Beginning elementary school teachers and the effective teaching of science

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Abstract

Many factors influence the teaching of science by beginning teachers in elementary schools. They have to confront a myriad of daunting experiences and tasks in their first few weeks at school, and on top of that are expected to teach a comprehensive curriculum including science with its attendant demands for a constructivist approach to teaching and learning, cooperative group work, and reliance on resources. This paper describes the experiences of four beginning teachers as they worked their way through the first year of teaching, with an emphasis on analyzing the influence of these experiences on their planning and implementation of science lessons in the classroom. A theoretical framework of self-efficacy, and related attitudes and motivation to teach science, is used for the analysis. Implications for the design of science education courses within preservice programs, and the development of induction programs for beginning elementary teachers, to ensure teachers' long term commitment to the effective teaching of science, are discussed in the paper.

Introduction

Arguments supporting the need for science education in elementary schools have been based on the desire to develop in students the knowledge, reasoning and problem solving skills required for a rapidly changing and technology based society (American Association for the Advancement of Science, 1993; Australian Science Technology and Engineering Council, ASTEC, 1997; National Science Teachers Association, 1992). While survey data do indicate a closer accord between existing reform ideas and science education in some areas, there remain sources of concern for science educators (Weiss, 1994). For example, less than a third of elementary teachers felt well qualified to teach science (Weiss, 1994), many classroom teachers felt uncomfortable and unqualified when asked to teach science (Abell & Roth, 1991), and many experienced teachers, along with teachers who had recently completed their preservice education, expressed a lack of confidence in their ability to teach science (ASTEC, 1997). The important objectives for science education embodied in national statements such as *Benchmarks for Science Literacy: Project 2061* (American Association for the Advancement of Science, 1993) and *A statement on science for Australian schools* (Curriculum Corporation, 1994) will not be achieved if elementary teachers continue to feel inadequately prepared, and lack the confidence, to teach science effectively in elementary schools.

This study is significant in that it focuses on the behaviors and experiences of beginning teachers as they face the task of teaching science on a regular and extended basis for the first time. Teachers are confronted by two major issues when they start teaching. On the one hand there is the sense of freedom and enthusiasm associated with the realization of their goal to become teachers. On the other hand, there are concerns associated with a sense of self and becoming a member of the profession (Huberman, 1995), being accepted by peers, administrators, students and parents, immersion in the school culture, settling in to teaching, and survival. Hence, teachers' behaviors, values, and volition to act may be cultivated or inhibited during their early career. The identification of factors that motivate teachers to persist with, and become effective teachers of science, or withdraw from the teaching of science, will assist science teacher educators to improve preservice and inservice teacher education programs.

The effective teacher of science

The nature of a preservice teacher education program and the expectations implicit in that program represent a useful starting point for examining the attributes of the effective teacher of science. Science content and methods courses in preservice programs may amplify broader generic course content concerning learning and development, curriculum, social issues and policy by addressing issues such as the nature of science and scientific knowledge; rationales for teaching science; approaches, strategies and techniques for teaching science, for example, a constructivist inspired approach; students' learning in science; and ways of evaluating learning outcomes (Appleton, 1997; Watters, Ginns, Enochs, & Asoko, 1995). There is an expectation that preservice teachers should develop a comprehensive science knowledge base (Borko & Putnam, 1995), concurrent with a deepening understanding of the links between the content knowledge and the teaching and learning process, or pedagogical content knowledge. It is also expected that preservice teachers should develop a sound understanding of pedagogy (Shulman, 1987) and along with the opportunity to apply successfully their understandings and skills in practical field based experiences. If a teacher's preservice experiences are grounded in contemporary theory, if the learning experiences are relevant and if the nexus between theory and practice is addressed, then one would expect the beginning teacher to be effective.

Contemporary science education theory suggests that students construct their own understandings of scientific phenomena within a social context (Driver, Asoko, Leach, Mortimer, & Scott, 1994), hence it is expected that effective beginning teachers of science would plan and implement science lessons in a manner informed by constructivist views of learning. In practice, the learning environment and models of practice established in classroom situations may complement and reinforce theory experienced in preservice education in a variety of manifestations, or in worst case scenarios, contradict theory. It is important to recognize that beginning teachers' theoretical understandings and knowledge, personal beliefs and intentions may, in fact, be tempered by the realities of adaptation to the class and school and the requirement to teach specific domains of knowledge.

Based on contemporary ideas about the teaching of science, it is suggested that the effectiveness of classroom science teaching may be analyzed using an interpretive framework which takes into account the beginning teacher's preparation and implementation of lessons and the classroom learning environment established by the teacher. In this study, an analytical framework was synthesized from the work of Neale, Smith and Johnson (1990), Kruger and Summers (1993), Taylor, Fraser and White (1994), Bybee (1993) and Yager (1991).

Neale et al. (1989) and Kruger and Summers (1993) developed criteria for judging the effectiveness of planning and teaching of science in elementary schools. The criteria established were: (a) conceptual accuracy, (b) conceptual emphases, (c) extent of the use of appropriate representations such as analogies, examples or metaphors and any linkage of these to the students' interests and everyday experiences, (d) appropriate tasks or activities, (e) the use made of students' ideas, (f) science teaching strategies, (g) flexibility, or the teacher's ability to respond to various situations and opportunities and, (h) appropriate differentiation and clarity of progression through the teaching sequence. These criteria were used as part of the analytical framework.

In addition, teachers should establish classroom learning environments that are sensitive to constructivist philosophies in order to cater effectively for students' learning. The analytical framework used to examine classroom teaching also included criteria identified by Taylor, Fraser and White (1994) as being important elements of a constructivist learning environment, that is, (a) making science seem personally relevant to the outside world, (b) engaging students in reflective negotiations with each other, (c) inviting students to share control of the design, management, and evaluation of their learning, (d) empowering students to express critical concern about the quality of teaching and learning activities, and (e) allowing students to experience the uncertain nature of scientific knowledge. Criteria developed from the instructional approaches advocated by Bybee (1993) and Yager (1991), who endorsed specific strategies to engage students in social learning and articulated particular roles for teachers and students, also informed the development and use of the analytical framework. A similar analytical framework was used to analyze the planning and implementation of a science program by an experienced teacher during a trial curriculum development project (Watters & Ginns, 1997a).

Theoretical background

Beginning teachers' persistence with teaching methods embedded in contemporary science education theory and their willingness to establish a constructivist learning environment may depend on the presence or absence of feelings of success with the planning and implementation of science programs incorporating these strategies. If teachers have initial successful experiences in teaching science, Bandura (1986; 1995) would assert that they should develop high levels of self-efficacy thus motivating them to persist with the task. In addition, Bandura asserts that observation of credible role models and verbal persuasion may also assist in the development of high levels of self-efficacy beliefs. Bandura's self-efficacy theory, therefore, provides an appropriate theoretical background for examining the general beliefs and actions of teachers (for example, Greenwood, Olejnik, & Parkay, 1990; Watters & Ginns, 1997b), and can help account for changes in those beliefs. Teachers' personal beliefs about their ability to teach and their beliefs about the effectiveness of their teaching on students' learning are two factors which can be derived from Bandura's (1986) work.

Based on Bandura's work, Riggs and Enochs (1990) postulated that two factors, personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE), may affect science teaching behaviors. The factors were derived from a quantitative research study into teachers' self-efficacy beliefs designed to validate the Science Teaching Efficacy Belief Instrument (STEBI-A). The factors identified by Riggs and Enochs, and domain specificity of those factors, are in accord with Bandura's (1986) definition of self-efficacy. The Science Teaching Efficacy Belief Instrument is, therefore, a useful tool for monitoring teachers' personal science teaching self-efficacy at various stages of their career.

This study reports the experiences and behaviors of beginning teachers as they immersed themselves in their new role, confronted a range of daunting experiences and tasks, and responded to the expectation that they should teach science, with all its attendant difficulties, in elementary school. Bandura's self-efficacy theory was used to interpret the teachers' personal beliefs and actions and changes in those beliefs and actions related to science during the study. The analytical framework was used to examine the teachers' planning and implementation of science lessons and establishment of a constructivist learning environment as part of their teaching. When considering both perspectives together, it was predicted that beginning teachers with high levels of personal science teaching self-efficacy would implement programs that reflect contemporary science education theory and the establishment of a constructivist learning environment for students.

The objectives of the study were:

a. to examine the relationship between beginning teachers' personal science teaching self-efficacy and the nature of science programs they implement;
b. to identify factors that contribute to the effective teaching of science by beginning teachers;
c. to identify factors that will sustain beginning teachers' long term commitment to the teaching of science in elementary schools.

Tentative assertions will be developed from the data concerning beginning teachers' professional growth towards becoming effective teachers of science. The study is an extension of the work of Riggs and Enochs (1990) and our own studies of changes in teachers' sense of efficacy in teaching science (Ginns, Watters, Tulip, & Lucas, 1995; Watters, Ginns, Enochs, & Asoko, 1995; Watters & Ginns, 1997a, 1997b).

Design and procedures

The design of the project was a multiple case study approach (Erickson, 1986; Miles & Huberman, 1994) that involved the observation and recording of teacher behaviors in science.

Participants

The participants in this study were four female beginning teachers, assigned to elementary schools in Queensland in 1996. Performance on the STEBI-B test administered to a group of graduating preservice teachers (N=61) in October 1995 was used as the main criterion for the selection of the participants. The desired cases were selected on the basis of PSTE scores that were representative of high and low scores of the whole group (Table 1), in order to be able to examine the behaviors of teachers with contrasting science teaching self-efficacy beliefs. The cooperation of the participants and convenience of the respective school for travel from the researchers' home base of Brisbane were also factors that influenced the selection process.

The Context

The participants in this study enrolled in a four year preservice Bachelor of Education (Primary) program in 1992. During the program the preservice teachers were surveyed to determine a range of beliefs including self-efficacy (Watters et al., 1995). All preservice teachers completed a core science content course (Science Foundations) in the first year of the program and a core science methods course (Science Education) in the third year of the program. The preservice teachers also completed a number of field experience sessions of various forms and duration. In the final semester, prior to completion of the program in November 1995, all available preservice teachers from a cohort of 98 were surveyed to determine their self-efficacy beliefs according to STEBI-B. After completion of the program graduates were offered teaching appointments in schools for the year commencing in January 1996.

Many teachers in their first year of teaching are assigned by the Department of Education, which has statewide jurisdiction, to schools located in numerous towns and rural areas throughout Queensland. Employment is competitive and based on criteria that include performance in preservice studies and an assessment conducted by the employing authority through interview. However, most graduates find employment eventually, either with the State Department of Education, or in private schools. Science is a key learning area in the elementary school curriculum. It is an expectation that all classroom teachers should teach science for a minimum of 1 to 2 hours each week.

The locations of employed teachers were identified at the beginning of the school year with the cooperation of the State Board of Teacher Registration, an accreditation authority with which all teachers must be registered.

Two visits to schools were undertaken. In the first visit a semi-structured interview was conducted with each participant. The second visit was conducted at the end of the year and included observation of a science lesson and a semi-structured interview with each participant. Other forms of communication were used with the participants at various times during the year and discussions were also undertaken with school administrators.

Reassessment of each beginning teachers' sense of self-efficacy using STEBI-A (Riggs & Enochs, 1990) was conducted at the mid-point of the first year of teaching. A further administration of STEBI-A was conducted in their second year of teaching along with the completion of the open-ended survey questions.

Data Sources

Qualitative and quantitative data were collected in a number of ways.

<u>Semi-Structured Interviews:</u> Beginning teachers' personal reflections on their own schooling and university experiences, tacit or prior knowledge, and other contextual issues were explored in the interviews. Their perceptions of school and science classroom contextual factors that have impacted on their teaching were also probed. Evidence of effort and perseverance was sought, and teachers' perceptions of intrinsic and extrinsic obstacles to teaching science were documented.

<u>Observations:</u> Observations of classroom practice were recorded in field notes supplemented by techniques such as videotaping, audiotaping, and photography. Transcripts were prepared from the audiotapes and analyzed for patterns of behavior. The observations were analyzed for features which met the criteria included in the analytical framework described previously, with a focus on the analysis of the classroom strategies implemented by each beginning teacher, for example, the use of a constructivist approach (Kruger & Summers, 1993), and establishment of a constructivist inspired learning environment (Taylor, Fraser, & White, 1994). When processing the data using the analytical framework, it was not expected that each beginning teacher would have to meet all the criteria to be deemed an effective teacher of science, an assumption in accord with the views of Sternberg and Horvath (1995) about expert teachers. Sternberg and Horvath argue that there is no well defined standard that all experts meet, instead there should be a prototype view of expertise that incorporates standards, but allows for variability in the profiles of individual experts.

<u>Survey Questions:</u> A survey instrument consisting of open-ended review questions was administered. The questions probed teachers' beliefs about teaching science, whether their beliefs had changed and, if so, what had initiated any change, and what constraints continued to impact on their teaching of science.

<u>Psychometric tests:</u> Preservice teachers' efficacy beliefs in the specific area of science were measured using the Science Teaching Efficacy Belief Instrument (STEBI-B), designed by Enochs and Riggs (1990). The instrument consists of two scales, the Personal Science Teaching Efficacy (PSTE) scale and the Science Teaching Outcome Expectancy (STOE) scale. The beginning teachers' self-efficacy was assessed with the STEBI-A instrument, an instrument designed for practising teachers by Riggs and Enochs (1990). This instrument also consists of a PSTE scale and a STOE scale. The PSTE scores of preservice teachers (STEBI-B) are a measure of their anticipated beliefs about their ability to teach science and the STEBI-A scores represent their actual beliefs about their ability to teach science.

Interpretations of qualitative data were produced in text as narratives and reviewd by each participant (Guba & Lincoln, 1993).

Findings

The personal science teaching self-efficacy (PSTE) scores on STEBI-B and STEBI-A of the four teachers are presented in Table 1. The mean score for the 1995 group of graduating teachers on the PSTE scale of STEBI-B was 48.9 (SD 6.6). The administration points of STEBI-B and STEBI-A are noted in the table. The major emphasis in this paper is to examine the relationship between beginning teachers' personal beliefs about their ability to teach science and the nature of the science programs they plan and implement, hence no data for STOE are reported.

Table 1
Beginning Teachers' Personal Science Teaching Efficacy Scores on STEBI-B (Preservice) and STEBI-A* (Inservice)*

Teacher	1992 (Feb) Preservice	1993 (May) Preservice	1995 (Oct) Preservice	1996 (Jun) Inservice	1997 Inservice
Rhian	42		36	34	56
Kirren	52		38	42	47
Welena	51	55	52	52	56
Ellen	50	42	55		51

N.B. * STEBI-B; STEBI-A: PSTE score out of 65

A profile was generated for each participant from the qualitative data. Each profile describes the respective teacher's background experiences in science courses, beliefs about teaching science, perceptions of her own classroom practice, and views about the main factors impacting on the teaching of science in her school. The profiles include an analysis of the effectiveness of each teacher's science teaching based on the use of the analytical framework developed from the work of Neale *et al.* (1989), Kruger and Summers (1993) and Taylor, Fraser and White (1994). The four profiles are now presented.

Rhian

Rhian was a Year 3 teacher at a large coastal school 100 km north from Brisbane.

As a student herself, Rhian could recall doing some science herself in Year 6 where there were three classes and the teachers would swap around teaching tasks, with one teacher taking all the classes for elementary school science. High school science involved experiments, learning from the text book, going into the exam, writing the answers out and getting good marks for them. She felt that she didn't have to understand the content, just learn it and regurgitate the answers. When Rhian left school she believed she knew quite a lot about science because she had studied biology and chemistry.

The core science content course at university made Rhian realize how much she did not know in terms of explaining phenomena and providing reasoning for her answers. During the course Rhian believed that she did not know anything at all, declaring:

> I'm trying to teach it and I can't explain it and I can't answer the questions about it as well, and it really pointed out to me how much I didn't know. And I think I got scared as well after that, thinking, oh it's just too much, just too much, I won't even bother or try. Yeah, so, it was difficult.

Although she felt intimidated by one of the university teaching staff in the science content course, she could remember some of the experiments as being very interesting. She was not courageous enough to ask questions and find out why experiments worked. However, Rhian considered that she made good progress in the course. This belief may have been due to the fact that she joined a group of about five or six preservice teachers who participated in regular study sessions where they shared perceptions and ways of explaining the science concepts in the science content course. Occasionally, impromptu sessions were held when the group wanted to find an answer to a specific question or problem. They saw the study group as a way of helping each other to organise their thoughts. Rhian considered that the study group did a lot of work together during the semester and provided each other with much scholarly and emotional support. The sharing and helping aspect was particularly important to Rhian, although it took a lot of perseverance for her to complet the course

She indicated that she would love to do the course again, if only to get the information and be able to stand up and say that she did not understand and ask "Can you explain it to me?" With this background Rhian felt that she would have been better equipped to go into her own class and explain why experiments did, or did not, work. Rhian reflected similarly on her other university courses where so much work was covered that it was difficult, at the time, to decide what was of long term relevance to her teaching career.

Rhian had limited recall of the Science Education course, just remembering looking at curriculum materials and the science resource books. In field experience sessions, Rhian remembered that, on most occasions, her supervising teachers insisted that she teach their science programs for them. She did not mind this task and the teachers usually had the resources available. Rhian would take the class and the students would have an overload of science for three weeks. Most of the science programs were taught from the relevant Queensland science syllabus and other resources. She could not recall seeing any supervising teacher take a science lesson.

On commencing full-time teaching, Rhian believed science was one of those areas you had to teach, and you survived by relying on the science syllabus and other resources. However, it seemed to Rhian that she had a disaster every week, particularly when an experiment wouldn't work. She developed a strategy of turning the situation around and asking, "Well how come it didn't work, what could we do, what could we have done to make it work? What was supposed to happen and why didn't it happen?" Creating a problem solving exercise from a potentially negative situation appeared to be motivating for the students. Rhian and her students became immersed in the problem, had fun doing the experiment, and the students appreciated the chance to explain why an experiment did not succeed. Rhian observed that a few students enjoyed conducting experiments at home and reporting back to her what they had done. In contrast, some students never made a prediction in fear of getting it wrong. Therefore, Rhian attempted to foster a supportive learning environment that would cater effectively for the variety of understandings, skills and attitudes that she described. This was also done, in part, as a reaction to her own negative personal experiences in the core science content course at university.

Finding resources for teaching science, and how to borrow them, were on-going problems for Rhian: The problems added to the pressure of teaching because "There were just so many other things to think about and setting up your classroom." Rhian expressed concern about approaching fellow teachers for resources and other forms of assistance, although some teachers, especially her Year 3 colleagues, offered help:

> We all taught the same unit for the first month of school so then we used the same materials and just passed them around and that really helped me a lot because and I think they did it for their sake as well because we all went into new classrooms and had nothing so then it was just decided on to do this and I thought, oh, that's a really good idea because it just was a huge help. And the lady who teaches the class next door to mine she's got grade 3's as well and we've often taught the same units just, often a lot of the time by chance but, and she will give me things that she's done and, yeah, help me out too.

She considered that her Year 3 colleagues were teachers who wanted her to improve and succeed, and they enjoyed being able to help out. Rhian noted that she was inconvenienced by having to teach in a partially completed and unfurnished building in the first few weeks of teaching.

Her other major concerns were associated with the progress of the students and the beahior of parents. Firstly, she did not want her students to proceed to Year 4 without being able to meet all the Year 3 requirements. Rhian was worried that anything less, in terms of student performance, would reflecting poorly on her own teaching capabilities. Secondly, parents were very guarded and watched her very closely at the start of the school year. After a few months she noticed gradual changes in the parents who started to display more profeesional and personal trust in her. Unfortunately, university courses had not taught her how to cope with parents and other day to day issues, and she conceded that "You'd have to learn it by experience as well, and, that isn't a concern (for me) any more."

Rhian had not undertaken any inservice in science since starting at the school. She suggested that she would like to look at some of her weaker areas next year and follow up with some form of professional development. Science was an area Rhian wanted to know more about because she enjoyed teaching it. Specifically, she wanted to learn more about different approaches to teaching science, and find additional ideas and activities for inclusion in her science program.

When reviewing her first few months of teaching she reflected that

> The good thing about the whole uni course in general is that it made me feel as though I could do it and so then that really helped me being able to walk in here and think okay now I'm a teacher I'm not a student any more I can do this.

In the second interview, Rhian observed that she always prepared hands-on, activity work in science because the students were more motivated when getting up and doing things. The students won't even listen if the teacher was just talking. One group of boys stand and watch if they are not properly engaged in the tasks and another child, in particular, always wants to know "Why are you doing this and how are you going to do this?"

Recalling her worries about getting everything right at the beginning of the year, Rhian had developed strategies for explaining herself to the students so that they understood what the lessons were all about and:

> Then letting them know that I don't know everything about it and I'll try and give them basic information but it's not always going to answer all of their questions that they might have and they might need to find out things for themselves, or I'll find it out for them later, and let them know and they're used to that now.

Rhian again referred to the lack of resources for science, citing one of the major problems as being the large growth in student population at her school, some 300 additional students each year. She resorted to providing materials herself and getting students to bring resources from home.

At the time of the second interview Rhian was teaching a science unit about *Weather* on a rotation basis with the other Year 3 teachers. The unit involved a visit to an interactive museum in Brisbane and included a talk from a high profile weather reporter from a local television station. The visit and talk were used to motivate students in subsequent lessons. Rhian had done a lot of group work with the students but had not settled on any particular structure for the groups. An important focus for Rhian's teaching was to place an emphasis on developing students' conceptual understanding because:

> It's basic concepts that you're teaching, and then it gives - they get a bit of an interest or they're learning something about why things work and why things happen. And then when you get to high-school and you have to do science, you've got something behind you to - to think back and "Oh, I remember doing that." or "Yeah, we learnt about that in grade 4, or - just something."

Overall, Rhian's confidence had grown during the year. She was now more organized in terms of lesson planning and acquiring resources. She always reflected on her science lessons and made appropriate evaluative comments about each one. Her involvement in the research project was a stimulus for attempting the unit on *Weather*, a topic Rhian believed she knew little about.

The lesson taught by Rhian was one from her current unit on *Weather*. The conceptual emphasis on the water cycle was evident throughout the lesson culminating in the completion of questions to be answered on a worksheet. The students were asked to write up their responses by imagining that they were a raindrop and explain what happened to the raindrop at each stage of the water cycle. The strategies used varied from whole class discussion situations to collaborative group work on the construction and calibration of the rain gauges, and individual work on the worksheet. An important skills component was included at the beginning of the lesson to demonstrate how the students should proceed in the calibration of the rain gauges. When group work was being carried out, the students engaged in discussions, but mostly the work was individual. Rhian provided attention and guidance to individuals and groups. The lesson reflected clearly the important issues raised by Rhian in the interviews, in particular, her desire to foster a positive learning environment for the students, the inclusion of hands-on activities to ensure that the students were fully engaged so that science would be fun for them, the use of everyday, easy to acquire resources, and the 'raindrop' to stimulate students' thinking about the concepts..

On examining Rhian's beliefs and attitudes to science a pattern can be observed. At school she believed she was a successful student of science on the basis of examination results and a study strategy that relied on rote learning. However, her lack of intrinsic interest in science at school may account for her initial, relatively low PSTE score of 42 on STEBI-B (Table 1). Rhian's introduction to a core science content course oriented towards understanding of concepts, rather than rote memorization, shook her confidence. Other compounding factors such as a personality clash with a university instructor further alienated her from science. Subsequent studies in the Science Education course, in which curriculum issues were explored, failed to generate any positive impact. The decrease in her PSTE score from 42 on entry to university to 36 at graduation supports these observations.

Clearly, Rhian possessed other attributes such as a desire and will to improve her teaching of science and her involvement in the study itself attests to an interest in her own professional development. Although no mentor program was available for beginning teachers, the school environment in which she found herself as a novice teacher supported her intentions. The climate of the school was positive in that both the Principal and Deputy displayed genuine concern for her as a beginning teacher and her Year 3 colleagues provided her with considerable support. It was clear from the interactions she exhibited with parents, seen by the researchers during school visits, that she also had gained their confidence. The teaching episode that was observed indicated she was able to implement a science program that was genuinely interactive and encouraged students to discuss, question and engage in the active learning of science. Her classes were fun for the students to be a part of. Because the students responded positively to this approach, one would expect conditions were achieved that would enhance her confidence and sense of self-efficacy. Her PSTE score on STEBI-A (Table 1) during the initial phase of teaching was still low (34) but a marked change can be seen in the follow-up survey conducted in the mid-point of the second year (56). Further evidence in support of this marked change is contained one of her responses to the survey questions:

> I believe science is more important than I did last year. Children need to be doing some science from year one. I am much more confident and enjoy teaching science.

An interesting feature of Rhian's beginning experiences relates to her initiative in meeting the challenges. Despite her low sense of self-efficacy on leaving university, concerns about her knowledge and ability to teach science and situational constraints, she persisted in teaching science, trialing different ideas and improving her teaching. The salient factor influencing Rhian's growth appeared to be the level of support and reinforcement she received, which was manifested through the activities of her principal and fellow teachers.

Kirren

Kirren was a Year 7 teacher at a large metropolitan elementary school.

In the first interview with Kirren she recalled that her experiences in upper elementary school involved a lot of copy work from the blackboard and very few hands-on activities. On one occasion her teacher actually made an electric circuit and demonstrated it himself without letting the students use it. In high school Kirren studied multistrand science, which she described as bits and pieces of science content from all over the place, lacking structure and coherence. Kirren left school after Year 10, and worked for four years before returning to study Year 11 and 12 biology at a secondary college for adults. She enjoyed the biology because it had plenty of practical, hands-on work.

Kirren recalled the core content course in her preservice teacher education program, particularly the compilation of a number of experiments into a folio, which she continued to use in her teaching. Working collaboratively with a partner in the content course was of benefit to Kirren. She also worked with the same partner in a child study assignment for the Science Education course drawing attention to a number of positive features of that assignment:

> Yeah, I interviewed my cousin on her understanding of temperature, and cold and hot, all that sort of thing, yeah that was good. I enjoyed actually interviewing a child because she surprised me, because at that stage you have no idea of what perceptions children have of science or anything really, and she was in grade 2, I think, at that time, and just seeing what connections she was making was really quite interesting. So in terms of practical, real hands-on school and understanding kids that was a very worthwhile piece of assessment.

Kirren reported that she did not teach any science in field experience sessions and saw only one lesson being taught by a specialist science teacher at one school.

Kirren admitted she was 'terrified' about having to teach science during her first few weeks of teaching in spite of being placed with an experienced teaching partner. She was presented with a pre-prepared science curriculum unit on *Weather*, which she was expected to teach in the first term. She found the pre-prepared unit was "Was all copy work. All of it was on overhead transparencies and you'd whack it up on the board and the kids would write it down."

Her response, which may be attributed to her own elementary school experiences, was:

> No way, I'm not doing this. So I'd zip out to uni and get all these, like very simple experiments, like with a tin can or anything that wouldn't take long to set up or would get a point, like with atmospheric pressure across, a balloon in a bottle, stuff like that. And I said to the kids, quite honestly I've never done these experiments before, so you and I are going to be learning together and if it doesn't work well does it matter, and they went no. Well at least we've both learnt something out of it. So they were quite good.

In order to sustain a hands-on activity approach, she resorted to borrowing equipment such as microscopes from the local high school so that her students could look at pond water, onion cells and so on. The additional and better quality resources enabled her class, which included below average learners and many students from deprived home environments, to learn more by greater exposure to the hands-on activities. Kirren showed the students what to do, and then sent them off to conduct their their experiments.

When it was suggested by the interviewers that she was taking a substantial risk she indicated that the lessons were very structured to begin with, and the equipment was not dangerous. The activities were taken very slowly and initially strict guidelines were established for appropriate classroom behaviors. Kirren spent, on average, between one hour and a half to two hours per week on science. Her willingness to take risks in being a co-learner in the enterprise was evident in the statement:

> I find that I make silly mistakes, I've set it all up and I haven't thought of something first and I'll make a mistake and go well, all right, why did this happen? And they'll go oh this way, well what am I going to do to fix it and they'll help me solve it. So I find I have more credibility with them if it's not all perfect all the time.

Kirren suggested that the status of science in her school was not high, although, for her, it was one of her high priority areas. The school focused on literacy and numeracy and several students in her class could not read properly. The balance Kirren achieved between her own priorities and, in part, those of the school were reflected in the equal emphasis she placed on English, mathematics, science and social studies in her program. Science was important for Kirren because of "The real life focus that it (science) has. If I can find somewhere that it will relate (to), I will."

Kirren admitted that the students were not good at explaining things to her, however, she challenged them to provide responses that required the use of more scientific language. Kirren fostered an approach to reporting whereby some students drew the experiment and others wrote about the question posed, the steps followed in the experiment, and writing the conclusion. The approach, which involved much discussion, took some time to develop, but led to improved reporting of science activities. Conflict did exist for Kirren between her expressed wish to take time to cover various topics and falling behind the other Year 7 classes.

Kirren indicated that there were no direct support measures for beginning teachers at the school. However, the Year 7 teachers, with the exception of her teaching partner, provided material support in the form of curriculum planning documents and advice about the school. Kirren became part of a cooperative planning process where each Year 7 teacher was delegated a program to write. The written programs were reviewed and revised, and finally copied for distribution among the teachers. Although nervous initially, Kirren believed she ultimately benefited from regular meetings with the Principal who monitored the development of her teaching programs.

In the second interview, Kirren reiterated her stance about providing hands-on activities and avoiding situations where students simply sat and talked or copied information from overhead transparencies. In the absence of positive feedback from other staff about her approach to science she commented that she had to believe firmly that she was doing a good job and be content in that belief.

She was happy with the approaches she had adopted. It had been a difficult task getting students to connect with information and link ideas together and she was still persevering with including as much language as possible in her science program. Getting students to understand was her goal, rather than standing there and saying "This is what happens." Kirren saw herself as being a facilitator and guide for developing students' knowledge and understandings. While maintaining a basic structure for each lesson she was not worried if the students went off track at various times. She wanted her Year 7 students to be able to go to high school and say, "I really enjoy science. I've done things in science and I've gained knowledge and I enjoy science. I understand what we've done so far."

Resources were still a problem for Kirren and often she would make them herself out of odds and ends, or actually purchase the resources. The most positive experience in science for Kirren was watching the students get excited by doing and manipulating things. The worst experience was holding the students back, making them sit down and copy material from the overhead transparencies for Year level tests.

Kirren's lesson began quietly with a series of questions about students' knowledge of magnets, with some questions requiring a follow-up or more thoughtful responses. Most were just short answers, yet there was much teacher-student dialogue. The practical tasks that followed allowed students to explore the properties of magnets. They were presented with the problem of identifying which objects were attracted to magnets and, as part of the activity, were invited to test numerous objects around the classroom. When reporting back as a group, both written and oral use of language and grammar were emphasized by the teacher. It was not clear if the key idea of magnetic objects being comprised of iron/steel was totally reinforced but the issue was addressed in some depth. Also the idea of the end of the magnet being the strongest part was considered and related back to the activity work. The conceptual emphasis was maintained throughout the lesson and the activities and tasks were appropriate for the conceptual relevance and sequencing. Kirren demonstrated flexibility during the teaching episode and attempted to make the content relevant to the students' own, out of classroom, experiences. She set challenging tasks for individuals and groups. Clearly evident were some of the important issues raised by Kirren in the interviews, that is, the provision of an abundant supply of resources; engagement of students in the activities; integration of language by encouraging explanation and giving positive feedback; and a willingness to take risks by admitting she was unsure about some of the students' responses and suggestions.

Unlike Rhian, Kirren entered University with a relatively high sense of self-efficacy (PSTE 52; STEBI-B, Table 1). This could be attributed to her positive experiences in doing senior biology at the secondary college for adults. There appeared to be no substantive problems for her during her preservice core science content and science education courses. She acknowledged that the assignment work in the latter was of particular value to her. However, she graduated with a low PSTE score (38). This may be attributed to several experiences she described, for example, during field experience sessions she saw very little science being taught in schools. This absence of a credible model would not reinforce her beliefs about her ability to teach science. Also, she was never given the opportunity to teach science and hence was deprived of genuine teaching situations on which she could build successful experiences. The salient factor with Kirren would appear to be that, although successful in the university coursework, she had not been given a worthwhile opportunity to implement her knowledge.

When confronted with the reality of science teaching in her new school, she saw the need to provide better experiences for the students. Indeed she may have had high expectations of what good science teaching was from the preservice course and was apprehensive about meeting these ideals. In contrast, the implementation of science in the school was well below these expectations and consequently the challenge to improve the program would appear achievable for her. From her story it is clear that she took the initiative, challenged her co-teacher and gained the tacit support and guidance of the Principal to implement her own strategies that were based on her preservice experiences. The beginning year's experience had developed her confidence:

> I feel much more confident (in) planning and implementing science. I have developed and found many resources and have an increased knowledge and understanding in the area. This has come about by getting in there and teaching science.

Her final comment is interesting in that she acknowledged the effort, or volition, necessary but that she did not believe that she had the strategies. However, from our observations of her teaching she was competent in teaching science and did possess the basic philosophies and strategies. The possible implication here is that whilst one may experience personally successful events, without external reinforcement and acknowledgement of the effectiveness of that behavior, one does not recognise fully the importance and professional significance of those events. Kirren's reports on the first year of teaching would suggest that her Principal did not provide the positive feedback that Rhian had received from her Principal. However, her success in coping with a difficult Year 7 class was evident to the researchers and it would be assumed that, in retrospect, this gave her the necessary feelings of success that may have been the basis of her increased sense of self-efficacy (PSTE 47; STEBI-A, Table 1) in the second year of teaching.

Welena

Welena taught a Year 5 class in a private denominational school in a semi-rural area on the outskirts of Brisbane. Welena remembered doing very little science in elementary school other than once cutting open a battery, and studying biology in secondary school. High school science was just rote memorisation from the textbook in order to prepare for exams.

Welena remembered having to do a lot of beginning reading at a basic science level for the core content science course at university and it was a real learning experience for her. She did not feel confident about teaching science at the time but qualified that by saying she felt incompetent about everything. She attempted to overcome her concerns about science by "Spending a lot of time sitting around the kitchen table playing with magnets, and bottles of floating water and you know, just trying to figure out the concepts myself." She also recalled talking to anyone who could help explain the concepts to her. She was unsure as to whether this gave her confidence, however, it did help her to achieve the marks she needed to get through the course. The Science Education course was good because it gave her a number of activities and practical ideas for use in the classroom.

Welena recalled seeing very little science taught by her supervising teachers in field experience sessions and had taught only a small amount of science herself. She commented that the preservice program equipped her with the skills to plan lessons and units of work but not the basic things you have to do in the first weeks of school such as record keeping, and assessing students. Behavior management should have received greater emphasis and been part of all courses.

Welena had all "these great ideas" when she commenced teaching and was determined to run her program right from the first week. However, she experienced problems with discipline at the start until an experienced colleague suggested that Welena reconsider her program, not worry how fast she went, and just get the class under control. Welena did slow down but became anxious about the students falling behind.

Her early science experiences contributed to the difficulties she faced. There was no teacher aide time and so anything that needed preparation she had to do herself. Welena found that the equipment was hard to get and typing up activity cards for group work was time consuming. The positive feedback from students about her science program was balanced by several concerns:

> It's really fun and the children really come to me and say they're enjoying science but, I just put so much work into it at the moment and it would be good to have something that's giving me more direction because the science sourcebooks like there's only a couple of activities you can do from there and then you're hunting around through all other resources to find something that's a bit more exciting, something with materials that you can get your hands on fairly easily sort of thing.

Welena's class had experienced little group work in previous years and her first few attempts to use group work were unsuccessful. She commented:

> So I had to go back and the first few weeks I just did science it was really sort of chalk and talk type science, and I just kept them in their desks and I was doing demonstrations and drawing diagrams on the blackboard and just sort of science like that to begin with. And then from there I could move on to getting them doing rotating activity groups. But I seemed to think that I should be able to do rotating activity groups right from the beginning of term.

When she did resume group work, the students were simply wanting to know the right answer. Welena responded by spending a lot of time encouraging the students to write down what they thought without worrying about whether an answer was right or wrong. The students contributed more freely to science classes now. Welena indicated that:

> What's so interesting now because a lot of these science concepts that I'm teaching the kids I go home and I have to figure out myself first of all. And I'm learning so much this year so that I can come in the next day and get them to do it and then explain it to them. We did, for example one little one where you get a black box and put a torch at one end, the children can see the beam coming out the other end and then you had to look down, and you can't see the light passing through the box, yeah where did it go, and those type of things. I thought that was a very good question. And so then I had to do some background reading myself.

Welena was looking forward to the introduction of the *Primary Investigations* (Australian Academy of Science, 1994) curriculum package, with it's emphasis on cooperative group work, into the school towards the end of the year.

The school appointed a mentor to work with Welena at a point during first term where she was experiencing a marked lack of confidence. The mentor provided guidance for Welena, particularly in the area of assessment and catering for students at different levels in the classroom. The school sent Welena to a two day conference for beginning teachers where sessions focused on issues such as behavior management, personal stress control, cooperative teaching, and the sharing of resources. Being able to relate her experiences at the conference to what was happening in her own classroom was of value to Welena and she reflected on the outcome of the conference as follows:

> That there were people in May who were floundering, I thought perhaps more than I was. And there people that were better organised as well but I just came away thinking oh yeah, no I'm going okay. Whereas you're not comparing yourself to anyone else when you're isolated here as a beginning teacher all I can see around me is teachers who've been doing it for years and probably doing it well.

When asked to explain changes in her preference to teach various courses, Welena indicated that a beginning teacher needed something really concrete to plan from initially. The mathematics program adopted by the school fitted this criterion very well, hence mathematics was her first choice as most preferred course to teach. Firstly, she knew exactly what she had to cover at different times during the year, secondly, mathematics was a good course for inservicing, and thirdly she felt that she had achieved success with the course

In the second interview, Welena reflected that group work was proceeding more effectively than at the beginning of the year. Students now read the instructions for doing the experiments and she liked to see the learning that arose from group work as the students talked to each other. She suggested that she would get students to this level of co-operation faster next year because she already knew the students in Year 4 and they have seen her in alternative situations.

> They're starting to understand what sort of teacher I am just because they've seen me out in the playground and because I talk to them about other things, and - bus duty and whatever. So next year it will be so much easier for them to come in and me set the standards straight away. At the beginning of this year I didn't know what the standards were that I was supposed to be setting.

Primary Investigations had just been introduced school-wide with support coming from the school Parents and Friends association to purchase the equipment needed to set the package up. Hence, a lack of resources was no longer a problem for Welena and she remained keen to teach science liking the integrated structure and approach of *Primary Investigations*.

> I like the way that the *Primary Investigations* are set out to begin with. For a beginning teacher to have something more structured for you to follow that actually follows through a sequential series of lessons that ties into something - like doing the systems like we've just done.

Welena could foresee that even with the advent of *Primary Investigations* she would have to supplement her science program with materials from other sources. She noted opportunities for linking science with other areas through *Primary Investigations*, for example, mathematics, social studies and English. Welena also had strong beliefs about not giving students the answers before commencing any activity work. She was frustrated by the fact that she was the only Year 5 teacher in the school and not having a colleague in the same Year level to talk about items such as preparing, revising, and completing report cards.

A high point for Welena was the belief that her science teaching had improved during the year citing a specific instance as follows:

> Yeah, I guess - science has got a lot better as the year has gone on, so it is more recent things. I mean, doing those pulley systems and then the children going out and figuring out how to make their own construction pulley systems - I think that was really fun. And talking about why the double one worked better than the single one. It's interesting now that even a lot of the girls are saying, "Oh, I really enjoy science."

Her initial experiences in teaching science at the beginning of the year were a low point for Welena. She commented that:

> So maybe at the beginning of the year you do have to do some teacher-directed, you know, like, maybe right at the beginning of the year I will do just a couple of science lessons myself to begin with, that they just observe, before I send them into the group work. Or just send them into the group work just for a little part, and then come back and do more as a whole class.

Welena felt that she had not asserted her authority firmly enough at the beginning. The problem was trying to survive getting through lessons without being able to look at other aspects such as individual discipline.

Welena's lesson on *A Telephone System* was drawn from the Year 5 *Primary Investigations* curriculum package and hence was structured along the lines of the relevant lesson from the Teacher's Resource Book. The lesson commenced with a reminder for students of the roles of speaker, manager and director in the cooperative learning model espoused by *Primary Investigations*. The teacher, through class discussion, embedded the underlying concept of transmission of sound in this lesson within an integrated unit on *Communication*. A major portion of the lesson was conducted outdoors with the students working in groups constructing and testing the string telephones. Welena visited each group regularly guiding their work, checking the apparatus and troubleshooting. Back in the classroom speakers shared their observations. The students were then asked to write down their own observations. In this phase of the lesson, Welena challenged the students to ask themselves what questions they would like answered, what interactions occurred in the telephone system they had constructed, what were the system parts, and finally answer the questions they had just posed. The structured approach of the lesson from *Primary Investigations*, the use of group work and getting students to think about the experiment by writing down responses to a set of focus questions were indicative of the issues Welena discussed in the interviews.

Welena expressed clearly an interest in science and a commitment to teaching science. Although she stated that she was not confident to teach science on entry to university her self-efficacy score was still high and her prior experiences appeared positive. She maintained this level of self-efficacy through her preservice program. Welena saw little science being taught and had little opportunity to teach science herself but she had confidence in her ability to plan and implement a worthwhile program from her preservice Science Education course. Her high sense of self-efficacy at graduation could be attributed to a combination of interest, perceived skills and a feeling of being prepared to teach science (for example, "these great ideas").

A salient feature with Welena was that her teaching experiences were somewhat highly structured but built around a constructivist approach. During the beginning year her concerns about resourcing and planning were ameliorated by the adoption of the *Primary Investigations* curriculum package which provided structure and direction. Support and reinforcement of her teaching were strong and helped her through periods of crisis. The school had a strong community base and provided constant acknowledgement of her success. She also acknowledged the role played by the researchers in contributing to her feelings of success and achievement and in the follow-up survey commented “This year science features strongly in my program, both *Primary Investigations* and sourcebooks.” Her high PSTE score of 56 in her second year of teaching is consistent with her experiences, sense of achievement, and the general support she received from the school and community.

Ellen

Ellen was a Year 4 teacher in a small country town situated 100 km north-west of Brisbane. She studied some science in upper elementary school, two science courses to senior level in high school and had completed one year of a science degree prior to entering the preservice teacher education program. She recalled receiving a distinction grade for the core Science Foundations course in the preservice program and recollected preparing a teaching unit on the Earth, Sun and Moon as part of a child study assignment in the Science Education course. Ellen contrasted her high school science experiences and those at university by expressing a belief that she was able to look at her own understandings in a better way at university because of the teaching approaches used there.

Ellen saw little science being taught by her supervising teachers in the field experience sessions other than some incidental discussions about plants and animals with students in the early Year levels. Some supervising teachers did exciting work in other areas but not in science.

> I saw some of the teachers doing really exciting stuff in other areas. A lot of concrete materials involved in mathematics, so I’m not particularly (describing) berating them as traditional teachers. They did a lot of exciting things there but, for example diagrams of circuits were always done straight off the board, there was no light globes there was no, wires, there was no boards there, no concrete stuff was taken out unless it was magnets. The only concrete materials used well is magnets, because it’s easy, it’s something that’s in the withdrawal room and the kids can go round and play with it. The other things require some sort of setting up.

She remarked that she saw no teacher dealing with, for example, chemicals or heat energy, and very little construction or practical work at all.

Ellen’s immediate concerns when commencing teaching related to problems with one child and the violent behaviors of that child which tended to dominate her day. The child was eventually suspended from school. Ellen’s concerns were then directed to a number of students with learning difficulties, a group of students represented approximately 45% of her total class. A positive aspect at this time was the mutual support relationship established with a beginning physical education specialist teacher. They were able to discuss aspects of behavior management, dealing with parents, how to sort out problems, and engage in brainstorming sessions for planning.

Initially, Ellen enjoyed not having a supervising teacher present in the classroom and no university lecturer coming round to inspect. After several weeks self-doubt increased which prompted Ellen to attempt a remedy for this lack of confidence.

> And, then after a couple of weeks I was nervous that there wasn’t somebody there to back up my decisions, who I could look to for, what should I do there, or I’ve noticed that this is happening and how can I fix this situation. That changed very quickly for me in the first few weeks. I had started doing, well not really a unit but I then went back and picked things that I liked the best that I’d done on prac so, started them, and after I got into those I picked an English, a Science and a Maths unit that I’d done on prac. I just felt a lot more confident after that. Changed them a bit and brought one up (a Year), one down, that sort of thing but after I got into that it was much better.

The usefulness of university assignment work was further acknowledged when she suggested that she tried to constantly find out “What the kids think about it before I go into a unit.” Asked to describe the nature of the science program she had taught up to the point of the first interview she stated:

> We do a lot of (science), the kids don’t necessarily realise it’s science. I’ve scabbed a fair bit of science equipment from the science room...for example the other day we were talking about the leaves and someone noticed that something was going brown so we got, you know I went down the road at lunch time and got the celery and we did the going through the tubes and we chopped it up and we’d do it as group work, we do it as me demonstrating it. I try and get a lot of colour, a lot of equipment. I would probably do more science than is technically allowed, I do more science

> than social studies, probably at least an hour and a half a week, formally. We' d usually have some sort of discussion time as part of a morning session...each morning there's a problem-type question, maths and but there's normally a science and technology one as well so, how does something work or, if I did this to this what do you think would happen, a fair bit of predicting. What we're concentrating on at the moment, we did a lot of, we didn't call it hypothesis for a while but, a lot of developing and aims and what we hope to find out but at the moment we're discussing the difference between results and conclusions, so we're doing observing and predicting.

In the second interview Ellen expressed the view that she was still happy to teach science and that she had now taken over the task of acting school science coordinator during the absence, on leave, of the incumbent. The initial, strong support of the school science coordinator and his assistance with resourcing was acknowledged as influencing the style of science program Ellen implemented, admitting that without that support "We would have done a lot of nice little colouring in sort of sheets." As acting science coordinator, she was engaged currently in the task of recommending the purchase of resources for the following year.

When asked to comment on how she coped with so many students with learning difficulties in teaching science she cited group work as an important strategy.

> I try and do some group work just for the simple fact of reading instructions that I give or listening to my instructions - try and make it half readers, half non-readers, which is why a lot - well, I'd say 75 per cent of activities that we did would be group work. The reason I do that is for the non-readers and those who don't follow instructions well, but the problem with that is there's a lot of personality clashes and a lot of tantrums, so as the year's gone on, it depends very much on the mood of the kids as to whether it's group or whether it's not, but that's the biggest challenge with it. I need to have them in groups to get them through the activity at some sort of speed, otherwise, we could spend all day doing it, but they don't work particularly well in groups, so that's the problem, trying to weigh that up.

Ellen reported some positive experiences with those students, for example, one child, a slow reader who rarely contributed to any writing activity at all had completed and labelled an illustration. Others had suggested experiments arising from an environmental studies teaching unit. Ellen encouraged these students to express their ideas in writing and illustrate those ideas in their own way. She expressed a preference for conferencing with students about the picture rather than the writing.

When asked to state what she had achieved with all the students during the year she believed that they had made progress at working scientifically and their observations were improving. Additional work was required to get them to explain their observations more clearly. They could verbalise but could not write down explanations.

Ellen believed that knowing how to teach a science topic was an important understanding she had acquired from her preservice program. The actual content can be found elsewhere, if not already known, but applying it and bringing it down to the students' level was important. The area of evaluation of students with different levels of ability remained of concern to Ellen admitting that she was not very confident about this aspect in any curriculum area. A further point of concern for Ellen was that problem areas for students in mathematics received remediation but this was not the case with science.

Ellen's lesson focused on the use of stored energy to propel a model boat across water. The initial phase of the lesson was designed to get students to consider the concept of stored energy for moving any type of vehicle. The teacher posed the problem and provided scaffolding through discussion with the whole class and smaller groups. The students were then provided with an instruction sheet for constructing a model boat powered using a balloon which they had to inflate. Some flexibility in the design of the boats was catered for. The conceptual emphasis was maintained through this classroom phase and the following outdoor component where the students actually tested the model boats. Ellen consulted with the groups as they tested their boats, guiding, checking, and reinforcing individual responsibility for contributing to the problem solving process. The groups were challenged to explain why designs did or did not work or why one design seemed to work better than another. On return to the classroom, the students commenced filling in a worksheet. In acknowledgement of the students with learning difficulties the teacher emphasised oral and written language development. The lesson contained important elements that were consistent with Ellen's views expressed in the interviews, an emphasis on group work; incorporation of sufficient resources for small groups; and getting students to draw diagrams and talk about those diagrams.

Ellen's background provided her with the basis for feeling confident about teaching science and a sense of high self-efficacy. Her practice teaching experiences did not contribute credible models of science teaching which would provide her with confidence or strategies to teach science. Although, she acknowledged the value of the preservice Science Education course, her sense of self-efficacy did decrease at the midpoint of her program but was restored to high levels on graduation. Perhaps, her observation of teaching in mathematics and other areas showed her that it was possible to implement effective and stimulating teaching practices. Given her own science content background and the collection of resources prepared through the preservice program, she felt confident about implementing similar strategies with science. Her high level of self-efficacy was maintained into her second year of teaching (PSTE 51). Her reliance on already prepared resources played an important role during initial class difficulties and provided the essential foundation to implement a worthwhile program. Like Rhian and Kirren she made the effort to gather the necessary resources from outside the classroom. Clearly, the school acknowledged her efforts and interests by appointing her as acting science coordinator. This event would provide the reinforcement necessary to sustain or enhance her sense of self-efficacy. She acknowledged that her confidence had increased and she was providing a more responsive and open-ended science program:

> Science involves children in exploring their environment, hypothesising and inferring about the how and why. Planning for science is not necessarily long term, possibly in three week blocks to explore children's current interests. I am gradually letting go of my need to see everything written down. As my confidence grows (I can implement) more realistic and flexible programs.

Conclusions and implications

The situation of the four beginning teachers can be contextualized by comparison with a previous study of teachers within a single school. deLaat and Watters (1995) reported on the range of teaching practices and science teaching self-efficacy levels in a large suburban elementary school staffed by experienced teachers. The mean PSTE score on STEBI-A for the whole staff was 49.6 (range 33-62) with a standard deviation of 5.9. In that study, teachers with PSTE of 44 still described themselves as confident and enacted an effective science program. With one exception, the STEBI-A scores on PSTE for the beginning teachers in this study fall approximately within one standard deviation of the mean PSTE for the whole school study.

Analysis of the interview and videotape data indicates that all four beginning teachers met a number of the criteria embodied in the analytical framework used to analyze the planning and implementation of science programs. For example, conceptual emphases were maintained (Rhian; Kirren; Welena; Ellen); suitable analogies were used (Rhian); linkages with students' interests and experiences were achieved (Welena; Kirren); and use of students' ideas (Kirren). The tasks and activities used by each teacher were appropriate. Each teacher demonstrated flexibility in catering for a variety of student abilities (for example, Ellen), and in adjusting her science program to meet unusual situations that arose in the classroom (for example, Rhian; Kirren). In each case, the classroom climate was conducive to individual and group discussions and frequent, constructive exchanges between the respective teachers and students. All the beginning teachers showed indications of becoming effective, confident and committed teachers of science by being able to apply situated knowledge, demonstrating an appropriate view of science and understanding what it means to be scientifically literate. Further, they developed communication and discursive practices in the classroom in which children engaged in the sharing of ideas, questioning, argument, and identifying problems. The implication is that contemporary theory underpins their planning and implementation of science programs. However, there needed to be more overt recognition by peer teachers, school principals and university science educators that the beginning teachers were engaged in appropriate practices for the effective teaching of science.

All four teachers referred to what might be described as successful features of their respective science programs. For example, these features can be categorized as: implementation of successful teaching strategies (Rhian; Kirren; Welena; Ellen); successful variation of strategies to suit students' needs (Rhian); positive experiences as a co-learner (Kirren); success with problem solving situations (Rhian); observing the enjoyment and excitement of the children (Rhian; Kirren); observing the enhancement of students' learning and skills (Rhian; Kirren); positive experiences with children (Ellen); and success with group work (Welena).

Bandura (1995) indicates that an individual's beliefs can be changed when the person experiences success with a particular task, observes a credible role model engaged in the task, or is subject to social persuasion. The experience of success for each beginning teacher appears to be derived mainly from the students' feedback such as their enthusiastic participation in hands-on activities, changed behaviors, and acquisition of knowledge and skills. In the case of Rhian and Kirren it appeared that the students' feedback has been sufficient to change their low personal science teaching self-efficacy, represented by their respective PSTE scores on STEBI-B at graduation (Table 1), to relatively high science teaching self-efficacy, or belief about their actual ability to teach science, reflected in their PSTE scores on STEBI-A in the first and/or second year of teaching. With the exception of Rhian, there is little evidence that the beginning teachers' implementation of science programs received positive feedback from the school administrators and their fellow, more experienced colleagues. The virtual isolation of the university from any mentoring process, other than links developed during the research project, meant that little positive feedback was provided to beginning teachers from this sector of the science education community.

It should be noted that Rhian and Kirren's anticipated beliefs about their ability to teach science, apparent in their low PSTE scores at graduation, 36 and 38 respectively, may have caused observers to have doubts about the nature and quality of the science programs they would implement in their beginning year of teaching. For example, it could be predicted that teachers with low science teaching self-efficacy beliefs would implement programs that are teacher controlled and not reflecting contemporary science education theory, or avoid teaching science at all.

Rhian and Kirren would have proved such a prediction to be incorrect. Kirren demonstrated a determination to avoid teaching a highly structured, teacher controlled program provided for her at the start of the year. Instead, she showed initiative by reorganizing the program and seeking equipment from a number of sources to cater for as much hands-on activity work as possible. Kirren revealed to the children that she intended to be a co-learner with them. Early experiences of success derived from the students' positive feedback may have provided the motivation for Kirren to continue using effective methods of teaching science thus changing her beliefs about her ability to teach science.

Rhian's early science teaching experiences were not promising although she displayed flexibility and confidence to turn difficult situations into positive experiences for the children and herself. Rhian did experience success with these problem solving situations by observing that the students enjoyed the opportunity to explain why experiments did not work. Although Rhian's PSTE score on STEBI-A was 36 at the mid-point of her first year of teaching, her initial, successful experiences with the methods adopted may have been crucial for her continued teaching of science. Rhian's increased confidence in her own teaching, and better organization in terms of planning and the acquisition of resources, may account for the positive change in her beliefs about her actual ability to teach science. The positive change is evident in the STEBI-A and survey data collected in her second year of teaching.

Self-efficacy beliefs do not appear to account fully for a teacher's decision to implement, or not to implement, science programs. In the case of Kirren and Rhian, we need to examine other factors such volition and motivation to teach science. However, successful experiences seem to be a key element in sustaining beginning teachers' persistence with approaches that are grounded in contemporary science education theory.

Several tentative assertions drawn from the evidence are discussed below.

Assertion 1: Preservice teachers need to have successful experiences and be made aware of those successful experiences during their teacher education program.

The personal science teaching self-efficacy scores of preservice teachers is a measure of their anticipated confidence in teaching science and any attributions they make would be based on their success in learning science content and methodology. All four participants entered the preservice program with a good content background and relatively high expectations about their ability to teach science. Success in the core science content course may have reinforced these beliefs for some, however, it is difficult to draw this conclusion from the data collected. The Science Education course was an effective experience in terms of developing pedagogical understandings and skills and these were presumably integrated into the whole preservice experience. While strategies for the effective teaching of science were developed in the Science Education course, preservice teachers do not typically get the opportunity to implement these strategies and receive effective feedback from mentors and tutors in the course. The absence of genuine opportunities to teach science in field experience sessions means that they are neither able to achieve early success in teaching science nor have the opportunity to implement strategies that will enable them to become effective teachers of science. A positive sense of self-efficacy requires the person concerned to believe that his or her previous experiences have been successful, that they can cope and are prepared to try in the face of setbacks. Without realistic feedback, preservice teachers will not be able to perceive the effectiveness of their teaching behaviors and practice and, therefore, will not receive a stimulus to growth in their own confidence and expertise to teach science in an effective manner. Of further concern is the lack of opportunity that preservice teachers have of observing science teaching in schools. Without the opportunity to observe effective and credible teachers of science and model their own behaviors on these teachers, vicarious experiences that contribute to developing self-efficacy are absent. Thus, without positive feedback from supervising teachers, school principals, and university supervising staff, the development of self-efficacy in preservice programs is left to strategies built around persuasion and internal motivational characteristics related to volition, will and persistence.

Assertion 2: Science courses in preservice programs must provide more authentic practices and experiences, and be the source of credible role models, for participants.

Instructional practices within science courses would seem to require an element of persuasive guidance. Convincing preservice teachers that they will be able to become effective teachers may not be the best way of enhancing self-efficacy but it does represent a point of initiation. Peer teaching and similar strategies used in the preservice curriculum course may contribute marginally to enhancing self-efficacy as our previous studies would suggest but do not represent genuine experiences that firmly establish a sense of self-efficacy (Watters *et al.,* 1995; Watters & Ginns, 1997b).

Alternatively, science education courses need to have a stronger impact on the development of attitudes. More authentic practices that enable preservice teachers to engage with students in demonstration teaching or with peers in micro-teaching are essential. The economics, logistics and practicality of these strategies may be problematic but need to be seriously considered if a sustained impact is to be made on the quality and effectiveness of science teaching in schools. More tangible connections between science education courses and field experience studies are also essential.

The Science Education course that the preservice teachers studied did involve working with elementary school students but only in a limited clinical situation. Nevertheless, this aspect did enhance their confidence and interest in teaching science and gave them much needed experiences with identifying a student's understanding of a science concept and the resultant planning and implementation of a program designed to restructure the student's understanding. However, opportunities to observe and to teach science in field experience sessions are random and beyond the control of the university science education staff. The impact of the strategies developed in the course often become subsumed by other pressures of the preservice program and unless preservice teachers have deliberately kept resources, and have the opportunity to revisit their course material when beginning to teach, much of the significance and value of the course is lost.

Assertion 3: Induction programs, experienced peer teachers, and school principals, must provide continuous and positive feedback to reinforce beginning teachers' beliefs about their ability to teach science.

There are also messages in this study for the role that principals and experienced teachers play in schools. Principals evaluate beginning teachers and monitor their induction. They have a key role to play in reinforcing good practice and explicitly acknowledging effective teaching of science. All four of these beginning teachers did receive some support from their Principals or colleagues. This support was welcomed and all participants acknowledged the impact of this on maintaining their confidence as teachers. However, the beginning teachers' feelings of success in implementing science programs were generated mainly from positive feedback by the students. Very little, or no specific feedback, was provided by principals and peer teachers about the beginning teachers' science programs. In fact, few principals would value science or recognize the importance of contemporary approaches to teaching science. Specialist science teachers could play an important role in filling this void.

Induction programs should provide this kind of support to enable beginning teachers to implement worthwhile and effective science programs grounded in contemporary science education theory. In particular, teachers who have high levels of personal science teaching self-efficacy and have already experienced success in teaching science in elementary schools should be appointed as mentors for beginning teachers. While university science teacher educators must be aware of, and support, preservice teachers' ability to cope with practical experiences in science and science teaching and design courses to either maintain or enhance their sense of self-efficacy, it is vital that similar support mechanisms continue into the induction year of teaching and beyond. If university teacher educators, experienced teachers and school administrators combine their expertise and efforts to foster and develop beginning teachers' sense of science teaching self-efficacy and their effective teaching of science, the driving force of change in the education system (Fullan, 1993), the individual teacher, could make important contributions to the betterment of science education.

In conclusion, by studying the practice of beginning teachers we have gathered data which have enabled us to examine changes in their beliefs about science teaching during the period of induction and adaptation to the teaching system, which is typically a period of genesis of teaching style involving a reconciliation between theory and praxis. We have also been able analyze their growth towards becoming effective teachers of science during the year. The results of this project, in addition to the work currently in progress, will provide a framework for developing and implementing appropriate strategies in existing preservice programs that enhance teachers' confidence in their ability to teach effective science programs. It is evident that preservice teachers need to have science-related experiences that are grounded in contemporary science education theory, are seen clearly as being successful, and impact on the affective domain. Evidence that this is an achievable objective has been provided by Haury (1988).

Greater attention must be paid to the wide variety of science backgrounds and relevant experiences of prospective teachers and their motivation for wanting to become teachers of elementary science. Preservice teachers studying science content and methods courses need effective and meaningful instructor-learner-curriculum interactions and discourse within supportive and interesting learning environments. During field experience sessions, preservice teachers need to observe and participate in a number of successful science experiences. They also need to engage in the practice required to develop the understandings and skills which are essential for planning and implementing effective science programs. In difficult and stressful times beginning teachers need to able to reflect and draw upon prior successful experiences and interactions with students. Beginning teachers need the continuous support of peer teachers and school principals to identify and analyze successful teaching episodes in order to enhance their professional development thus enabling them to sustain a long term commitment to the effective teaching of science.

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