiences in science have left me wondering if we know what we want to achieve when educating students in science. An important question for science educators is how authentic is the science presented in science classrooms. To answer this, science educators need a clear idea of what it is they believe to be the purpose of science and then how they can portray that in their classrooms. This paper represents my journey in thinking about and researching these ideas. It is my belief that, if we are to engage students in science, then science education has to be far more authentic than it has been in the past. In this sense, the title is apt – it is no wonder students are confused as I believe that, as educators, we have not been successful in creating the bridge between science and science education. In this paper, I will make a number of assertions that are a consequence of my journey in science and science education. However, to begin I will start with a story about the experiences of some teacher colleagues of mine – Rebecca and Vojtech.

Year 9 Big Picture Science Unit

Rebecca and Vojtech have developed a unit of science called 'Big Picture Science'. The idea for this was taken from a collaborative workshop run by science educators at Monash University and their partner schools in an ASISTM (Australian School Innovation in Science, Mathematics and Technology) project.[1] The focus of this unit was the ethical issues in Science, Medicine and Technology and who makes the decisions.

An initial prompt was provided for students through the viewing of a television program – *Grey's Anatomy*[2], in which an ethical decision was posed about which one of two accident victims should be saved. Students were then asked to form groups to research answers to a series of questions based on assigned roles of a doctor, a pharmaceutical research scientist, the government, a relative, and a member of a 'Right to Life' group. Examples of questions that were posed included: Russell Tytler, Professor of Science Education, Deakin University, Melbourne has been involved over many years with Victorian curriculum development and professional development projects. He was principal researcher for the highly successful

[1] Australian School Innovation in Science, Mathematics and Technology Project is a DEST funded project. Details can be found at http://www.asistm.edu.au/

[2] *Grey's Anatomy* (Episode 6 in Season 2) 'Into You Like a Train' in which several seriously injured patients, including Bonnie and Tom, a pair of passengers who have been impaled on a pole, are brought to hospital following a train crash.

School Innovation in Science initiative, which developed a framework for describing effective science teaching and learning, and a strategy for supporting school and teacher change. His research interests also include student learning, student reasoning and investigating in science, and public understanding of science.

Who has the final say on a medical procedure?; What laws might govern the type of research a scientist can do?; and Can scientists research whatever they wish? All roles also had a requirement to find real-life examples or recent examples from the media.

Rebecca and Vojtech had clear purposes for this project. They wanted to explore how their own knowledge and teaching practice might develop, and what promoted such development over the course of the project. They also wanted to see if and how students' learning might be challenged, reshaped and/or enhanced through such an approach. Decision making was an important focus of the project at two different levels; first at the level of deciding on the work itself (the topic); and second, the work the students will do (and their decision about how to do the task).

Student responses were gathered as the project progressed and it became obvious that the students felt quite strongly that the topic had some meaning for them and was relevant to them. They also saw that the content they were covering was clearly science, but the decision making that occurred in science, they believed, went far beyond the boundaries of science.

After 4 weeks on the project (one hour a week while 'normal' science classes continued for the other two lessons a week), Rebecca and Vojtech raised a number of questions about their experience from doing this project.

> *Where does science fit into society? How much 'say' does science have in issues that arise in society? How much credence is given to science when it comes to various aspects of society? How much of an influence does science have on the daily lives of people in our society? How relevant is science to the students' daily lives? Have we given students the tools to make responsible decisions in the future? Have students made a link between the decision making and the presence of science? We've amalgamated science with ethics, legalities and politics, but is there science in all of these areas? Have we emphasised that there is a link between decision making and science? Should we have made it more explicit? How do we get them [the students] to establish links between science and what they're actually doing?*

Not only have Rebecca and Vojtech been concerned about their teaching and the learning going on their classrooms, they have also raised some issues related with their curriculum planning:

> *Can you run a science curriculum at Year 9 that is solely based on our Big Picture Science? Why wouldn't we make this part of the science curriculum? We are thinking more and more that this is something that should be just like any other topic. During this unit there has been no emphasis on content. The content has been left up to the students to explore. If your curriculum was like this for an entire year, would the link between science and society be more observable for the students?*

This experience has led Rebecca and Vojtech to rethink their own notions of science and science education:

> *We feel that it is science simply because decisions are made in science and a large aspect to this assignment was decision making. We view science as having two aspects: content and application. In terms of what is science and what we teach in science, we as teachers make a decision about what is science content and what is application. You could therefore teach a unit that is all content without necessarily considering the applications of the science within society. Do the students view science as all content? How familiar are students with the fact that science has content and a role in society? It is obvious that for students to appreciate science's role in society they need to be familiar with some scientific content. Thus, we ask the question: Is teaching science's role in society teaching science?*

This story highlights a number of important issues that we face as science educators: what is science, and what is the difference between science and science education? As science educators, we need to re-examine our own notions of science as we need to think about how our ideas of science influence what happens in the science classroom. Rebecca and Vojtech have begun this process as indicated above. They felt they were taking a huge risk in proposing such a unit of work. They did not know if their students would like this unit or consider it science, let alone whether their parents would approve and parent/teacher interviews were looming. This unit was very different to anything they had done previously and they did not know what the outcomes would be. As indicated in their comments above, they did not know what science students would learn and if what they learned was legitimate science.

I chose this story from our ASISTM research project as I think it provides a good example of the journey that I have been travelling for a number of years, as a student of science, a teacher of science, as a parent, and as a researcher in science education. In writing this paper I realise I have not thought much about science in terms of my role as a member of the community, or at least not in the explicit way I would think of science in any off the other roles mentioned.

A journey of science experiences

From a constructivist viewpoint, my experiences have influenced my concept of science and why we should learn science. Science should help us make sense of what is around us. If this is what science is about, what does it mean for what we teach in science? My experiences (and I will not detail them all here, only highlight a few) have led me to frame a number of assertions. These include:

- The context matters and it needs to be meaningful;
- Purposeful learning and the applications and use of knowledge in different ways matters;
- Purposeful teaching matters;
- Doing science matters; and,
- Science is making sense of what's around you, using your knowledge, skills and abilities to create meaning.

I believe that we, as science teachers, can do so much more for our students as they learn science. Some of the research that I, and others, have done which highlights some findings that support this belief follows. Science educators need to provide a bridge between science and science education if students are to appreciate what science can offer in a number of roles such as a scientific worker, a consumer and as a responsible citizen. It is my belief that science educators have not understood this responsibility very well and are confused by what science is and how science education is linked to it. It is therefore not surprising that students are confused.

Meaningful contexts

Research from my PhD (Corrigan, 1999) indicated that when technology and industrial tasks were introduced into chemistry curricula (VCE Chemistry as a specific example) with the purpose of introducing contexts that were relevant and meaningful to students and part of their real world, their success was limited for a variety of reasons. Chemistry teachers' own experiences of technology arose from a largely science-dominated curriculum (Fensham, 1988). The shift in curriculum emphases (Roberts, 1982) in this instance meant they were now asked to teach from a technology-dominated curriculum. Consequently, teachers were being asked to teach using contexts that were largely unfamiliar to them. Their response to this situation was to focus on the task itself rather than providing an opportunity for students to experience the work of a chemist.

In addition, this research highlighted how problematic it can be to introduce contexts that are meaningful and indeed what makes contexts meaningful. For a context to have meaning implies that there is a sharing of understanding, between all involved, of the context. If the contexts used to create meaning are not familiar, such as the chemical industry for many chemistry teachers, then teachers in developing their own limited understanding of such contexts, often act as filters to help create meaning for their students. In some instances, teachers provided students with structural frames, such as through an issues-based or a community-based approach (Ziman, 1994), and provided mechanisms for developing contexts that were meaningful for students across settings such as school, home and industry. Ziman, proposed a multiplicity of approaches that can be adopted that may help to extend and complement the exploration of the domain of valid science. Such approaches include:

- the approach through relevance where attention is drawn to the relevance of science to everyday life and its social role;
- the vocational approach where attention is given to the professional and social roles science plays in a person's career path;
- the transdisciplinary approach where science is considered across discipline areas rather than as a discrete discipline on its own;
- the historical approach which recognises the historical activity associated with research;
- the philosophical approach which recognises that science should be presented as a more or less coherent body of knowledge, organised logically around theoretical principles and validated through observation and experimentation;
- the sociological approach which recognises science (and technology) as social institutions, internally organised to produce knowledge and know-how, externally linked to and embedded in society at large; and
- the problematic approach where attention is given to the problems of our time, e.g. overpopulation, and present science in an interrelated way to the rest of society.

Purposeful learning and the application and use of knowledge

Science educators need to have a clear purpose of what they hope their students will learn. In order to do this, they also need to have a clear personal idea of what they believe to be knowledge worth learning and the nature of science itself. There has been much research into this and I will not detail this here. Grandy and Duschl (2005) suggest that the nature of science has shifted to the present model-based explanations where science is seen as a cognitive, social and epistemic practice. That is, science is about the thought and skill processes involved in acquiring knowledge and skills of different types that are embedded in our society. The knowledge types here should not be limited to traditional academic or conceptual knowledge (knowing science) but should also include, for example, vocational-based knowledge (knowledge to be able to do) as Peter Fensham and myself have detailed previously (Corrigan & Fensham, 2002). Or knowledge should include knowledge represented in some curriculum with an STS emphasis which 'emphasize the basic facts, skills and concepts of traditional science, but do so by integrating the science content into social and technological contexts meaningful for students' (Aikenhead, 1994, p. 59).

Other research I have been doing (Corrigan & Gunstone, 2006) has explored the values within science and science education (and maths and mathematics education). In exploring values, we used Halstead's (1996) description of values:

> The principles, fundamentals, convictions, ideals, standards, or life stances which act as general guides or as points of reference in decision-making or the evaluation of beliefs or actions and which are closely connected to personal integrity and personal identity. (p. 5)

In this research we have been working from the premise that there are inherent values embedded in a person's ability to distinguish and discriminate between knowledge claims. The knowledge claims in science are clouded by the need to bridge the world of science and the world of school science. Rennie (2006) distinguishes between Science, shown with a capital S, that is familiar to scientists as it is the product (and process) of scientific research, as opposed to science that requires some interpretation of Science if a layperson or student is able to access it. This interpretation may include encoding, but requires deconstruction and reconstruction of the Science information into a science-related story. Rennie proposes the use of the word 'story' here as according to

Science as process (Scientific inquiry – note science as an adjective which turns it into something that's not exclusively science)
experimental method
being able to investigate
asking questions
using evidence to (attempt to) explain things around us
communication of results, ideas (within and outside team) and the language of science compared with communication of scientific ideas in popular culture
working in a team
the nature of the evidence, e.g. respect for data and work

Human qualities (Private vs public understanding)
passion
honesty
integrity
fairness
curiosity
sharing
ethical
openness to change (including change in behaviours)

Cognitive
Challenge current theories and practices (includes other knowledge claims, e.g. science and religion)
Not constant, changing, developing

Theories
Intellectual rigour (logic, creation, elegance); How do we know?
Science makes mistakes; there are no absolutes (e.g. controversial issues such as genetic cloning); can be interpreted in a variety of ways

Societal
Value of contributing to society
Science has and will impact on society (including its problematic nature)
Where does it exist in real life?
Science is wide ranging/universal/applies in numerous contexts
Science's ability to (assist in) solve(ing) problems

School Science
Learning tools, e.g. research skills
How students learn science, e.g. kinaesthetic
The skills we want including science literacy
* Groupings and labels for these generated by author.

Figure 1 Teachers responses to the question 'If you were working with other scientists, what would you value?'

Milne (1998) 'once ideas are presented selectively in science we are no longer telling the facts. We are instead telling a story' (p. 176). So science education must be telling a science story, but how close to the original Science are these stories?

The model of the nature of science as proposed by Grandy and Duschl (2005) appears to fit more closely with teachers' views gathered from a science professional development activity exploring their ideas of 'Big Ideas in Science' where they were asked: 'If you were working with other scientists, what would you value?' While the expectation was that teachers would come up with more obvious values such as logical thinking and experimental evidence, the list they produced was somewhat richer than anticipated, as indicated by the summary of their responses generated at the professional development sessions, and reproduced in Figure 1 (left).

The list in Figure 1 demonstrates that these teachers consider a wide range of values to be associated with the science they teach. Expected values such as the cognitive dimensions were present, but also present were values associated with science as a process that can also be used in ways that are not clearly identified as scientific. For example, being able to ask questions is seen as important in the scientific process, but is also central in many other pursuits. Science was clearly seen as a human endeavour, with human qualities featuring in the list, and a human endeavour that is embedded in society. The category of school science that emerged from the teacher responses was also an important one as it implies that school science by its very nature must be different from science and have different values associated with it.

The list in Figure 1 is an example that there is acceptance, among teachers at least, of values in science education, but it appears that there remains very broad and vague perceptions by teachers of what values are.

Doing science matters

My PhD research (Corrigan, 1999) found that secondary school chemistry teachers have well-developed notions of the nature of scientific knowledge, a realistic perspective of the role science plays in society, the authority of science in society and scientific research being purposeful. However, their notions on the way scientists work, the reward system that operates for scientists and the communal nature of scientific work remained relatively naïve. This has implications for the teaching of chemistry as the societal aspects of chemistry will be represented largely by the authority role science has in society in developing content knowledge that has purpose. It will not include the activity of scientists in creating an acceptable body of knowledge, or the procedure of obtaining recognition in science through research and the publication of research – the practice of chemistry was absent!

The practice of science is not bound by regimes such as in the Scientific Method, which I believe only exists in school science and not in Science. There is research around the work of scientists (Latour & Woolgar, 1976) and what can be recreated, modelled and considered in the science classroom. Osborne (2000) has talked about the role of argument in the science classroom, Hart et al. (2002) have talked about the role of practical work to name a few. The shift in more recent times to scientific investigations is responding to a need to engage students in more authentic approaches to the way scientist's work and communicate their ideas. Hence the role of discourse and argumentation become crucial in developing more authentic work practices within the science field. But these approaches do not capture the large field of vocational science, which is more competency-based and sometimes about mastery. Coles (2002), Gaskell (2002) and Corrigan (2002) have outlined how the practice of science in these contexts can take many forms. For example, a lithographer requires quite sophisticated chemistry knowledge, but this knowledge is only known in order to master techniques of etching.

Purposeful teaching

One of the most difficult things to do as a teacher is to have a clear purpose for why you are doing something and plan ways to provide evidence that you know this has been achieved. It is something I try to model in my own teaching and a constant plea that I make to pre-service teachers and experienced teachers alike. Over the last couple of years, I have been focusing more on two things – tracking the learning of my students and myself, particularly through learning logs (Korthagen, 2001) and re-examining both my own (and also as a teacher educator, my students') development of pedagogical content knowledge or PCK. Shulman (1986) conceived that PCK acknowledged the importance of the transformation of subject matter knowledge into subject matter knowledge for teaching. PCK is the knowledge of how to relate specific content in a way that all students can learn it. There is an increasing number of research studies in this area in science (for example, Loughran et al, 2006) and, while many of these studies explore traditional science content such as Forces, The Particle Model and Cells, I believe PCK has the potential to explore science knowledge of different types and in multiple contexts. For example, what, if any, is the PCK that a master lithographer uses to pass on his skills and knowledge to an apprentice. These are areas yet to be explored. However, the benefit of PCK is that the teacher must critically examine what, why and how they are teaching something and provide evidence of what learning has been achieved if they are to develop their PCK further.

Rebecca and Vojtech's Story – making sense of our world using science

Rebecca and Vojtech's story has raised a number of questions. For example, the question 'Is teaching science's role in society teaching science?' might be answered by explaining that I believe they have it the wrong way around. Since science is a creation of society, embedding it in a social construct should be science. However, I believe that the power in Rebecca and Vojtech's story is more about raising questions and taking a value position of one's own on a range of things that are important in teaching and learning science than actually answering these questions – context, purposeful learning and the application and use of knowledge, doing science, and purposeful teaching that can help lead to using science to help make sense of your world. Values are a fundamental part of science (and many other areas) and should be a fundamental part of science education. Unfortunately, they are often left out of science education. I think what Rebecca and Vojtech are doing is putting them back in and consequently, the science education in this instance is far more authentic science than what they or their students have experienced previously.

I think Rebecca and Vojtech's story begins to achieve what I have represented above as the current thinking about science and science education. They are re-examining the contexts they use, the learning and use of knowledge, getting their students doing science, re-examining their own teaching and their purposes in an effort to help students use science to make sense of their world. And we need to be explicit about this to students so that they can take an active role in making meaning of this science in their world (and not only the teachers' world). Science should explain the natural world and if you take the students' natural world, then the explanations that follow look vastly different from what is often represented in science education texts.

I think these are important things to think about if we are to really engage students in science. No wonder kids are confused about science – science educators are confused about science and its relation to science education.

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