CHAPTER THREE

THE TERRARIUM UNIT:
A CHALLENGE TO TEACHERS' CONCEPTS OF WHAT IS SCIENCE TEACHING

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ABSTRACT

This paper discusses how teachers interpret outcomes-based science syllabuses and design open-ended and interesting science units. The study focused on the implementation of a new outcomes-oriented syllabus in Year 8. A tension existed between two groups of teachers. One group was excited and willing to design new content, pedagogy and assessment. The more traditional group focused on how they could adopt the new syllabus but retain much of their previous pedagogy and assessment practices. Qualitative data showed that innovative planning, teaching and assessment are crucial to the success of outcomes-based learning. Despite careful planning, there were discrepancies between the ideal outcomes-based unit and the actual teaching and learning.

INTRODUCTION

The introduction of the new *Science: Years 1 to 10 syllabus* (Queensland Schools Curriculum Council (QSCC), 1999) into Queensland schools provides a new direction for science curriculum and a renewed focus on *effective science* teaching and learning. One of the foundations of effective science teaching and learning is the planning, teaching strategy and assessment decisions that the teacher makes.

The purpose of the research was to provide a critical account of the planning and writing process of a Junior Science workprogram, and subsequent implementation of science units developed in harmony with the new QSCC syllabus (1999). Participant observation and in-depth interviews enabled detailed insights into the criteria these teachers use to make decisions during planning, writing and implementation. The research uses case study methodology centred on two of the participants, and the story of their interactions is told and discussed. The main focus on one teacher as she wrote a new science program and the paper explores the constraints she faced when in implementing curriculum change. These insights broaden the focus of the research and add to existing knowledge about the nature of effective science teaching in an outcomes-oriented program.

The centrepiece of this paper is the *Terrarium Unit*, an outcomes-based science unit written for Year 8 science students by a teacher we call Tina.

BACKGROUND

The interest in this topic stems from statistics indicating a decrease in numbers of students choosing science subjects in post compulsory studies (e.g., Hildebrand, 1989; Stewart, 1991; Dekkers & de Laeter, 2001; Goodrum, Rennie & Hackling, 2001). These studies suggest that junior secondary science fails to provide the necessary motivation and interest for students to continue to senior science (Speering & Rennie, 1996). They show that students' positive attitudes to science decrease in the transition from primary to secondary. This is disturbing considering students' attitudes towards science and their choice of career is likely to be determined during the early years of secondary schooling. Thus, the question becomes, "what are science teachers doing or not doing in their science lessons that causes this decreasing motivation?" (p.284). According to Goodrum, et al (2001), many science lessons in junior secondary are based on a transmissionist approach and involve traditional chalk-and-talk teaching, copying notes and "cookbook" practical experiences. This essentially teacher-centred approach does not allow the interests and experiences of students to be considered in a meaningful and relevant way. Nor does it encourage students to raise questions and suggest investigations to answer their questions.

The introduction of the *Science: Years 1 to 10 Syllabus* (QSCC, 1999) provides a new curriculum direction for science and potential for science teachers to address these concerns through planning and implementing science units in harmony with the syllabus. However, one cannot assume that changes to factors external to the classroom environment, such as curriculum documents, will result in changes internal to the classroom, such as teaching practices. The classroom teacher remains the critical component of any science education reform (Bybee, 1993). As Connelly and Clandinin (1988) explain, "curriculum development and curriculum planning are fundamentally questions of teacher thinking and teacher doing ... it is teachers' 'personal knowledge' that determines all matters of significance relative to the planned conduct of classrooms" (p.4).

"The process of change and the implementation of innovation is complex" (Robson, 1993, p.429) and when seeking to help bring about change, an understanding of what exactly is involved is crucial. This study, exploring the planning for science units by teachers and the decisions made during this process, provide valuable insights into current practice and the process of change. These insights can be used to inform professional development directions for science teachers and support the implementation of the new science syllabus.

Much research on the effectiveness of science courses has been conducted over the past two decades (Longbottom & Butler, 1999). Emerging from this research are policy reports calling for scientific literacy to be a national goal. However, the "accompanying onerous tasks of revising curriculum, changing the way we teach, and adapting new methods of assessment fall upon schools and those who work in and with them" (Lumpe, Haney & Czerniak, 2000, p.276). Suggested changes to curricula have centred around demands for more interesting and relevant science content, and teaching strategies that are more in tune with how students learn, while sensitive to their gender and culture (Longbottom & Butler, 1999). Questions about the nature of science are at the heart of this debate, as the view portrayed to students by teachers provides an image of science that may potentially encourage or discourage students from pursuing science study. Australia can ill-afford this outcome. Senior science enrolments have been in per capita decline for over 10 years and a turn-around is urgently needed (Dekkers & de Laeter, 2001)

TEACHERS IN SCIENCE

It also is noted that the teacher's role is central and crucial to the attainment of effective science teaching in schools. Bybee (1993) stated "I remain convinced that the decisive component in reforming science education is the classroom teacher ... unless classroom teachers move beyond the status quo in science teaching, the reform [restructuring in science education] will falter and eventually fail" (cited in Lumpe et al., 1998, p.124). The teacher plays a critical role in the ultimate implementation of science learning experiences; and therefore their beliefs and opinions are a key factor influencing science reform agendas (Tobin, Tippins, & Gallard, 1994). However, as Lumpe et al., (2000) found, "the beliefs of teachers are not necessarily consistent with the literature about best practice in teaching" (p.276) but they are stable and resistant to change.

Implicit to quality learning experiences in science are teachers who themselves are intellectually excited by science and comprehend its value to their own lives and the lives of their students. According to Gallagher (1996), for many teachers this is not the case. Gallagher sees the challenge to science education as both a reform within schools focusing on what is taught and how it is taught, and a similar reform within universities responsible for preparing pre-service science teachers. Changes to program content, instruction and assessment are necessary to prepare science teachers who will be able to perceive the logical character of science, and who are able to understand and use scientific knowledge and structure learning activities to facilitate a reciprocal understanding in their students. Gallagher concludes that if students are to be scientifically literate, then secondary science teachers also need to be scientifically literate. For teachers to develop scientific inquiry and problem-solving skills in students, they must understand these characteristics of the scientific enterprise.

FORMATIVE ASSESSMENT

One suggested way of raising standards and improving the quality of learning in the science classroom is through formative assessment (Black & Wiliam, 1998). Formative assessment is defined by Bell and Cowie (2001) as " ... the process used by teachers and students to recognise and respond to student learning in order to enhance that learning, during the learning" (p.536). Black and Wiliam (1998) qualify this by stating assessment is only formative when the evidence collected is actually used by the teacher to adapt the teaching in the classroom to meet the student needs. Thus, when teachers respond to and interact with students' thinking in the classroom they are engaging in formative assessment. The purpose of formative assessment is to provide students with feedback that will enhance their learning and provide teachers with a better understanding of student learning that can then be used to directly inform practice.

Black & Wiliam (1998) provide a compelling argument for enhancing both the quality and quantity of formative assessment occurring in science classrooms. Goodrum et al's (2001) report identifies assessment as a key area of science teachers' pedagogical skills and knowledge that needs to be refined in order to improve student learning in science. Black, Harrison, Lee, Marshall and Wiliam (2002) tell us how this reform can occur and state unequivocally that there is "evidence that improving formative assessment raises standards". This is further supported by Bell's (1995) claim that formative assessment is a "crucial component in teaching for conceptual development". Despite this apparent need Treagust, Jacobowitz, Gallagher & Parker (2001) report that most assessment in secondary schools follows a familiar cycle of teach a topic, test the topic, assign grades and continue to the next topic. This model allows little room for the meaningful dialogue between student and teacher essential to the success of formative assessment.

Enhancing learning quality in science "through improved formative feedback takes classroom time", and is problematic where teachers feel under pressure to "cover a statutory curriculum" (Black & Wiliam, 1998, p.18). Furthermore, science teachers' pedagogical skills and knowledge need to be refined to accommodate meaningful formative assessment (Goodrum et al., 2001). Thus, there are several implications for science classrooms arising from an emphasis on enhanced formative assessment. Meaningful dialogue between teachers and students (Bell & Cowie, 2001) is crucial, as is the provision of class time for these discussions. New ways to enhance formative feedback between teachers and students require new modes of pedagogy and significant changes to classroom practices. Substantial support needs to be provided to teachers on how to enhance the quality and variety of formative assessment.

Tina's Terrarium Unit was particularly interesting because it provided many opportunities for formative assessment that could enhance the teacher's teaching and student learning.

METHOD

Overview of Research Project

This research contributes to the existing knowledge on effective science teaching in schools. The project set out to investigate the planning, preparation and teaching of science in the junior secondary school. Specifically, it focused on teacher planning for the QSCC (1999) syllabus and the subsequent implementation of a unit of work based on outcomes from the *Life and Living* and *Science and Society* strands of the syllabus. The research explored teacher views, planning decisions and implementation practices to identify benefits and constraints to effective science education under the new QSCC syllabus. Insights into teacher decision-making and practices can be used to inform initiatives aimed at closing the gap between the actual and ideal pictures of science teaching and learning, and help design future professional development for junior science teachers.

RESEARCH APPROACH

Qualitative processes (Guba & Lincoln, 1989) were used to research this problem. In-depth interviews and observation of teachers at work formed the basis of the qualitative data collection process. This method has been chosen to maximise opportunities for teachers to explain their planning decisions. Whilst there is a whole field of research on teachers' planning decisions using interviewing as a key element of its methodology, there appears to be little research, using this methodology, specifically focused on the planning and implementation decisions of teachers working in outcomes-based education in middle school science. A study by Mulholland and Wallace (1999) of a beginning primary school teachers' experiences teaching science, using case study as its orchestrating perspective, highlights the usefulness of this strategy as a tool for obtaining detailed data on teacher thinking and decision making.

CASE STUDY

Qualitative case study method (Merriam, 1988) aimed at description and interpretation provided rich understandings of the processes underpinning this curriculum change. As a research strategy case study is very appropriate for in-school settings as it provides insights into educational practices and problems (Walker, 1983) due to its particularistic, descriptive, heuristic and inductive characteristics (Merriam, 1988). Case study approaches problems of practice from a holistic perspective and provides the rich in-depth representations required to illuminate meanings. This case study was particularistic and descriptive with respect to the collection and interpretation of data. The case study is particularistic because it focuses on a particular situation – Tina's class – and it is descriptive because it provides a detailed account of the student's learning.

The case centers on a regional secondary school teacher who attempted the transition from an objectives, content, and marks based system of science teaching and assessment to an outcomes-based system focusing on concepts and evidence. Data were collected using semi-structured and focused interviews, participant observation and tape recorded professional discussions. The data were categorized according to the interview themes, and reported and interpreted as a case study. Analysis was underpinned by the literature reviewed and the notion of dilemma (Altrichter, Posch & Somekt, 1993), with a focus on the 'ideal' and 'actual' teacher planning and implementation.

Research Questions

Given the educational research problem, the specific research questions ask

1. What pedagogical practices best support effective teaching and learning in science units planned for an outcomes-based science syllabus?
2. What role does the science textbook play in teacher planning and assessing decisions with the new *Science: Years 1 to 10 Syllabus*?
3. What constraints do science teachers encounter when planning and implementing outcomes-based units of science?

Findings

The research findings support the conclusion that a gap between the ideal picture of science teaching, and the actual state of science teaching described by Goodrum et al. (2001) still exists. Teachers committed to change experience a number of barriers that constrain their ability to put into practice the reform initiatives underpinning the QSCC syllabus (1999). Furthermore, science teachers' understanding of formative assessment processes and how they can be used to support and enhance the quality of teaching and learning in classrooms appear impoverished.

DATA AND INTERPRETATION

Biography of Participants

Tina's willingness to write units of science based on syllabus outcomes and grounded in *working scientifically* and meaningful assessment made her an ideal participant in the research. Tina is in her second year of teaching and has taught Years 8—10 Science and Year 11 Biology. Tina's approach to teaching is 'hands-on' and constructivist investigations underpin her philosophy and teaching. From Tina's perspective, the development of a new science program in the school was an opportunity to be innovative and improve the quality of the science currently experienced by students. She believes that the science syllabus (1999) places more emphasis on "students experiencing and working scientifically" than on "how much they can regurgitate at the exam".

Another key participant in the research was the Science Head of Department. In contrast to Tina, Patty has been teaching for over 30 years. Her approach to science planning and teaching emphasizes content, worksheets and activities. Patty commenced the planning process by "mapping out everything [that could be done] from the textbook and [her] resources". Patty favoured end-on, marks-based assessment techniques focusing on science content and felt that she "must have marks". These teachers' contrasting beliefs about science teaching became an underlying, and at times visible, tension during the planning and implementation of the terrarium unit.

Other Year 8 science teachers contributed to the project as they implemented the terrarium unit written by Tina. Their actions and views are included, where necessary, to illustrate the teaching and learning environment in which Tina worked. Likewise, the views and actions of students and the laboratory attendant were a valuable inclusion for the perspectives they provide. Participating teachers selected the students for interview and thought it important to choose a representative sample. They explained a representative sample as "a few who didn't do much, a few average kids, and a few that had excellent terrariums".

Textbook reliance

Despite early assertions by the teachers that the textbook should not drive the science program, subsequent discussions and actions indicated otherwise. During a discussion on the criteria to be used for deciding on a new textbook, Patty responded that the first criteria would be "Does it have a work program written for it?" Later, in response to an inquiry as to whether they wanted the textbook to drive what they taught in their science units, Patty responded, "apart from a health and safety unit I'd like to add, I'm happy for the text to choose what we teach". Patty maintained that the "text [was] the main resource for the teachers". It became evident that the newly selected textbook, *Queensland Science* (Chandler, 1999) was the 'new' science program providing not only the scope and sequence, but also the unit and lesson plans. The following comments by the teachers' lend support to this assertion, "the text we've got ... has all the outcomes at the front of the chapter so I think you can make the assumption that the text chapter does cover those outcomes, without that it would be very difficult. The text still drives it rather than the outcomes" and the "textbook provides direction rather than the outcomes".

Patty's recurring criticism of *Jacaranda Science* (Ash et al., 1999) and the structure of its double page spreads indicate the degree to which the teachers rely on the text for their planning and preparation. Patty felt the book was set out for double lessons not single lessons and explained her concern with this as "... double page spread will suit 85 minute lessons but not 45 minute ones, got to be able to cover or at least attempt to cover or give exposure to each of these things and then revisit them to ensure they have learnt it all".

The teachers chose a textbook they felt best represented 'all the science knowledge' and they saw their role in the classroom as transmitting this body of knowledge, hence the emphasis on covering all the textbook content. This assertion is lent further support by Patty's statement that, "the textbook has to be not only a student reference but the main resource for the lesson". One construction of this data may be that these teachers' believe the textbook is always right and knowledge resides within the textbook. This would suggest a naïve realist position in that these teachers may hold a positivist view of the text as the source of truth and knowledge.

Discussions on the value and merits of science textbooks, suggests that the teachers perceive a good textbook as functioning almost as a surrogate teacher providing pedagogy, behaviour management and science content. Comments such as, "if you're away you can leave work from the text", "if they're not behaving you can say right open your books and do such and such" and "[we need a textbook] that's got a bit of everything in it for all learners, low, middle, high ability" support this idea.

During this time the difference in beliefs between Patty and Tina concerning the qualities of a good textbook became more evident. Both were looking for a textbook that reflected their pedagogical values, Patty was looking for abundant content and explanations, and Tina was looking for many activities to actively involve students in the learning. While it is certainly true that Patty has more science teaching experience than Tina and was drawing on that experience in her selection of a textbook, at this stage in their teaching careers Patty and Tina held different beliefs about what are effective learning experiences in science. Abd-El-Khalick and Lederman's (2000) assertion that the teacher's choice of teaching and assessment strategies are related to their image of science and what counts as knowledge, seems pertinent and suggests that the teachers chose a textbook that reflected their image of effective science education. Thus, the choice of textbook is crucial to the manner in which science is implemented at the classroom level in junior secondary classes in this school.

TERRARIUM PROJECT AS A WAY TO ENHANCE THE SCIENCE PROGRAM

Two professional development days with the researchers were held at the school early in 2000. The year's scope and sequence was derived as a combination of the old science program and the new textbook. Thus, the 'new work program' was not new; rather, it was constructed by auditing past programs. During the planning days, the teachers planning their science units by selecting the relevant core learning outcomes (CLOs) for each term, canvassing possible ways to assess each outcome, and identifying learning experiences that could develop the facts, concepts and processes embedded in the CLOs.

Tina had previously indicated that she would plan directly from the textbook and started by scrutinizing the textbook to identify the CLOs it addressed, as these were listed at the start of each chapter. After spending considerable time examining the textbook chapters, the CLOs linked to each chapter, and the syllabus, she decided that the textbook inaccurately assigned the CLOs to the chapters. Tina then determined the CLOs that she considered were addressed in each chapter. She realised that the textbook did not completely address what she considered to be the important learnings for the targeted outcomes. At this point, one hour into the planning session, Tina closed the textbook and it was not reopened that day. This action is contrary to Tina's previous planning and is especially pertinent, as all the teachers spent the entire previous day deciding on a textbook, deeming it crucial to the planning process.

In choosing a suitable assessment task, Tina decided that "something interesting, some type of project the kids could get into and enjoy doing" was needed. She arrived at the idea of a terrarium where the students could design, build, and study a terrarium of their choice. Tina decided that the project would enable teachers to assess students on *Life and Living* CLOs 4.1, 4.2, 4.3 and *Science and Society* CLO 4.2 with potential for some students to demonstrate *Life and Living* CLOs 5.1, 5.2, 5.3 and *Science and Society* CLOs 5.2 and 6.2 (QSCC, 1999). Tina devoted the remainder of the day to deciding the specifics of the task and developing an assessment task sheet. In response to Patty's decision that a written test of definitions and content should be included, Tina replied that this "wouldn't be necessary, the terrarium project will encompass any content assessment necessary". By day's end, a task sheet for the assessment task, 'The life story of my terrarium' was in draft form. It required groups of 2-3 students to design, make and evaluate a terrarium, that would survive for 28 days. Students were to maintain a logbook of descriptive, analytical and evaluative details of their terrarium, beginning with their initial design through to the end of the 28-day period. It was agreed that questions such as 'Are there any practical applications of this closed system?' and 'How can you apply the knowledge you have gained throughout the unit to real life situations?' should be added to extend students.

An interesting point to note is that Tina's approach to planning closely followed Piaget's learning theory, whereby she sifted through old ideas to see if anything matched the new situation. Appleton and Harrison (2001) refer to this behaviour as the "audit model", where teachers scrutinise past planning and teaching to identify known strategies that can be used or adapted in the new program. Tina's terrarium came from a prior experience she had enjoyed at school; so she extended and adapted it to fit the new situation.

UNDERSTANDING ASSESSMENT IN OUTCOMES-BASED EDUCATION

A recurring question from the teachers and the authors asked, 'How do we know if a student has met a certain CLO level?' Most teachers believe that only a pen and paper test will provide evidence capable of 'truly validating a students level'. These teachers focus on the assessment instrument as the determiner of a level, rather than the quality of the student response. As Spenceley (2000) explains "levelness does not come from the questions asked or the task set. It comes from the response provided by the student" (p.18). This view involves a mind set change for secondary science teachers who are used to tests comprising closed questions which provide information as to whether the student knows something or not. Tina's terrarium project illustrates how she was attempting to break out of this mould but was constrained by her colleagues to remain firmly within it.

The use of open questions such as those proposed by Tina for the terrarium project require analysis of student responses to determine the level the student is working at. The 'openness" of Tina's task was congruent with Spenceley's (2000) recommendations for effective assessment in an outcomes framework. Spenceley advocates using open questions and open investigations that provide students with opportunities to develop and demonstrate their conceptual understandings of the core learning outcomes.

An outcomes framework also implies the collection and monitoring of student work in progress and, traditionally, secondary science teachers have not explicitly devoted time to this task. Thus, the change from closed to open assessment tasks that Tina was attempting is quite novel. She drew confidence in her plans from the support she gained for her ideas during the professional development days. This supports Senge's suggestion (cited in Schofield, 1999, p.14) that "when people have to go through a period of profound change, they cannot do it in isolation – they must do it together" and this is a powerful argument for continuous support of teachers during curriculum change.

INSTRUMENTAL AND RELATIONAL UNDERSTANDING

We have suggested that teachers choose a textbook that matches their conception of science. Patty (Head of Department) devoted considerable effort to ensuring that the textbook contained what she believed were adequate content and explanation of key scientific concepts. This suggests that her goal for understanding in the classroom may have been instrumental (Skemp, 1976). Tina's interest in *Jacaranda Science* and her need for students to experience and actively participate in science suggests that she leans towards relational understandings. She is, however, constrained by Patty and the school's assessment practices that appear to reward instrumental understanding. Nevertheless, Tina planned to teach this unit in a way that fostered relational understanding. However, her actual teaching reflected both relational and instrumental goals and may have been her attempt to ensure that her students were not disadvantaged. The choice of textbook, the reasons provided and the assessments used in the terrarium unit suggest that most teachers at this school saw their role in the science classroom as teaching content knowledge rather than relational understanding.

As Skemp explains, there are many good reasons why teachers choose instrumental understanding – it is quicker, easier to teach, and more apparent. For teachers pressurised by an overcrowded curriculum, instrumental activities appeal as a way to meet timelines. Conversations with Tina and Patty showed that they both felt pressured to complete the course in limited time. We also found that teachers believed that instrumental understandings were easier for low achievers. Tina's comments indicate that she saw a need for both types of understanding in the classroom; however, whether or not she feels the need for instrumental understanding is a response to assessment pressures cannot be determined. Tina did not favour instrumental understanding for the ready feedback it provides her on her teaching. She professes that she does not "value regurgitation of facts and rules as an indicator of understanding". This suggests that Tina ascribes higher value to relational understanding, whilst teaching and assessing for both instrumental and relational understanding.

GAP BETWEEN IDEAL AND ACTUAL SCIENCE TEACHING

An anomaly existed between Tina's expressed mode of teaching in the interview and that observed during the terrarium unit. Although Tina asserted that covering all of the chapter content was not her teaching emphasis, in the implementation of the unit, textbook content was emphasised. Observations indicated that the main focus of lessons once the terrariums were built was the textbook content, and that the terrariums were relegated to lesson end periods and lunch times. This action may have resulted from the additional assessment tasks that Patty insisted be done so 'they had some marks'. Trying to accommodate 'old' and 'new' pedagogies introduces real teaching and learning tensions. It also reflects the real tension that can manifest between teacher beliefs and the practical constraints of student, parent and school expectations.

Tina's initial intent was to integrate assessment with the ongoing teaching of the terrariums using the students' logbooks. This approach is consistent with Sanchez and Valcárcel's (1999) recommendations for constructivist-based science teaching. However, Patty argued that the logbook was not a valid assessment task and as science head insisted that the teachers use the assessment tasks imposed after the unit's start. These tasks were content-laden and unrelated to the CLOs. These actions are consistent with Sanchez and Valcárcel's (1999) assertion that teachers use assessment predominantly to assign grades based on "the correspondence between the content taught and the knowledge acquired" (p.505).

Although Tina prefers interactive formative assessment, she did not capitalize on the opportunities to do this with the terrarium logbooks. Neither planned formative assessment (Bell & Cowie, 1999), nor interactive formative assessments related to the terrarium project were a significant part of the teaching of the unit. The reasons for this are unclear, however Black and Wiliam's (1998) contention that science teachers have an impoverished understanding of formative assessment may apply. How to best use logbooks for formative assessment remains an important issue for future research.

FORMATIVE ASSESSMENT AND DIALOGUE

As a way of motivating students and engaging them in working scientifically, the terrarium project was successful as indicated by the student comments below.

> *Yep. I think it was good, cause like it's more interesting than sitting in a classroom and just reading and writing things, whereas this time you actually get to experience it.*
>
> *It's better than doing an assignment or having to study for a test cause we're getting hands on experience instead of just sitting there writing out stuff. Like you're actually having a go.*

Student comments on the logbook indicated that they valued it as a learning tool.

> *You had to do observations, it wasn't as if you made it and ignored it. You had to do a log and this made you realise what was happening in it.*
>
> *... when you're thinking about what happened it all fits together when you look at the past .... cause you can look back at what you did and what happened.*
>
> Had to really *think* about what was happening....cause you could look back and see the changes.

Student conversations about their terrariums showed that they were actively involved in creating knowledge.

> *A home for animals that you have to try and make it like their habitat and where they live. I think she also said it keeps the air in. Like the plants produce water when they respire and it forms condensation on the gladwrap and drops back in so you close it off to keep the moisture and oxygen the plants give off in the terrarium.*
>
> *It's like a biosphere and a biosphere's exactly like a terrarium only bigger, closed off and everything has to survive in it.*
>
> *We did some things wrong and we didn't have enough plants and we think the plants we had weren't actually the ones the caterpillars eat and that's why they died.*
>
> *We put a cactus in ours as we weren't sure how much H_2O was gonna be in there, and we thought a cactus doesn't need much H_2O so that's why we put it in. As it'd have more chance of surviving the 28 days.*

The students also had some concerns with the terrarium project and these mirrored the concerns of the teachers.

> *Like Amy had a good one with a goldfish and like something happened to the water and it died. I think there was no air in it like no oxygen left, they had to just leave it there and like all the skin was flaking off it and they had to watch it decompose.*
>
> *Didn't like watching animals like the goldfish die.*

Student responses to an inquiry as to whether goldfish were suitable for a terrarium provided further support to the assertion that meaningful learning was occurring for the students.

> *No, cause they need oxygen in the water, like from a bubbler and you have to change the water.*
>
> *... you have a responsibility to make sure they're treated properly and they don't die ... once something goes from an environment it all just collapses.*
>
> *Like you've got to try and made the terrarium as much like the environment as possible like the balance, so it's self-supporting with oxygen and food.*

Although these comments indicate that the terrarium project engaged students in working scientifically and creating knowledge, as an indicator of outcome attainment it was only partially successful due to the way it was implemented in the classroom. Observations pointed to a lack of both adequate formative assessment processes and interactive two-way dialogue (Friere, 1973) to support the concept teaching. This may explain why the teachers reverted to the textbook to supply the content and understandings that could have been drawn from the student terrariums.

The opportunity for discussion in the classroom to be built around the student's terrariums and to situate the relevant content in context was not taken up by Tina or the other teachers. For example, during one of our meetings, Tina spoke about how she was still troubled by the death of some of the animals used in the terrariums: "the death issue is still a concern". She had not fully resolved the conflict she felt over her moral and ethical responsibility to the animals with the potential learning to be gained by discussing this issue with the students. However, she continued to say that she felt that it was not acceptable to put animals such as frogs, lizards, and goldfish in small terrariums and that it amounted to cruelty. It is significant that she had not discussed how she felt about animal cruelty with the students. This was an excellent opportunity to raise the controversial issue of the use of animals in the work of scientists and to perhaps discuss the ways in which scientists in the workplace deal with these issues. This would have facilitated the type of dialogue advocated by Freire (1973) that is meaningfully based on student concerns.

Tina reported that some discussion of class group terrariums had occurred in response to the death of some of the animals, such as "*the animals need oxygen and the plants supply this, and the food source is always going to be a limiting factor and that's why you need small animals*". However, there were no in-depth discussions of the progress of the terrariums due to time constraints and the need to cover the textbook chapter. It was largely left to students to make sense of their terrarium observations. Students were not required to discuss or account for what they wrote in their log books.

Dialogue based on empathy and two-way communication as advocated by Freire (1973) was not consistently evident in the classroom in relation to the terrarium unit. This reinforces the crucial role teacher's play in science reform, and supports Black and Wiliam's (1998) contention that the success of reform agendas depend on changes to factors inside and outside the classroom. Reform must be complemented by substantial support for classroom teachers. Indeed, this support needs to address the actual business of teaching, implementation and assessment of units of work. Inputs, from reform agendas like the new QSCC (1999) syllabus, are not effective in changing the learning outputs unless change in classroom practice is supported throughout the change period.

SUMMARY

The terrarium project initiated by Tina embodied many of the attributes of the ideal picture of science teaching described by Goodrum et al. (2001). It was enjoyable, related to the personal experiences of students, centred on investigation, explanation and testing of ideas, and students had ownership of the decisions regarding their terrariums. The proposed assessment promoted learning and was designed to integrate with and complement teaching.

However, for various reasons the "ideal" unit planned by Tina was not congruent with the "actual" unit implemented. Constraints that contributed to the gap between the ideal and actual were pressure from Patty favouring a content dominated teacher-centred approach, and assessment practices promoting rote learning and instrumental understanding. Despite Tina's commitment to change, she was constrained to implement the terrarium unit in a traditional way with closed, end-on assessment techniques. This made it necessary for her to focus on the chapter content so that her students were not disadvantaged by the assessments that replaced the logbook. This highlights the mismatch that occurs when teaching is constructivist and relational and assessment is rote or instrumental.

Another crucial factor contributing to the gap between the intended and achieved unit was the lack of sufficient formative assessment and dialogue in the classroom related to the terrariums and the logbook assessment task. This highlights the need for substantial support to be given to teachers on how to improve the quality and variety of formative assessment used in their classroom teaching. The quality of teacher-student interaction and dialogue is a crucial element of this approach to teaching for outcomes and conceptual understanding.

DISCUSSION AND CONCLUSION

This research set out to contribute to the existing body of knowledge on effective science teaching in schools – especially where an outcomes-based syllabus replaces a content and objectives dominated syllabus. The project investigated the planning experiences of science teachers in a large secondary school and found that teachers seeking to change their practice had limited success in moving towards open-ended investigations like those that recommended in the QSCC syllabus. Further, science teachers' understanding of formative assessment processes and how it can be used to support and enhance the quality of teaching and learning in classrooms remains impoverished.

This study suggests that changes to inputs alone, such as disseminating a new syllabus to schools, will not yield enhanced relational learning nor will it promote student interest in science. Science unit planning, teaching, investigations and assessment should be congruent and the cooperating teachers should ensure that they agree on the selected content and pedagogy chosen for in-class use. These findings agree with Sanchez and Valcárcel (1999) with respect to planning and with Bell and Cowie (1999) with respect to assessment. The study also shows that professional development that is not school and classroom based will not achieve the critical partnerships needed for curriculum change to succeed. Sustained professional development that motivates teachers to implement 'ideal' science units in the classroom is required. In addition, teachers need expert support when writing open-ended assessment tasks and they need assistance with the formative assessment processes required to implement constructivist units of work.

Another difficulty appeared to be the writing of the criteria to judge whether or not an outcome was demonstrated by a student. It seems that teachers lack confidence in the criteria they write for the outcomes they teach and this contributed to this study's teaching and assessment anxieties. To validate whether an outcome has been demonstrated, teachers need to feel confident that the student knows and can do what is asked by the syllabus and that the student is able to demonstrate the outcome in several contexts. This is a professional judgment about which science teachers seem anxious. Perhaps this is due to their lack of experience in making professional judgments; or their past professional judgements have not been sufficiently valued to instil in them the confidence to make professional decisions and stand by these decisions. Many science teachers still assess using 'numbeers' and remain unaware that the process of equating a number to a grade is itself a very subjective process.

The central role that the textbook plays in this school in determining and limiting the nature of the learning experiences in the classroom is evident.

The findings also support the assertion that the choice of textbook by teachers reflects their scientific beliefs. This implies that many of the teachers hold a traditional view of science as a body of knowledge to be passed on to others. Those teachers attempting to move towards a contemporary view of science – that knowledge is fluid and is negotiated in research communities – are inhibited by the existing structures and practices.

Teachers aiming at relational understanding are compromised by assessment techniques focusing on rote learning of content. Still, as long as the assessed content is directly linked to the textbook, teachers will feel pressured to cover all the textbook content so that their students are not disadvantaged. But even this approach disadvantages students because it prevents the open investigations Goodrum et al. (2001) state are essential if reform is to be realized.

CONCLUSIONS AND RECOMMENDATIONS

This study and the literature indicate that some teachers need a richer and deeper understanding of the nature of science and how scientific knowledge is constructed by students and teachers in science. Science knowledge in textbooks can be treated as truth and absolute rather than as tentative and changeable in response to new ideas and technologies that test old explanations. When teachers with a content dominated view of science are asked to adopt outcomes-based courses, support is needed with planning, teaching and assessment. Collaborative partnerships are effective; however, such partnerships can be divisive and counterproductive if not all members of the teaching team hold similar views. It is recommended that a whole science staff approach be taken and that considerable time is needed to discuss values, negotiate shared meanings and resolve differences when curriculum change is attempted.

These research findings have implications for future professional development programs aimed at changing the model of science teaching in junior secondary science. Despite Tina's enthusiasm, interest and commitment to change, the eventual implementation of the terrarium unit did not resemble the intended picture. As a way of motivating and engaging students to work scientifically, the terrarium unit was successful. Student responses overwhelmingly indicated that they enjoyed being actively involved in the learning process and they constructed useful knowledge of the concepts involved. However, as a way of making science more relevant and meaningful it was only partially successful as the evidence suggests. Despite opportunities to situate the unit learning around the student's terrariums, the science teachers felt compelled to follow the textbook chapters and cover all the prescribed content. It is evident that teachers need time and support to reduce their reliance on textbooks and to collaboratively plan and implement rich, relevant and exciting tasks. It is likely that these findings will apply in other schools

As Black and Wiliam (1998) argue the "overarching priority has to be to promote and support change within the classroom" (p.14). Changes to curriculum documents will only be as effective as the support that is provided for teachers to implement them. Significant change will only be realized when what happens in the classroom is addressed. The findings of this research support Black and Wiliam's (1998) call for professional development aimed at assisting teachers to incorporate the pedagogical principles underlying new syllabuses into their own patterns and modes of classroom practice. Goodrum et al. (2001) and Black and Wiliam (1998) both recommend that professional development be school-based and directly related to the business of teaching and learning in the classroom.

It also is recommended that future research should focus on researching teaching in ways that are both accessible to teachers and useful to their work. Ways of overcoming the constraints felt by classroom teachers to reform changes need to be identified along with initiatives that empower teachers to move towards a more critical approach to their work as leaders in learning.

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