'I do feel a little more confident': An Initiative in Primary Science Content

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Abstract

This paper reports an initiative funded by the Education Department to support primary school teachers to become more confident and effective in teaching science content. This initiative raises important issues related to (a) professional development (PD) of teachers and to (b) research in adult science learning. In relation to professional development, what are we asking of primary teachers when they teach science? Traditionally, science educators have focussed, in a variety of PD settings, on how content can be made 'teachable'. However, we also need to ask how can we develop primary teachers' pedagogical content knowledge if their content knowledge is limited? How can we expect primary teachers to make valid judgements about student learning in the conceptual strands of the Student Outcome Statements if these same teachers have limited understanding of related content? In relation to research, this initiative has raised an awareness of under-researched questions, including: What motivates adults to learn science concepts? What are major obstacles to their learning of science concepts?

The Role of 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. Support for this type of course can be found in many studies that define what teachers know and don't know about science, what forms of courses can have a successful impact, and they generally agree on the need for better levels of understanding on the part of teachers.

Smith and Neale (1989) investigated the subject matter knowledge and beliefs of ten primary teachers through interviews and videotapes of their teaching. They began their report in this way:

> 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 ..., and when taught is usually in a recitation format that relies mainly on a textbook (p. 1).

There has been a shift in emphasis from *process skills* to *content* in primary science (Kruger and Summers, 1989). They reported a study of the views of nineteen primary teachers about changes in materials: changes in a burning candle, a boiling kettle and other everyday phenomena. They note that primary teachers will not be required to teach about such changes 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).

The mismatch' between primary teachers' understanding of science concepts and the demands of the U. K. curriculum has prompted large scale programs in the UK (the Oxford University *Primary School*

Teachers and Science Project (PSTS) to address this problem (Kruger, Palacio and Summers, 1992). The Open University has produced a complete teacher' s professional development package in conjunction with the BBC, as a set of 6 workbooks with video support (see Tresman and Hodgkinson, 1993, and, Tresman and Fox, 1994). This was done in response to the National Curriculum and the evidence that teachers did not have sufficient science background to teach the key stages effectively. On this point, Summers and Kruger (1994) note that:

> ... in the past the science curriculum at the primary level has not taken account of the extent to which the teachers have knowledge and understanding of the concepts specified, or the ease with which these concepts can be acquired (p. 517).

Pedagogical Content Knowledge

The focus on pedagogical content knowledge has been stimulated by the proposition that unless teachers have the scientific models to contrast with student models, they are not likely to be able to foster their students' conceptual change. To be an effective science teacher, you cannot just be one step ahead of your students. It would be like teaching year 5 maths if you only have a 'personal best' of Year 6 maths.

In the course, participants examined the potential for lack of knowledge to be a dangerous and potentially 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'?

The need for better levels of understanding on the part of teachers, in order to improve students learning in science is described by Geddis (1993) as beginning teachers' simplistic views of teaching and learning, particularly the transmission view: 'teaching is telling and learning is remembering' (p 674). He then introduces 'the intellectual heart of the teaching enterprise': transforming the beginning teachers' content knowledge into pedagogical content knowledge. This is a process of transforming subject matter knowledge into a form which makes it teachable to a particular group of children. There are a number of aspects of pedagogical content knowledge: knowledge of students' concepts, strategies for teaching content, and shaping and elaborating the content. Smith and Neale (1989) concluded from their investigation that "staff development programs that focus on content-free skills and strategies, or even on particular curriculum packages [are] especially beneficial for teachers to focus on a particular content and the ways in which that content is translated in teaching." (p. 17).

These studies provided a strong basis for this course for primary school teachers and science leaders to 'upgrade' their science knowledge in response to the increasing importance of science lessons in the school curriculum. These courses cannot be just short term, as extending learning in many aspects of science as covered in primary science, requires long term commitment.

Effective Levels Of Science Knowledge

The majority of science educators agree on the need for more science content knowledge; however, the extent and depth of adequate levels of teachers science knowledge is under debate.

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. Another study reports 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). For some courses, little change was evident: Gustafson and Rowell (1995) investigated the views of 27 primary teachers in a science education unit and reported few changes over 13 weeks of the views of learning, teaching and the nature of science.

Our experience with this course supports the view that 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 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.

Course Outline

Participants met on three days, July 8, 9 and 10 in 1996. Fifteen of the eighteen teachers were also able to meet on days 4 and 5 of the course, on October 1 and 2. The five days of the professional development course to 'train the trainers' had as an important characteristic the emphasis on best practice in adult education. It involved an intensive introduction over three days. This was followed by a term's break, which provided a longer period of personal reflection and development with continuing contact with course presenters. The culmination phase, on Days 4 and 5, served to consolidate understandings and strengthen skills. This approach provided a model for trainers to use for their own courses.

The objectives of the course were to: 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 you in mini presentations; and 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.

The course participants engaged in various activities to stimulate discussion of their existing concepts; evaluate their own, other participants and students' work in a cooperative mode; research aspects of their own interest; present mini sessions to other participants of how they would tutor concepts; refine their presentation skills, such as use of voice, eye contact, clarity, sequence, gestures and use of models. create models, develop analogies, draw diagrams and practice explanations; review effective questioning and response; interact with experts in the field eg Energy Research Institute, and experience environmental analysis work in a laboratory; develop an understanding of the links between *Primary Investigations*, the

Student Outcome Statements and their role in learning area statements and support documentation, and the developmental nature of science concepts and skills.

Materials were developed by the project leaders to support participants. The first three days of the course resulted in the production of a workbook of 66 pages, together with a set of 50 pages of supplementary readings. The second two days of the course resulted in the production of a workbook of 106 pages.

Course Evaluation: Phase I

At the end of the first three days participants were asked for feedback, to gauge the general strengths of the course format, to inform changes in format and design for the last two days, and to determine what content for the following two days was requested and should be included.

Responses indicated participants' awareness that one of the prime considerations of the course developers was to create an atmosphere where participants were free to recognise, confront and deal with their own misconceptions and level of knowledge. This characteristic of the group emphasis, the openness of the presentees to not being 'fonts of all knowledge' but being prepared to share their own science growth and the idea of science as a constant development of better and better theories, was mentioned as a key to the success of the course in days 1-3. Sample comments included:

- A great atmosphere - relaxed, informative and realistic.
- Ironically, perhaps it was my lack of understanding of such phenomenon as 'moon phases', 'the seasons' and 'floating and sinking' that proved to be most useful. Indeed there appeared to be very few who understood these concepts and this provided me with confidence to pursue an understanding of these concepts.
- 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.

When asked about the relevance of sessions, and possible improvements, the majority of participants felt that all sessions were useful and relevant. Participants' comments supported that the period of five days was vital to allow participants to 'grow' into the mode of change, and to allow time for revisiting the concepts in different formats. This led to continuation of energy and chemistry strands in days 4 & 5, within realistic contexts such as water quality and weather patterns. The focus on presentation was given insufficient time in the first three days, but served to stimulate participants desire to learn more about it, which was given higher profile on days 4 and 5 with more extensive feedback and planning sessions. There is a clear need for a mechanism for trusted colleagues to give feedback to developing presenters - an impression supported by the final feedback when over half the participants indicated they would like to work with another course participate or a district science leader. Sample comments included:

- I felt all sessions were relevant - challenged old ideas and concepts.
- 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.

Requests for sessions focused on presentation skills, safety, links to local issues or habitats; the weather and the seasons; concepts of sound and forces; linking science concepts of chemistry and energy to our own bodies; and, understanding how these concepts are located in the Student Outcome Statements.

Course evaluation: Phase II

Reports from participants at the end of the five day course indicated that most moved from continuous models of matter and energy change, into molecular and atomic explanations for the first time. Reports indicated that for some, the course had helped them create more robust models of events, and promoted more skill in explanations and linking diverse concepts into complex events taught in primary school curriculum. Others reported that although they had met these ideas in high school, they were forgotten, and the course refreshed and consolidated their understanding. For some, it made the content of high schools classes understandable and relevant, with this content losing its mystique, for the first time.

For all participants, the course was very successful in stimulating a growth in science understandings; a desire to continue their own personal learning; an interest in working with others to share this new attitude and understandings. For example:

> Attending the course has in many ways undermined my confidence, which I have in sound measure in other areas of my work. 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.

This five-day course contributed information on the desirable and achievable level of content knowledge for this type of intensive course. Feedback from participants indicated strongly that fewer days would not have supported such widespread change in thinking about the nature of science, personal conceptual change, and the growth of a positive attitude to personal change and construction of science knowledge. One participant noted:

> This course has renewed my interest in science and has helped me see it in a new light. It has brought home to me the fact that we can learn anything with enough time and clear enough explanation. The course has encouraged me to endeavour to find adequate explanations, examples and analogies to do justice both to science and the students. Emphasised again the responsibilities we have as teachers.

Participants were asked to assess how well they thought the overall aims of the course were achieved. The responses of the fifteen participants are summarised in the tables below. The number of participants choosing each category of response is shown in each table.

Q1 *To what extent has this course increased your level of confidence in teaching science by increasing the level of your science understandings and skills.*

Table 1

Level of Confidence

a little	1
to a reasonable extent	3
a lot	7
to a great extent	4

Over 80% of the participants indicated that there had been a substantial increase in their understanding of science content, to the extent that their level of confidence has been increased. Sample comments were:

- I want to read more physics and chemistry books because now I feel I can understand some/most of it.
- There was a large gap to fill at the start of the course from my background content knowledge, to what I'd need to bring about confidence in this area of teaching. At first, I viewed this as a negative, but now fell that I have a sense of direction to follow, and that confidence can be achieved, though in the longer term.
- The course has refreshed my memory - I have a science background which I haven't used for many years. I've taught science, but it hasn't been a priority in my program and I haven't taught it well. I think it's always been a "poor relation" to other subjects, but I have more confidence and inspiration now, to change this attitude.
- To explore some of the 'main' science concepts in a way that individuals could participate without feeling threatened or stupid.
- The 'scary' things like chemistry are not so scary - in fact when you do 'hands on' they're really quite simple.

Q 2To what extent has this course developed your skills as a presenter of science content?

This proved to be one of the key achievements of the course (see Table 2), and over half of those completing the five days saw the course as contributing in a significant way to their personal development as a presenter. The group varied from those who had never presented at all, to those with more extensive training or experience. The links between increased confidence in the content and presentation skills were made clear.

Table 2

Developed skills as a presenter

a little	2
to a reasonable extent	4
a lot	7
to a great extent	1

Sample individual comments included the following.

- By demonstration modelling and more indirectly though discussion throughout the course. I feel the course presenters and other participants offered valuable strategies and information, tried and true ideas for presentation of science content.
- A greater understanding of science content has enabled me to present with confidence.
- I do feel motivated to develop and improve my skills as a presenter, however I am sceptical about how to get an audience.
- I had already attended a 10 day train the trainer course which made me aware of the skills needed to present - only the content of the presentation varies.

Q 3. To what extent will this course through you, assist teachers in our schools to gain their own confidence in science content, and in turn, help their students to like and learn science.

Participants showed a more limited sense of success for this aim, perhaps due to an awareness of the limited extent of their control over factors in the broader school context. However, over a quarter felt that they saw the course as contributing a lot to this aim, as shown in Table 3:

Table 3

Assist others to gain confidence in science content

a little	2
to a reasonable extent	7
a lot	5
to a great extent	1

Sample individual comments included the following.

- Having been through the process of trying to "bridge the gap" in order to upgrade my science content knowledge, I now feel that I can relate that experience to the many teachers who remain apathetic to science teaching. Have genuine empathy as one who has so little science background, yet can see science as being important, yet fun. Definitely into demystifying science for those who feel it's beyond their scope.
- I've gone some way to making teachers in my school more aware of science content.
- I'm hoping my new found enthusiasm and knowledge of science content will assist teachers to develop their own levels of understanding of content.
- When teachers who know you see you presenting science in practical interesting ways - they tend to want to have a go and pass their new found knowledge on.

Rating Of Level Of Comfort

Participants were asked to rate topics they now feel more comfortable about helping others, using the three categories: Pretty confident (PC); OK with more research (OK); and Not confident (NC). The responses are summarised in Table 4. Participants indicated high levels of confidence for the two topics in *Working Scientifically* and *Energy & Change*, with increasing discomfort for the topics in *Life and Living* and *Earth and Beyond*. Both of these strands are traditionally seen as the province of primary science, so it is interesting that frequently taught concepts of plants, the moon and seasons are still proving conceptually challenging for the participants. This indicates the need to include these topics in future courses and to allow more time to come to terms with the concepts within these topics.

Table 4

Rating of comfort level

Strand	*Topic*	*PC*	*OK*	*NC*
Working scientifically	1. Fair testing	12	3	0
	2. Evolution of ideas	9	6	0
Energy & Change	3. Energy transfers	9	6	0
	4. Floating & sinking	6	9	0
Natural & Processed Mat.	5. Matter	7	7	1
	6. Water analysis	7	7	1
Earth & Beyond	7. The moon	3	9	3
	8. The seasons	1	11	3
Life & Living	9. Light & photosynthesis	4	11	3
	10. Inheritance & DNA	5	6	4

Participants were asked to indicate which topics they would prefer to tackle, and some were happy to work with a few topics they felt comfortable with, others felt able to tackle a much wider range. Others were more aware of the need to respond to the interests of the audience and choose to link to their needs.

Extent of Change Of Knowledge

Participants were asked to rate their change in knowledge from 0 (know or knew nothing) to 10 (know it all or knew it all), *before* the five day course and *after* the five day course. The average of participants' responses are given in Table 5. Results indicate a general improvement in all strands, with the highest average movement for water analysis, light and photosynthesis and fair testing. Individual movements were more varied, with little movement for topics of high familiarity (eg fair testing has been a focus of some individuals) and very dramatic movement for others (chemistry and matter topics). For many, apparently simple concepts were shown to be very complex to explain scientifically. In the words of one participant:

I was intrigued by the complexity and the number of science concepts involved in everyday occurrences. I was particularly intrigued with 'seasons' and 'phases of the moon'. The course greatly helped me to increase / fine tune my conceptual understanding, but more than this my approach to science, my perception of science and what science is about has been redefined.

Table 5

Mean self-rating of knowledge

Strand	*Topic*	*Before (0-10)*	*After (0-10)*
Working scientifically	1. Fair testing	4.5	7.6
	2. Evolution of ideas	3.7	6.7
Energy & Change	3. Energy transfers	3.1	6.2
	4. Floating & sinking	3.9	6.3
Natural & Processed Materials	5. Matter	6.6	7.3
	6. Water analysis	2.1	5.6
Earth & Beyond	7. The moon	3.8	6.1
	8. The seasons	3.9	5.8
Life & Living	9. Light & photosynthesis	3.8	7.0
	10. Inheritance & DNA	3.3	6.3

Discussion

This course provides strong support for an increased focus on the content involved in primary science in teachers' professional development. Significant change was observed and reported by participants, perhaps because of the high motivation levels of the individuals (they had to apply and be accepted) and the intensive but shared group focus of the activities (the five days allowed effective interpersonal relationships to develop of mutual trust and support), and the high value their participation was awarded by the course organisers and presenters (participants were seen as high achievers and very talented individuals). Increases in confidence levels, in a more positive attitude to continuing self education, and a desire to promote science content as a way of improving student learning were the three most powerful outcomes of this course.

The title of this paper supports our belief that changers in adults' long held views and concepts is a lengthy developmental process which brief 'one - off' PD sessions will not address.
Our experiences in working with this group of enthusiastic and dedicated professionals has raised important theoretical and practical issues relating to the identification of the most effective ways to develop primary teachers' content, and thus pedagogical knowledge in science, with the expectation it will assist them make valid judgements about the level of achievement of their students.

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