CHAPTER FOUR

DILEMMAS FACING PRIMARY SCHOOL TEACHERS OF SCIENCE AS THEY IMPLEMENT A NEW OUTCOMES-BASED CURRICULUM

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ABSTRACT

During 2000-2002, the outcomes-based Science: Years 1 to 10 syllabus is being progressively implemented in Queensland schools. This paper explores the experiences of two primary teachers as they planned, implemented and assessed a science unit as their contribution to the advancement of a professional development program for teaching-with-outcomes. Key dilemmas faced by the teachers were the need for resources to provide content knowledge and activities, and sufficient time to plan and implement effective science lessons. The study established the need for on-going professional development, and a range of essential support to successfully implement the new syllabus.

INTRODUCTION

Professor Peter Doherty, Australia's newest Nobel laureate, recently stated that "A good measure of general scientific literacy is essential if Australia is to remain a free and prosperous society through the 21st century. This must start with the education of our children." (2000, p. 9). This challenge places a

heavy burden of responsibility on teachers of science, one that they cannot be expected to face unsupported. This study, therefore, set out to uncover the dilemmas faced by primary teachers as they endeavour to successfully implement the substance and philosophy of the new Queensland School Curriculum Council's (QSCC) *Science: Years 1 to 10 syllabus* (1999a). Implementation of this syllabus is mandatory for Education Queensland schools, whilst its adoption by the non-government sector is optional (Education Queensland, 2000, p.6).

The new syllabus presents a major philosophical change to the teaching and learning of science. Its epistemology is constructivist (QSCC, 1999a, p. 7) and far more conceptual (p. 8) than earlier syllabi which focused on specific content (Department of Education Queensland, 1981). Its principal focus is inquiry science or working scientifically (QSCC 1999a, p. 1). Its outcomes orientation aims to enhance the understanding of key science concepts and content is proscribed only broadly. Difficulties for teachers adopting a syllabus presenting such a changed approach must be expected, as teachers cannot implement curricula appropriately unless it matches their established philosophy and teaching approaches (Biddulph & Carr, 1992). Consequently, a regional non-government education office decided to help its teachers by commissioning research into the teachers' professional needs for teaching to outcomes. This study is one part of the primary school phase of that research.

PRIMARY SCIENCE TEACHING IN AUSTRALIA – AN OVERVIEW

The recent comprehensive report into science teaching in Australia (Goodrum, Hackling & Rennie, 2001) concluded that while some science teaching in Australia is of high quality, the general picture is very uneven. In 1999, Appleton and Kindt reviewed forty years of surveys and concluded that "many elementary teachers do not teach science, and frequently when it is taught, strategies used tend to be teacher discussions, explanation, watching science television shows, library research and teacher demonstrations" (p. 2). Investigative science is not common in primary classrooms (Goodrum, Hackling & Rennie, 2001; Appleton & Kindt, 1999).

Teachers often 'cannibalize' new initiatives, extracting parts that suit their existing practice (Olsen & Eaton, 1987). In new curricula, teachers may be looking for ideas compatible with their own, rather than for new approaches to teaching (Watt & Simon, 1999). In fact, teachers' existing craft knowledge

may seriously interfere with the implementation of any innovations in science teaching (van Driel, Verloop & de Vos, 1998). This effect was noted by Appleton, Hawe, Biddulph and Osborne (1984) when studying teachers implementing teaching guides. Although Appleton et al.'s teachers believed they were implementing the suggested approaches, they made crucial modifications in terms of their own beliefs, conflicting with the intended philosophy of the authors.

Low levels of confidence to teach science are a major factor contributing to teacher difficulties (Appleton & Harrison, 2000). Teachers' main concerns were inadequate content knowledge, uncertainty about scientific methods, and their own dissatisfaction that they used didactic methods when they lacked confidence (Bencze and Hodson, 1999). Increased confidence can improve the teaching of science in two ways. First, as teachers become more confident, they are more likely to improve their science content knowledge by either independent or structured studies in science (Appleton, 1992). Second, teachers with the self confidence to seek information with students rather than being intimidated by limited knowledge, can model lifelong learning skills (Hickey, 1999).

Beginning teachers often cope with their lack of science content knowledge and pedagogical content knowledge[1] by using 'activities that work' (Appleton & Kindt, 1999). These are believed to enable students to achieve the desired learning outcomes simply by doing the activity, usually with a predictable result. 'Activities that work' however, are successful only to the extent that science is being taught, usually with a hands-on-approach, but they do not satisfy the need for structured conceptual development. The 'Activities that work' approach is "probably antithetical to [the] constructivist views of learning" espoused by Education Queensland because their mostly predictable outcomes present a positivist view of science (Appleton & Kindt, 1999).

Questionable teaching approaches include exploiting 'fortuitous events' or the inclusion of science in an holistic theme in which the value of the science component may be debatable. In particular, the use of strategies more appropriate to language or social studies lessons, often appear to dominate science teaching (Appleton & Kindt, 1999; Scott, 1989)

The low levels of science knowledge characteristic of many primary science teachers inhibit concept learning. Watt and Simon (1999) identified the salient features of this type of teaching practice as:

- closing down student discussion;
- teaching only preferred areas of science;
- teaching activities rather than to objectives; and
- emphasising process or referencing skills rather than understanding.

In the UK, the demands of the National Curriculum in science were found to be "simply beyond the capabilities and knowledge of the average primary teacher" (Osborne & Simon, 1996, p. 139). The demands of the various new science curricula in Australia may similarly be beyond the average Australian primary teacher.

> *Research into effective professional development is a recent trend in Australia, developing since 1989 (Appleton, 1993), perhaps influenced by the adverse comments contained in the Department of Employment , Education, and Training's 1989 review of teacher education in mathematics and science. To effectively address change, professional development needs to "address and support social, professional and personal development" of teachers by providing new theoretical ideas and teaching strategies, and by allowing for opportunities to practice and evaluate these new approaches collaboratively over time (Bell & Gilbert, 1996, p. 13). Provision of science content has been found to be of value only if presented in ways that teachers can relate directly to their professional situations. (Tobin, Roth & Brush, 1995). Ultimately, to transform the teaching of science, professional development should utilise a constructivist approach to build from teachers' existing knowledge and skills (Louden & Wallace, 1990).*
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> *Building on the fragmented 'activities that work' approach. Appleton and Doig (1999) proposed the idea of 'units that work'. Professional development which modelled planning a 'unit that works', followed by teachers being collaboratively assisted ti create their own unit was trialled by Appleton and Harrison (2000). It is in the continuance of their research, that this study is located.*

DESIGN AND METHOD

This study forms part of Appleton and Harrison's research entitled *Units that work: Case studies for the teaching of science in Years 1-10*. For this paper, two teachers were observed and interviewed as they participated in a

professional development day, then planned, implemented and taught a unit of science to accord with the new syllabus (QSCC, 1999a). The paper claims only to report the experiences of two teachers who attended our professional development days and who were courageous enough to invite us to observe and scrutinize their practice. The teachers were aware that their teaching would be 'put under the microscope' and we thank them for welcoming us into their classrooms.

The use of qualitative research methods is suggested if a "program implementation is characterized by a process of adaptation to local conditions, needs, and interests ... [as] the methods used to study implementation must be open-ended, discovery-oriented, and capable of describing developmental processes and program changes" (Patton, 1990, p. 106). These methods match the situation where a new syllabus is being implemented. We needed to explore the teachers' science teaching decisions, to make sense of the pressures and tensions that teachers feel when teaching unfamiliar content and concepts.

Interpretive methodology and case study are recommended as appropriate to educational research by many authors (Cochran, DeRuiter & King, 1993; Denzin & Lincoln, 1994; Erickson, 1986; Guba & Lincoln. 1989). Case study is advocated for research into educational innovations (Merriam, 1998), and to document practical experience. In keeping with the constructivist paradigm, case study provides thick description to allow readers to participate by making judgments in relation to their own experiences (Erickson, 1986; Stake, 1988).

Case studies were constructed for the two teachers. The primary data collection instrument was the researcher as participant observer in the professional development and teachers' classrooms (Robson, 1993). Audio- and video-tape recordings supplemented observations and notes, and a reflective journal was kept of all in-class and out-of-class interactions. The research commenced with the researcher joining the teachers in a professional development day, facilitated by Appleton and Harrison. In the following weeks, the teachers taught the science unit which they planned as a result of that day. During this period, they were observed and interviewed. The resulting data were analysed inductively, in a search for recurrent themes and categories, as well as for discrepant events.

CONTEXT

The study was conducted in an established, non-government primary school in a regional Queensland city. In this school, each year level comprises

two classes, with teachers in each year engaging in cooperative planning. Eight teachers from the school were involved in a full day workshop as part of the larger project. The workshop was originally planned as three half-day sessions, the first two as a full day, with the final session held about a week after the others. Time constraints meant that these three sessions were combined into a single extended day.

> *The day began with small group reflective discussions about teachers' current practices. Next, the new science syllabus was examined in terms of conceptual strands and levels, 'working scientifically', outcomes, and core content, before involving the teachers in an open ended experiment designed to elucidate the differences between 'working scientifically' and the 'scientific method' approach of the previous syllabus. Constructivism was explored through activities which highlighted the roles of perception and prior knowledge in learning. Participants then worked through various activities before the facilitator led a group construction of these into a 'unit that works'. Finally, with support, pairs of participants were to collaboratively plan their own 'unit that works'. Time constraints and fatigue meant that this step was seriously truncated.*

The focus of this study is the experiences of two teachers, Liz and Ann. Liz is a teacher in her third year of full time teaching. She also previously taught on a part time basis. This year is the first time she has taught Year 4. Ann is in her second year of teaching, and also taught Year 4 last year. Both readily admitted to limited science content knowledge and little interest in science. They were initially reluctant participants; teachers involved in research like this take "the risk of publicly acknowledging the need for improvement" (Bell & Gilbert, 1996, p. 17).

DATA INTERPRETATION AND FINDINGS

Reflections on Professional Development

Following the professional development day, Ann and Liz continued to see the need to obtain more content knowledge and to access suitable activities. They were satisfied with their knowledge of pedagogy and organisational skills, but concerned about how to "get this [science] across to the kids if we haven't got ideas and resources". Liz wanted "to learn more about the concepts, more than learning about how to teach the concepts".

They commented that the expectations set by the syllabus "can't just assume that teachers know the content" and they were left to feel "frustrated".

Their frustration applied to the range of QSCC modules as well as to the actual syllabus (QSCC, 1999a). Ann stated that "the syllabus can't assume that we know what every definition is and how to bring that across to kids," as she acknowledged her limited PCK in this curriculum area. In looking at the available modules, they found differing levels of usefulness. One module "just assumed we knew everything" while another "had really good definitions ... a bit more depth". Ann thought there "needs to be a lot more to help the teacher, not just to help the student".

Ann and Liz would both like "more examples because we've only got a few actual units [prepared modules provided by QSCC]". Liz stated that the [old] SOSE and Mathematics syllabi provide content, yet Science does not. During the professional development day, they were disturbed about where the activities used by the facilitators had come from. Their concern for their future teaching was where *they* would find suitable activities.

Other expressed concerns related to time. When the internet was suggested as a source for additional QSCC sourcebook modules and other material, Liz felt that time constrained her. "You can't be hunting around looking for resources all the time." Ann was "not really confident on doing the net".

Time to teach science was problematic. Liz thought activity based lessons such as were demonstrated in the professional development would be "hard to timetable in an hour here, an hour there." Both teachers prefer to teach science by integrating with language and other areas. As Ann said, "You have to integrate, otherwise you're never going to cover everything".

Two key dilemmas constrained the teachers, prior to commencing the teaching cycle: where to find resources to provide content knowledge and activities, and sufficient time to plan and implement effective science lessons. The issues related to time indicate a need for support in planning to help provide the required resources, and ways of managing the implementation of activity based lessons.

Planning

Liz and Ann's planning strategies showed they were willing to change their teaching practice. Rather than looking for ideas compatible with their existing approach, as Watt and Simon (1999) found some teachers to do,

they tried ideas that differed markedly from their previous practice. However, it seems that the professional development did not equip them with the ability to cope with those changes (Ginns & Watters, 1996).

Having chosen to teach the topic, *Energy and Change*, Liz and Ann resorted to the hard copy modules prepared by QSCC, even though the professional development had aimed for them to plan an 'original' unit. It is likely that they went to this module as Ann had taught it the previous year.

> Ann: To the source book module [*Force and motion,* QSCC, 1999b] ... the example, and obviously this is level 4 which is about a grade 7. What Liz and I did was look at the activities and brought it down to our kids' level. We didn't go too much into like kinetic energy. We just sort of focused on basic things.

Their strategy of considering only prepared QSCC modules is limiting. The mismatch between the number of ready prepared units of work and the breadth and depth of the outcomes highlights the need for teachers to design their own science units.

By taking a unit aimed at *Energy and change* Level 4 and 'bringing it down' to Level 2.1 for Year 4, the possibility that students will be exposed to repeat versions of this unit over the next three years is very strong. A further concern in 'bringing down' the unit conceptually (i.e. adapting activities aimed at a higher level to achieve a lesser understanding), is that this would require a very clear understanding of the scientific concepts involved. It seems that Ann and Liz may have focused more on the language used than the relevant concepts. Ann stated, "We just had to bring down the language so it didn't go too much into like kinetic energy." However, Outcome 4.1 requires that "*Students design and perform investigations into relationships* between forces, motion and energy" (QSCC, 1999a, p.22, italics added). This is far more advanced conceptually than Outcome 2.1, "*Students demonstrate different ways* that forces (including push and pull) change the shape and motion of objects." (QSCC, 1999a, p.21, italics added). It appears that Liz's and Ann's focus on language based teaching caused them to misunderstand that the basis of this syllabus is that students should "develop their understanding of concepts" (QSCC, 1999a, p.8) as they progress through levels which indicate "increasing sophistication and complexity in learning outcomes" (p. 10).

Crucially, Ann and Liz changed the 'working scientifically' foci that "need to be considered when planning learning experiences" (QSCC, 1999a, p32)..

From the module activities that they used, they deleted 'discussing thinking' and 'identifying and controlling variables'. It is unlikely that the learning benefits of activities included in the various sourcebook modules provided by QSCC can be achieved without using the appropriate aspect/s of working scientifically.

Liz and Ann worked from an existing unit that they perceived would 'work'. Unfortunately, the adaptations that they made to it meant that, as Appleton and Kindt (1999) found, science was not being taught as part of a structured series of lessons to achieve conceptual development. As the preceding instances demonstrate, the teachers in effect, 'cannibalized' (Olsen & Eaton, 1987) the QSCC (1999b) *Force and motion* module but rather than to align it with their previous practice, it was cannibalised to fit *their perception* of the new syllabus (QSCC, 1999a). This highlights the need to provide teachers with in-service help for as long as the teachers need support in designing, trialing and refining new units of work. One appropriate method of support may be a series of collaborative action-research cycles (Kemmis & McTaggart, 1988).

Implementing

Liz and Ann planned their unit using the generic 'Orientating, Enhancing, Synthesising" approach, rather than a science specific teaching approach. Their plan did not make explicit the strategies to be used. It seems that strategic approaches were chosen without consciously considering the range available. This approach to planning indicates that in addition to appropriate content knowledge, and despite satisfaction with their current pedagogy, teachers like our participants will benefit from education in a range of creative strategies like interviews-about-instances and prediction-observation-explanation (White & Gunstone, 1991).

Liz and Ann appear to have used a version of the investigation approach detailed by Appleton (1997, p. 108f). However, the key final segment in which the data gathered are discussed to help the students arrive at the lesson's outcome was not included in three lessons, and in the other lesson the first two steps of focusing student attention and clarifying goals and procedure were excluded. These omissions were likely to have impacted on students' understanding of the concepts involved. Collaboration with a critical friend or mentor will help identify and, ideally, help teachers avoid, 'missing out' these key steps.

Another explanation for the omission of the 'making sense' segment of the investigation strategy may be that Ann and Liz made a conscious choice not to discuss these activities as they felt that their content knowledge was inadequate to cope with an open discussion. Watt and Simon (1999) listed four signs indicative of low levels of subject knowledge: closing down opportunities for discussion; teaching to activities rather than objectives; teaching only preferred areas of science; and emphasising process or reference skills rather than understanding. Liz closed down opportunities for discussion, and both teachers actually avoided opening opportunities. In this unit, they appeared to teach to activities rather than outcomes. But to their credit, they also demonstrated a willingness to teach outside their preferred areas of science and to step aside from what they stated to be their more usual practice of "emphasising process or reference skills" (Watt & Simon, p. 387). This indicated a willingness to change and school-based processes are needed to sustain such willingness to take risks in order to improve science teaching.

Liz and Ann demonstrated what Fullan and Pomfret (1977) called a failure to achieve 'fidelity of implementation'; not only with regard to the module on which their planning was based, but also to their own unit as planned. They (possibly unconsciously) deviated from their plan to discuss questions suggested in the *Force and motion* module (QSCC, 1999b) using them instead as pen-and-paper assessment items. In line with their previous practice, Liz and Ann also focused on language more than conceptual understanding in their discussion about types of forces. Changes such as this to modules can completely change the focus of lessons and their epistemological basis.

Liz's and Ann's implementation of their unit showed that, as van Driel, Verloop and de Vos (1998) found, views about the teaching and learning of science are relatively fixed in existing craft knowledge. Because Ann and Liz continued to be satisfied with their previous practice, their conceptions will need to be challenged before they will see any justification for lasting change (Sanchez & Valcárcel, 1999). Again, critical friends and mentors would help achieve this and we recommend that schools and school systems prioritise the establishment of reflective partnerships both within and between schools.

Assessment

Liz and Ann initially planned for students to 'display' their achievement of outcomes through the activities conducted. The only written assessment

noted in their unit plan consisted of children completing a resource sheet in pairs in Lesson 1 and completing a worksheet in Lesson 4. All other assessment was based on anecdotal notes. However, as they implemented the lessons, questions which were planned for 'questioning and discussion' were instead used as individual paper-and-pencil tests. The work sheets became individual tests. These changes may have been caused by reluctance to discuss a topic in which Ann and Liz lacked confidence. It may also have been a return to their more usual language based practice in which they expect written evidence of children's learning. Or they simply may not have fully considered assessment in their initial planning (Sanchez & Valcárcel, 1999).

Whatever the reason, the assessment used by Liz and Ann did not accord with the syllabus requirements that assessment use a comprehensive range of techniques and instruments (QSCC, 1999a, p. 42). It is likely that Liz and Ann's attitudes towards assessment were influenced by their need to meet their school's expectations and to complete report cards. Due to the "climate of accountability that prioritizes the acquisition of factual knowledge" (Bencze & Hodson, 1999, p. 523) in which they worked, Ann and Liz were very aware of issues of accountability, maintaining a strong focus throughout this study on obtaining information for forthcoming report cards. This directly conflicts with the implicit notion of authentic science being open-ended.

Finally, as Crocker found in 1979, these teachers were constrained rather than supported by the collective view of the school staff that science should be integrated with language if at all possible. The School Curriculum Coordinator's view that science should be 'married' to an English genre so that it can be assessed in writing, may have influenced Liz and Ann to focus more strongly on written assessment than their unit plan suggested. This is an important consideration for education jurisdictions: is the assessment and reporting regime compatible with outcomes-based teaching and learning?

Knowledge of science

Teachers with positivist views of science will encourage similar attitudes in their students (Gess-Newsome, 1999). Ann and Liz taught much of their unit in ways that did not display positivist views of science. They allowed students choice in their activities and encouraged students to contribute their thoughts to definitions. But they also were concerned about what they saw as their ignorance of the body of scientific knowledge, reminiscent of Ostman's (1998) 'Correct Explanations' emphasis. Their reliance on pen-and-paper

assessment is symptomatic of a view of teaching as the transmission of knowledge (Sanchez & Valcárcel, 1999).

Positivist beliefs about science promote the view that scientific content is constant and inflexible (van Driel, Verloop & de Vos, 1998). Liz and Ann were concerned about their inadequate content knowledge and uncertain about which scientific practices to use. Rather than being dissatisfied with the use of didactic methods, their concern was with using activities and 'working scientifically'. Initially, they were confident about their ability to teach this unit. However, their eventual dissatisfaction aligns very closely with the findings of Watt and Simon (1999) who point out that low levels of confidence stem from insufficient information regarding: organising and assessing a practical subject; knowledge about children's conceptions of science; understanding of how to present concepts to children in an appropriate form, and knowledge of suitable questions (perhaps in this case, of suitable answers) to check for student understanding.

DISCUSSION AND RECOMMENDATIONS

The teachers stated that they were very happy with the previous syllabus. They appear to have become accustomed to a prescriptive syllabus and thus looked for prepared units, what Erickson (1986) called a 'cookbook' approach to meeting their chosen outcomes. They need support to develop an understanding of when and why sourcebook modules are or are not appropriate. They also need support that will enable and encourage them to write their own units 'from scratch' when an appropriate module is not available. The difficulty that Liz and Ann experienced coping with the content knowledge required for this particular unit, may have been avoided if they had taught a unit planned within their own capabilities. In planning to 'bring down' the unit which they used, Liz and Ann used a unit which was neither appropriate for their targeted outcomes, nor appropriate for the age group of their students.

Furthermore, Ann and Liz need support to develop a better understanding of the philosophy of the new science syllabus (QSCC, 1999a) and its impact on the teaching and assessing of science. Their unit plan showed a limited understanding of scientific practice when they deleted two of the key 'working scientifically' aspects of the *Force and motion* module (QSCC, 1999b)—'discussing thinking', and 'identifying and controlling variables'.

There appears to be a need for a considerable mind-shift in assessment practices in their school's philosophy. This is a need which also is likely to impact in other Key Learning Areas. Adopting the sorts of assessment practices recommended in the new science syllabus (QSCC, 1999), may help with the issue of time for implementing science lessons. Assessment focusing on students demonstrating learning outcomes during the course of their lessons, negates the need for additional testing. This requires a major mind shift for teachers, schools and the community.

Liz and Ann believe that increased content knowledge is the answer to their concerns. Skamp (1989, 1997) established that this is not necessarily the case, and as Hickey (1999) noted, it is not realistic to expect to know all the content that a flexible curriculum may require; especially given the primary school teacher's need to cope with eight key learning areas! It also appeared that they did not realise the diversity of content which could be used to reach their planned outcomes, much of which may have been within their existing knowledge base. Although increased content knowledge is certainly a real need, perhaps teachers also need to be shown how much they already know.

This emphasises the importance of teachers designing their own units of work. To achieve this goal, they need *appropriate* content knowledge, an *understanding* of effective teaching strategies and a *changed emphasis* from summative assessment to more diagnostic and formative assessment (Black & Wiliam, 1998). In other words, teachers like Liz and Ann need to enhance their pedagogical content knowledge. This need can be met provided education jurisdictions recognise the mismatches present in certain policies (e.g., outcomes need a revolutionary approach to assessment and reporting) and provide teachers with mentors, and the time to work reflectively.

Further professional development would help to resolve the dilemmas initially identified by Ann and Liz, and ensure a more effective implementation of the new syllabus. However, it is clear that a single day of professional development is insufficient to bring about change being asked of teachers.

CONCLUSION AND IMPLICATIONS

For implementation of the new science syllabus (QSCC, 1999a) to succeed, it is vital that teachers understand the views of science which underpin it. Understanding of a contemporary view of science could be facilitated by professional development which begins by focusing on the historical development of different views of science. To then reflect on their own views

and the implications for their teaching, teachers need time (Sanchez & Valcárcel, 1999). This intimates the need for ongoing professional development, allowing teachers time to accommodate these changes (Bencze & Hodson, 1999).

Professional development for teachers of science should use every opportunity to enhance teachers' content knowledge and range of activities suitable for students' learning of content or concepts (Bell & Gilbert, 1996). This will be achieved, in part, by eliciting from teachers what they already know. Teachers possess a "broad range of knowledge and experience, shaped by their gender, socioeconomic status and geographical location and by other aspects of their background" and can contribute to their own professional development (QSCC, 1999a, p. 6). Driver (1995) has suggested that an individual's understanding may be enhanced through discussion, not only by the scaffolding provided by others, but by "the opportunity for each individual to reorganize his or her own ideas through talk and listening" (p. 395).

Conducting the professional development as a single school experience, there are not the numbers of teachers working to achieve common goals. Future professional development should be organised at a system level. Even within regional areas, it should be possible to bring together a group of teachers from the same year levels, teachers with common goals.

Teachers could work in small groups to develop their ideas into unit outlines to be conferenced by the facilitator. Only when the skeletal plan has been discussed and the teacher and facilitator are happy that it has the potential to become a 'unit that works' should the unit be planned in detail.

Further professional development should then be programmed for at least a week after the initial day, allowing time for teachers to reflect on the initial session, and to collect their resources. The second session could allow for further group discussion, and completion of the unit plans, with the facilitator ensuring that the units meet syllabus expectations. This approach should maximise the chance that the unit actually will 'work', and that teachers will experience success in their first step towards implementing a changed teaching practice. This process should also begin the establishment of ongoing peer group support.

Examination of some QSCC sourcebook modules should be included as part of professional development. The modules contain excellent activities, teaching considerations, and questions for discussion. Teachers need to identify

when using modules is appropriate. They should understand that it is not appropriate to use a module planned for a higher level, or one that their students have previously encountered. It is not appropriate to merely change the language contained in a unit without considering the underlying scientific concepts.

The new science syllabus (QSCC, 1999a) espouses learning which "accommodates, acknowledges and builds on prior knowledge" (p. 6). If teachers understand the developmental structure of the syllabus levels, sequenced to be "qualitatively different" (p. 32), it will enhance their ability to judge the appropriateness of pre-planned modules. It also will enhance their ability to plan their own original units to aid student conceptual growth.

The use of alternative assessment strategies focusing on science learning rather than language or other competencies is a vital component of the new syllabus. To use the preferred approach of the school at which Ann and Liz teach, science is usually assessed through an English genre, so that a student with a flair for science and poor language skills may be disadvantaged. Alternative assessments relating to outcomes are a requirement of an increasing number of key learning areas. As such, provision of separate professional development focusing on assessment across the curriculum may need to be provided for teachers.

During the teaching of a 'unit that works', teachers should have access to a mentor by telephone or email. This would enhance teachers' chances of personally experiencing success in their first attempt at new teaching practices. In Central Queensland where many schools are small and isolated, this is especially important

Finally, a joint reflection and discussion on the teaching of these units should be conducted to allow teachers to discuss their experiences, both positive and negative, with the help of a mentor. Giving teachers the opportunity to reflect on and question their current practice, are necessary to sustain changes in teaching methods (Sanchez & Valcárcel, 1999). Teachers also could share the units written by their peers to establish a valuable resource base, and a further foundation for future success.

Teachers are willing to change to be able to teach science effectively, but they must be adequately supported. In this situation teachers are co-learners. Education systems' administrators would do well to read the "Understandings about learners and learning" contained in the science syllabus (QSCC, 1999a, p. 6ff) and to consider how it applies to the

professional development of teachers. To teach science effectively to students, teachers must have "adequate" knowledge of science and pedagogy (Hickey, 1999; Shulman, 1987), and professional development must be "adequate" to support their needs.

ENDNOTES

[1] Pedagogical content knowledge, briefly, is the way "of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9).

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