Pedagogical content knowledge for teaching concepts of the nature of science

Paper presented at 9th Nordic Research Symposium on Science Education. June 2008
Reykjavik: Iceland

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Abstract

This conference contribution seeks to provoke discussion of the question: If pedagogical content knowledge (PCK) can be represented for key science concepts, can it be established for aspects of the nature of science?' I start from the premise that explicit, rather than implicit, teaching of aspects of the processes and practices of science is now expected in science curricula (variously labelled as 'how science works', 'ideas-about-science', 'nature of science'), presenting challenges in classroom practice. The evidence base for understanding effective teaching and learning of the nature of science is developing but still limited. Much early research took the perspective that if teachers have a good understanding of the nature of science sound practice will follow. More recently, research projects have suggested a complex relationship between teachers' understanding and their classroom practice. Little is known about how pupils develop and progress their understanding of the nature of science, adding to the difficulties in curriculum design and in understanding the PCK needed for effective practice. Nonetheless these are not reasons for not attempting to gain a better understanding of PCK for the nature of science. This contribution attempts to promote discussion of how barriers to understanding may be overcome. It will present examples of seeking PCK.

<u>Background, aims and framework</u>
The processes and practices of science (nature of science) have always had an implicit role in science curricula. Latterly, in science curricula across the world, teaching and learning about the nature of science (NoS) has become far more explicit (e.g. the 'how science works' element of the science curriculum in England). The need for explicit teaching has sharpened efforts to understand what knowledge and skills teachers need in order to engage youngsters in effective learning.
Arguments for teacher development have started from the perspective that a good knowledge of the nature of science is a pre-requisite and that many science teachers have an unrefined understanding (e.g. Lederman, 1992). Thus developmental work has focused on teachers' understanding (e.g. Schwartz, Lederman & Crawford, 2004; Akerson, Morrison & McDuffie, 2006). However, some research projects have shown that there may be links between engaging students effectively and specific teaching approaches rather than just teachers' understanding of the subject (e.g. Bartholomew, Osborne & Ratcliffe, 2004; Zohar & Schwartzer, 2005). Such research projects go someway to start to articulate the pedagogical content knowledge (PCK) for teaching the nature of science (even though PCK is not always used as the terminology).

<u>Concepts of the nature of science</u>
When considering the teaching of say, forces, many educators have a clear idea of the conceptual base under discussion. However the same is not true when discussing the

teaching of NoS. It has proved difficult for both philosophers of science and science education researchers to come to a consensus on the nature of science (e.g. Alters, 1997). However, a Delphi study has demonstrated agreement by science educators, scientists, teachers, philosophers and sociologists of science on some key elements of NoS which should be taught as part of the science curriculum (Osborne et al, 2003). Concepts such as the tentative nature of scientific knowledge; correlation and cause; validity and reliability of data; hypothesis and prediction; peer review now feature in the science curriculum in England and in many other countries.

This conference contribution seeks to provoke discussion of the question: 'If PCK can be represented for key science concepts, can it be established for aspects of the nature of science?'

There have been some studies that have examined teachers' practice in teaching aspects of the nature of science. For meta-level aspects of science processes - 'higher-order thinking'- Zohar and Schwartzer (2005) used questionnaires and observation of practice to explore teachers' pedagogical knowledge in the context of higher-order thinking. They showed some of the practices that teachers started to support as they became more focused on teaching higher-order thinking. Practices included supporting pupils in constructing arguments and counter-arguments and in identifying assumptions. From a framework of developing evidence-based practice, Bartholomew, Osborne & Ratcliffe (2004) have shown how five dimensions of practice (use of discourse, conception of role, understanding of NoS, conception of learning goals, nature of classroom activities) can be used to characterise teachers in their general teaching of 'ideas-about-science'. Other exploratory studies have shown emerging trends in teachers' understanding of specific aspects of NoS. For example, Bowen and Roth (2005) show that pre-service teachers do not demonstrate the authentic practices that scientists routinely undertake when interpreting data or graphs. Taylor and Dana (2003, p726) in exploring some physics teachers' conceptions of scientific evidence, demonstrate that these teachers were better able to 'identify flaws in the experimental designs or data collection strategies used by others than to design sound experiments or data collection strategies themselves.' Such studies provide further evidence that it may be difficult for teachers to articulate their own understanding of NoS and appropriate pedagogical practice. A further complication in understanding PCK for effective teaching of NoS is that some studies have suggested that teachers develop their understanding through teaching rather than them having clear views on NoS at the outset (Water-Adams, 2006; Ratcliffe, Hanley & Osborne, 2006). Thus one barrier to understanding PCK for specific concepts of NoS is finding appropriate ways to capture teachers' conceptions and practice.

There exists little empirical evidence for curriculum progression in relation to NoS. For example, what is the hierarchy in developing a sophisticated understanding of the tentative nature of scientific knowledge? We can postulate that understanding of, for example, limits of experimental data, scientific modelling, and nature of theories are steps along the way, but little research exists that shows the development of understanding of such concepts. In contrast, research evidence guiding curriculum design and pedagogy for scientific concepts, such as electricity, forces etc., has been established for some time (e.g. Driver et al, 1994). Some seminal work has been undertaken to explore views of pupils of different ages on NoS (Driver et al, 1996). This work has influenced curriculum design in England but links have not yet been clearly made with teachers' PCK. For some concepts, such as the nature of scientific evidence there have been more studies of students' conceptions than of teachers' (Taylor & Dana, 2003), reinforcing the perception that there is lot to be learnt about teachers' pedagogical content knowledge in relation to the nature of science.

Conclusions and Implications - Mapping PCK

There is an increasing body of research which seeks to demonstrate the pedagogic content knowledge needed to teach established science concepts, like particles, forces (e.g. Loughran et al, 2000). Even though there are debates on the definition and interpretation of PCK (e.g. van Driel et al, 1998), there is some consensus that teachers' practice in terms of detailed knowledge and skills can be established for key concepts in biology, chemistry and physics. Loughran et al's (2000) attempts to map teachers' content representation (CoRes) to pedagogical and professional experience repertoires (PaP-eRs) help 'unpack the teacher/s' pedagogical reasoning, that is the thinking and reasoning of a science teacher in teaching a specific aspect of the science content' (Berry, Loughran & Mulhall, 2007).

Loughran et al's framework of CoRes supports teachers'reflections on specific questions to obtain content representations for specific ideas: e.g. What do you intend the students to learn about the idea? Why is it important for students to know this? What else you know about this idea (that you do not intend students to know yet)? Difficulties / limitations connected with teaching this idea? Specific ways of ascertaining students' understanding or confusion around this idea?

I would suggest that, based on research evidence showing lack of refinement of teachers' understanding of NoS, some teachers would be limited in their responses to these questions. Nonetheless these are crucial questions to ask in promoting effective teaching of concepts of NoS. Should we start by promoting teachers' reflections on these questions for some specific aspects of NoS – i.e. see if we can develop CoRes for NoS ideas? Mapping of such reflections to the practice that teachers adopt may give a clearer idea of PCK for effective teaching of NoS.

Some examples of seeking PCK for NoS using Loughran's framework will be presented. In particular, it is expected that some CoRes of a an aspect of NoS for novice teachers will be the subject for discussion.

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