What is the role of content in primary school science?

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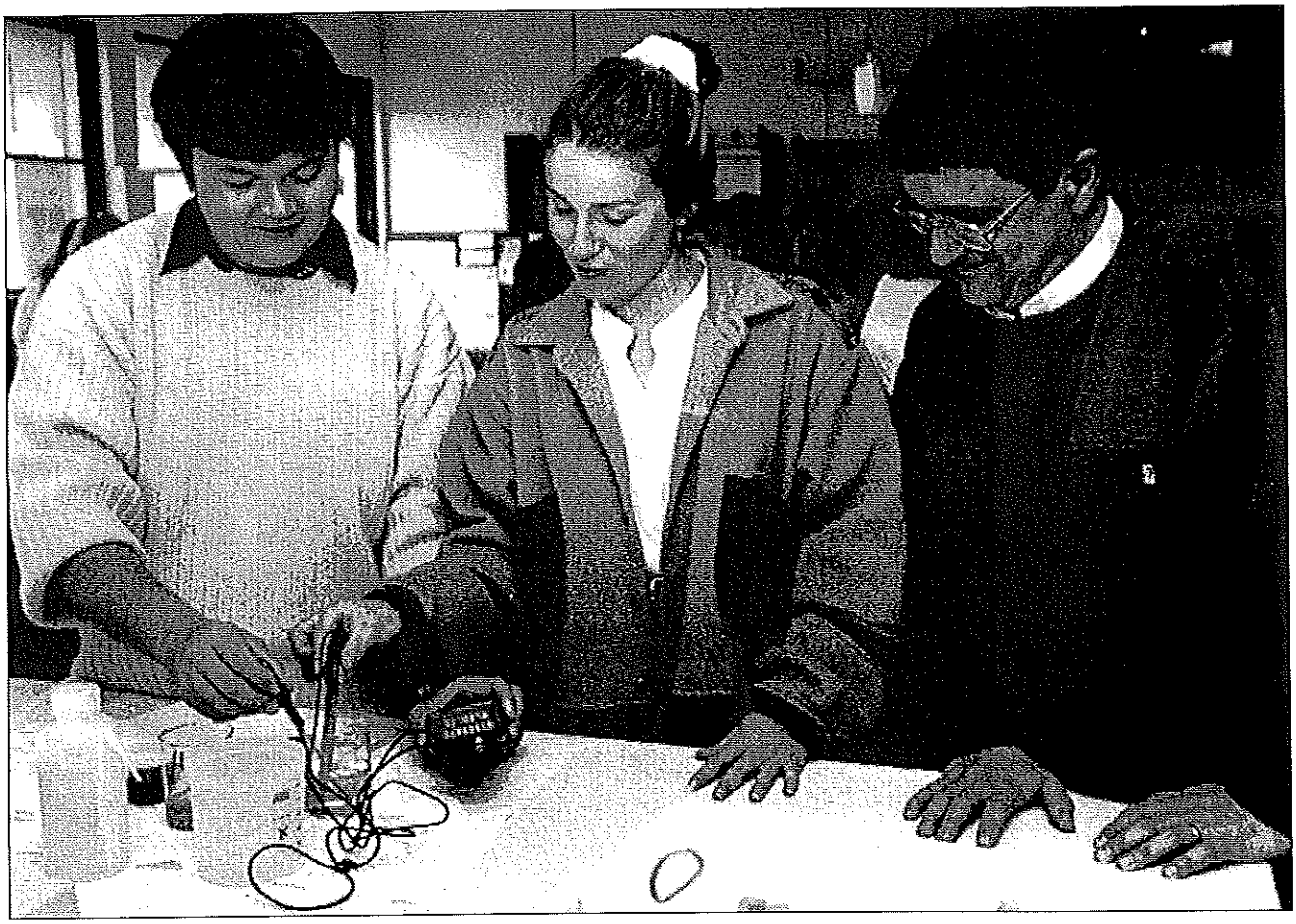

Renato Schibeci (right) with two participants in the five day course

Ironically, perhaps it was my lack of understanding of such phenomena as 'moon phases', 'the seasons' and 'floating and sinking' that proved to be most useful. Indeed there appeared to be very few [at the course] who understood these concepts and this provided me with confidence to pursue my understanding of them.

So wrote a primary teacher who attended a five day course designed to upgrade science content knowledge (Schibeci and Hickey, 1996). This type of sentiment was expressed by the majority at the course, who found that, while they had enrolled to learn more about science content, they also experienced a strong collegial sense of shared misunderstandings and concerns and confusions about a broad range of aspects of scientific topics and concepts. These teachers had accepted the challenge of 'upgrading' their own personal science knowledge in the interests of improving their teaching and developing opportunities to share this understanding and confidence with other primary school teachers at their own schools or district.

Interest in the area of science knowledge of teachers, rather than just of their students, has been given increasing attention overseas. What Smith and Neale (1989, p1) wrote of the situation in the U. S. A. could have been written about the Australian scene:

Science teaching in the primary grades has been a persistent problem ... Teachers in those grades are under pressure to focus on reading and mathematics ...; in addition they feel untrained and uncomfortable with science ... Science is not allocated much time in the school day ...

In Australia the development of the Australian Academy of Science's (1994) Primary Investigations science curriculum package has helped to fuel Australian teachers' awareness of this change of focus in primary science. Its publication was, in part, stimulated by this awareness of teachers' lack of confidence with science. It provided teachers with a clear basis for lessons, with appropriate scientific background information, and, especially in the upper levels, provided support for teachers who were unfamiliar with concepts relating to energy and change, ecology and environment and natural and processed materials.

The role of science content knowledge.

What is the role of *content* in the teaching of primary school science in this climate of change? The term content refers to the science concepts that are linked to terms such as buoyancy, energy chains, light and heat, strength, flexibility , interdependence, colour and weather.

Traditionally Australian primary teachers have 'taught science' as a hands on activity based lesson, and the process side, rather than the content side of things, was emphasised. It was felt that you didn't need to know science to be able to teach it well.

However, the relevance of content, as a way of improving student learning, through teachers' learning, is increasingly gaining acceptance. Large scale programs in the U. K. have been offered in response to the National Curriculum and the evidence that teachers did not have sufficient science background to teach science effectively. Programs have been offered by Oxford University (Kruger, Palacio and Summers, 1992) and by the Open University (Tresman and Fox, 1994). Carre and Ovens (1994), discussing the impact of this National Curriculum, made a strong case of the essential nature of adequate teacher science knowledge as partially determining the effectiveness of teaching , for example, when analysing a teacher's work in promoting student's understanding of night and day: *He was sufficiently competent in his content knowledge to ask appropriate questions and provide spontaneous, simple representations to explain a difficult idea (p. 7).*

So, how much science does a primary teacher need to know?

Kruger and Summers (1989) noted that primary teachers will not be required to teach about changes to materials in molecular terms. Nevertheless, an understanding of such changes may be necessary because they believe that "it is difficult to see how children can be correctly led along an experiential path leading to understanding of changes in materials and the associated role of energy unless the teacher guiding them has some deeper understanding of the processes involved" (p. 26).

What about in Australia? Symington and Mackay (1991) followed up the 1989 *Discipline Review of Teacher Education in Mathematics and Science* (Speedy et al., 1989) by surveying a sample of early childhood and primary teacher educators (19 in Victoria). The Report had recommended 'the equivalent of one unit of science discipline knowledge (including physical science) which is explicit and assessed.' The teacher educators who took part in the survey disagreed on this recommendation. A second study reported a study of 139 pre-science students' views about science teaching (Appleton, 1992). Several students 'felt a small amount of knowledge was sufficient for the teachers, provided they (approached) the teaching of it as co-learners with the children.' (p. 17). Are these valid views?

If teachers do not have the scientific models to contrast with student models, are they able to foster their students' conceptual change? How will they be able to ask the right questions, recognise when the views of a student are 'on the right track', and avoid the unpleasant scenario of saying a student is 'wrong' when it is really the teacher's own misunderstandings that are acting as a barrier.

This change does not mean primary teachers must suddenly be conversant with the equivalent of post compulsory understanding in physical, chemical, biological and earth sciences. What it does mean is that the role of content is no longer marginalised, but viewed positively at a teacher's personal level, as a way to promote better student learning and a more positive attitude to science and technology by our students, who often opt out of science in high school at the first opportunity. Knowing more supports a teacher to help students know more in an accurate and confident manner.

However, the key issue here is that science content alone is not a sufficient basis for good teaching. Effective teachers need both subject matter knowledge and pedagogical content knowledge. Transforming teachers' content knowledge into pedagogical content knowledge is a process of transforming subject matter knowledge into a form which makes it teachable to a particular group of children. Aspects of this pedagogical content knowledge include: knowledge of students' concepts, strategies for teaching content, and shaping and elaborating the content.

Describing teacher preparation for effective science teaching, Osborne and Freyburg (1985) argued that the preliminary phase of teaching using the model for generative learning should include:

- *ascertaining the typical ideas which children will bring to the topic, together with the prevalence of these views in the class concerned;*
- *understanding the ideas that scientists use to describe and explain these phenomena;*
- *open appreciation by the teacher of the ideas he or she tends to use to describe and explain the phenomena (p. 108).*

This shared emphasis on effective pedagogy, in the use of constructivist techniques to ascertain students' existing knowledge, is also connected with a requirement that teachers are in touch with their own and with general sciences, concepts and terms and explanations, of events. This stance can be used to argue for not just 'learning with the children' but for teachers to take a more active role in ascertaining their own knowledge, and determining if it is adequate to promote their students' learning.

A pilot project to upgrade science content knowledge.

A five day course was designed to provide a firmer basis for teachers in key areas of science knowledge, to increase their skills in translation of this into pedagogical content knowledge and to develop skills in working with others as a presenter in science education. This course was sponsored by the Education Department of WA and is described in detail in Schibeci and Hickey (1996). The objectives of the course were as follows. (1) Increase participants' level of confidence in teaching science by increasing the level of participants' science understandings and skills. (2) Develop participants' skills as presenters of science content and in effective teaching by involving them in mini presentations. (3) Through participants, to assist teachers in our schools to gain their own confidence in science content and, in turn, help their students to like science and to learn science effectively.

In the course, 18 participants from city and country schools in WA, met for a first session of three days, touching on all ideas from many science disciplines, with a break over the next school term to put ideas from the course into practice. A two day follow up session focussed on sharing experiences, with further sessions on science content and strategies for effective communication with colleagues interested in furthering their own science knowledge.

Topics, themes and concepts examined in the course related to all five strands and levels of science (Deleuil & Malcolm, 1994), and linked to the Primary Investigations (1994) curriculum. Sample concepts examined in the course are as follows.

Working Scientifically. Ideas on fairness in investigations, reliability and validity, public perceptions of the nature of science, and changes in scientific theories.

Natural and Processed Materials. Design in living and non living structures, molecular and atomic models with valencies and energy levels;

Energy and Change. Forms of energy such as heat, light and sound and transfers between them.

Life and Living. Gene technology and genetic structure, and photosynthesis and carbon cycles;

Earth and Beyond. Energy forms and how these models can be used to explain and predict situations such as the seasons and weather, animal adaptations to cope with temperature and pressure.

The course was based on constructivist principles, so it provided stimulus activities to engage participants and help them share in small groups what they knew about the phenomena; an information section where the course leaders clarified or extended the understandings of the group; an application phase where participants applied these ideas to new contexts. For example, for the weather theme, groups examined weather maps and tried to fit definitions of weather effects to the maps and then clarified their ideas about events like Coriolis effect, land and sea breezes, and wind patterns. These ideas were then linked back to concepts of heat exchange, movement of molecules, and pressure differences met with earlier in the course.

This approach proved successful, as it avoided the lecture style in which an expert transmits information. Rather, our approach valued what teachers already knew and supported them to extend this and not feel distressed about their perceived level of knowledge.

Participants also examined the potential for lack of knowledge to be a dangerous and misleading barrier to supporting student learning. They also discussed issues such as: is the time to learn the content with the students, or before them? Do the advantages of co-learning outweigh the potential for mutual misleading and non-learning and, if you don't know why things float, will you be left with the option of sharing intuitive rules such as 'light things float?'

Our experience with this course supports our view that: (1) extensive exposure of teachers to science content must be done in a way that links content to pedagogy, so the relevance and practical use of the content is paramount, in order to develop a positive view of participants to the material; and (2) that such changes cannot be achieved in the short term, but require intensive and continuing education and support. The course described in this paper is a first attempt to meet these needs in pedagogical content, and to define effective levels of knowledge.

Because of the length of the course, five days spread as two sessions over a school term, the teachers involved had an opportunity to develop.

Interest in understanding more of scientific ideas, concepts and reasoning.

Collegial links and the development of a mutually supportive environment.

And, a sense of shared misunderstandings without being made to feel incompetent or unable to comprehend the content.

What sorts of misunderstandings or areas of unawareness did teachers in the course display ? It was the course designers' view that such intuitive or alternative ideas were not 'wrong' but 'developing.' The approach taken was that we don't say to a baby it's 'wrong' to crawl, rather we accept it as a step in the right direction. So if a child (or teacher) says the sun sets in the east, our response would be to take out a compass and treat this as an opportunity to discuss direction and the rotation of the earth.

Teachers in the course displayed difficulty with many concepts and held many 'interpretations of the world' (Gunstone and Watts, 1985, p.87) that were related to their intuitive experiences about topics that frequently form part of a primary science curriculum - weather, the seasons, heat, floating and sinking, colours and energy. Explanations of the seasons relied almost exclusively on the earth's distance from the sun as the sole cause; most referred to energy being used up; few were comfortable with ideas of energy transfer such as in a light powered by a steam engine; knew that water was 'H20', but could not expand on this shorthand using models of atoms and molecules; had difficulty explaining what the familiar term 'photosynthesis' meant; why green plants were green at all; and were at a complete loss to explain why a brick would float on mercury.

Other areas in the course were new to the majority but were very popular due to the powerful insight they gave as to why things behave as they do. These areas often relied on molecular models to explain water capillary action in tall trees, and effects such as dissolving and melting, the structure of the chromosomes as a model to explain genetically inherited defects, and by the last day of the course, to atomic modelling to show how different materials are constructed as different numbers and arrangements of particles. As one participant said:

The 'scary' things like chemistry are not so scary - in fact when you do 'hands on' they're really quite simple.

The group displayed a huge range of levels of knowledge. Some had done some high school science and found the course put them in touch with vaguely remembered ideas often dispelling the negative connotations held for many years.

Initially I didn't want to hear any of the physics lessons as I didn't understand them, but they were presented in a simple format and paced at the right level so that I do feel a little better about them.

For others, this course was more of a first step towards a longer term process of unfolding new ideas and concepts.

- Attending the course has in many ways undermined my confidence. However, I can now, on completion, see that this could become a strength to take on the challenge of re-education in this field and derive satisfaction and new confidence by doing so.
- To explore some of the 'main' science concepts in a way that individuals could participate without feeling threatened or stupid.

An interest in working with others to share new attitudes and understandings and support other teachers to also develop an interest in furthering their own knowledge level was a frequent outcome of the course :

- I'm hoping my new found enthusiasm and knowledge of science content will assist teachers to develop their own levels of understanding of content.

For all participants, the course was very successful in stimulating a growth in science understandings and a desire to continue their own personal learning. For example:

- In all the lessons I discovered that I know so little, so I enjoyed all of them. I still don't understand many of the concepts or even 'Why', but I do feel a little more confident in teaching these strands.

Discussion

What did this course suggest as the appropriate level of science content for primary teachers? While there may be a minimum level of science content knowledge for teachers to have, finding a common starting point proved impossible, as the range of knowledge held by those in the group was characterised by the diversity within each individual. No assumptions could be made about the group's common level of content knowledge, as differences for each individual occurred across the range of concepts and topics included in the course. That is, one individual may have found concepts of heat exchange very new, but ideas of light more familiar, the next person, may have the opposite situation. And then, in the next section, the second individual may have found concepts related to buoyancy remained very problematic, while the first found only a quarter of an hour with some equipment and supportive explanation sufficient to clarify ideas about density and displacement. Similarly, setting minimum times of exposure to content courses was not an appropriate way to define effective levels for course participants.

Any suggestion that junior primary teachers need lower levels of content just because they teach younger children was rejected by those in the course, it was in many cases recognised that individual students in their classes had already exceeded their own personal levels of knowledge in many areas frequently asking questions that could be fielded by responses beyond those currently held by the teacher, and who would have benefited from the teacher having a higher content level.

So, while the general conclusion of course participants was that 'more science content is better', just more science content alone is not as effective for course participants. Just as important was linking it to what teachers already know, and ensuring it is in an highly interactive atmosphere, with plenty of group work and discussion which is primarily supportive of an acceptance of the idea that a lack of science content knowledge is not insurmountable. Making the effort to learn more science will result in better teaching,

Thus, a 'textbook approach' to more science may well be counterproductive, as it will isolate the content from its relevance to the primary classroom. Teachers in this course made successful inroads into relatively esoteric and abstract atomic and molecular explanations of common physical, biological and chemical events. They had experienced the sense of power and control such 'high level' concepts gave them when framing questions, using models and analogies, giving more accurate explanations, and laying a better groundwork for high school studies even when working with students who are at 'lower levels' of conceptual development.

In conclusion, how important is science content knowledge? Our hypotheses are as follows.

(1) Content alone will not necessarily lead to more effective teaching. We can all think of many people who are knowledgeable about their subject, but not effective teachers.

(2) General pedagogical skills can lead to science lessons which are fun for students.

(3) Effective science teaching requires a level of comfort with content knowledge and the knowledge to make the ideas 'teachable'.

(4) Teachers with greater content knowledge are in a better position to help their students develop.

For those involved in this course, familiarity with content and confidence with ideas was seen to facilitate more stimulating questioning, more accurate explanations and more interest and enthusiasm for science, all of which support better student learning. Both personal growth in content and pedagogy must be developed together for science courses to be accepted as relevant and useful by practitioners.

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