Journal of Science Teacher Education, 10(4), 287-313.

Beginning elementary school teachers and the effective teaching of science

Ian S Ginns and James J Watters

Beginning elementary school teachers and the effective teaching of science

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. They are also 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 three 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, was 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 research does 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 they were 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. Two major issues confront teachers 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. In preservice programs, science content and methods courses present opportunities for further exploration of generic content addressed in learning and development, curriculum, and cultural and policy studies courses (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 have the opportunity to apply successfully their understandings and skills in several practical field experience sessions. 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 an effective practitioner.

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 investigated using an analytical framework that 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, synthesized from the work of Neale, Smith and Johnson (1990), Kruger and Summers (1993), Taylor, Fraser and White (1994), Bybee (1993) and Yager (1991), was used for the purpose of making judgements about the effectiveness of science teaching.

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 they 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. These criteria were, (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), both of whom 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 asserted that observation of credible role models and verbal persuasion might 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 that 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), might affect science teaching behaviors. The factors were derived from a quantitative research study into elementary teachers' self-efficacy beliefs designed to validate the Science Teaching Efficacy Belief Instrument (STEBI-A). The two factors identified by Riggs and Enochs, and domain specificity of those factors, are in accord with Bandura's (1986) definition of self-efficacy. Enochs and Riggs (1990) developed a similar instrument for preservice teachers (STEBI-B). Both instruments consist of two scales, the Personal Science Teaching Efficacy (PSTE) scale and the Science Teaching Outcome Expectancy (STOE) scale. The Science Teaching Efficacy Belief Instruments are, therefore, useful tools 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 both perspectives were taken into consideration, 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 the science programs they implemented;
b. to identify factors that contributed to the effective teaching of science by beginning teachers;
c. to identify factors that may sustain beginning teachers' long-term commitment to the teaching of science in elementary schools.

Tentative assertions were 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' beliefs about their ability to teach 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 (Yin, 1994) that involved the observation and recording of teacher behaviors in science. Theoretical frameworks of social learning and effective science teaching informed the study. The cases were explored for confirmatory or disconfirmatory instances of congruence with theory.

Participants

The participants in this study were three female beginning teachers, assigned to elementary schools in Queensland in 1996. Overall, eight beginning teachers were monitored in the study. Three are reported in this paper because the interpretations and issues arising from the three cases are replicated in the eight.

Preservice teachers' performance on the Science Teaching Efficacy Belief Instrument (STEBI-B), 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. In order to be able to examine the behaviors of teachers with contrasting science teaching self-efficacy beliefs, 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). 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. At the commencement of the program, the preservice teachers were surveyed to determine a range of beliefs including science teaching self-efficacy using STEBI-B (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 of their program, STEBI-B was administered to sixty-one preservice teachers, from a graduating cohort of ninety-eight. After completion of the program, graduates were offered teaching appointments in schools for the school year commencing in late 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, and 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. The first visit was timed to allow the participants a settling-in period of two to three months. During the first visit, a semi-structured interview was conducted with each participant. The second visit was placed at the end of the school year and included observation of a science lesson and a semi-structured interview with each participant. All interviews were conducted in informal settings, either in the classroom during pupil free periods or in a withdrawal room adjacent to the classroom.

The respective teacher's planning, and the classroom layout and resources, for teaching science were examined during each visit. Other forms of communication were used with the participants at various times during the year. Discussions were also undertaken with school administrators during the two visits.

A deliberate decision was made to avoid intensive, prolonged observations. There was a concern that a balance between researcher intrusion and the natural situation should be maintained. Discussions with school administrators confirmed that the planning and practices observed during visits were representative of the teachers' normal classroom approaches. The researchers deliberately avoided providing any form of critical analysis of the teachers' responses during the interviews, their planning for science teaching, and their classroom practice.

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 a questionnaire.

Data Sources

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

<u>Semi-Structured Interviews:</u> The interviews consisted of open-ended questions that required the beginning teachers' to reflect on their own schooling and university experiences, and tacit or prior knowledge, in order to acquire insights into their beliefs about their ability to teach science. Other background issues, such as their involvement in science related activities outside of formal school and university science experiences, were also examined. Their views of school and science classroom contextual factors that impacted on their teaching at various times of the year were probed in both interviews. Evidence of effort and perseverance was sought, and teachers' perceptions of intrinsic and extrinsic obstacles to teaching science were documented. All interviews were transcribed.

<u>Observations:</u> Observations of each teacher's classroom practice were recorded in field notes supplemented by techniques such as videotaping, audiotaping, and photography. Transcripts were prepared from the videotapes and audiotapes. The observations were analyzed for teachers' behaviors that were in accord with the criteria established in the analytical framework described previously, for example, use made of students' ideas, and the engagement of students in reflective negotiations with each other. Observations of the teacher's planning for science teaching, and the classroom layout and resources for science teaching, were also recorded in field notes. Records of other forms of communication with the participants, and discussions with school administrators, were maintained in field notes.

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 argued that there was no well-defined standard that all experts meet, instead there should be a prototype view of expertise that incorporated standards, but allowed for variability in the profiles of individual experts.

Questionnaire: A questionnaire 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.

Psychometric tests: Preservice teachers' science teaching self-efficacy beliefs were measured using the Science Teaching Efficacy Belief Instrument (STEBI-B), designed by Enochs and Riggs (1990). The beginning teachers' self-efficacy was assessed with the STEBI-A instrument, an instrument designed for practising teachers by Riggs and Enochs (1990). The PSTE scores of preservice teachers (STEBI-B) were a measure of their anticipated beliefs about their ability to teach science and the STEBI-A scores represented their actual beliefs about their ability to teach science.

Explanations of qualitative data, within the adopted theoretical frameworks, were produced in text as narratives and reviewed by each participant (Guba & Lincoln, 1993).

Findings

The personal science teaching self-efficacy (PSTE) scores on STEBI-B and STEBI-A of the three teachers are presented in Table 1. 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 only PSTE data are reported. For comparison purposes, 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.

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

Teacher	1992 (Feb) STEBI-B	1995 (Oct) STEBI-B	1996 (Jun) STEBI-A	1997 STEBI-A
Rhian	42	36	34	56
Kirren	52	38	42	47
Ellen	50	55		51

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

A case report was generated for each participant from the qualitative data. Each case report consists of a profile, a teaching practices component, and explanatory comments. The profile describes the respective teacher's background experiences in science courses, beliefs about teaching science, her perceptions of her own classroom practice, and views about the main factors impacting on the teaching of science in her school. The teaching practices component describes an exemplar of the teacher's implementation of a science lesson and includes 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 explanatory comments examine the links between the teachers' beliefs about their ability to teach science and their school and classroom experiences. The three case reports are now presented.

Case Report: Rhian

Profile

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

Rhian could recall doing some science herself when a pupil in Year 6. There were three classes and the teachers would swap around teaching tasks, with one teacher taking all the classes for elementary school science. For her, high school science involved experiments, learning from the textbook, 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. Rhian now believed that she did not know any science content, 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, it's just too much, I won't even bother, or try. 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. Rhian explained that 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 ways of explaining the science concepts. 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 organize their thoughts. Rhian considered that the study group 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 complete the course

She indicated that she would love to do the course again, if only to acquire a better understanding of the science content and develop the courage to ask "Can you explain it to me?" With an improved 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 other university courses where so much work was covered that it was difficult, at the time, to decide what was of potential 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 recalled that, on most occasions, her supervising teachers insisted that she teach their science programs for them. She accepted readily these opportunities to teach science, and most of the lessons were drawn from the existing Queensland science syllabus. She could not recall seeing any supervising teacher implement a science lesson during her field experiences sessions.

On commencing full-time teaching, Rhian believed that science was one of those areas she had to teach, and she would survive 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 the students, "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?" In her view, creating a problem solving exercise from a potentially negative situation appeared to motivate the students. Rhian and her students then became immersed in the problem and had fun doing the experiment. 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 for fear of getting it wrong. Therefore, Rhian attempted to foster a supportive learning environment that would cater effectively for the variety of students' understandings, skills and attitudes that she described.

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. 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, we all went into new classrooms and had nothing. So, then it was just decided on to do this and I thought, 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 3s as well, and we've often taught the same units, a lot of the times by chance. She will give me things that she's done and 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 behavior 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 reflect 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 professional 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 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. Rhian asserted science was an area she 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 university program had been useful:

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

In the second interview, Rhian noted that she prepared hands-on, activity work in science because the students were more motivated when engaged in "doing things." She believed that the students would not listen, if she just talked all the time. She commented that one group of boys usually stood and watched if they were not properly engaged in the tasks. Another child, in particular, always wanted to know “Why are you doing this and how are you going to do this?”

Recalling her worries at the start of the teaching year about the science content aspects of her teaching, Rhian had developed strategies for explaining herself to the students so that they understood what the lessons were all about and:

> Letting them know that I don’t know everything about it and I’ll try and give them basic information. It’s not always going to answer all of the 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. 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 three hundred 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 given by a 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. 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 think back and “Oh, I remember doing that.” or “Yeah, we learnt about that in grade 4.”

Overall, Rhian’s confidence had grown during the year and she believed that she was now more organized in terms of lesson planning and acquiring resources. She always took the opportunity to reflect on her science lessons and make appropriate evaluation comments about each one.

Teaching Practices

The lesson observed was one from Rhian's unit on *Weather*. The conceptual emphasis on the water cycle was evident throughout the lesson, which culminated in the completion of questions to be answered on a work sheet. The students were asked to write up their responses by imagining that they were raindrops and explain what happened to the raindrops at each stage of the water cycle. The strategies used included whole class discussions, collaborative group work on the construction and calibration of the rain gauges, and individual work on the work sheet. A demonstration of how to calibrate the rain gauges was included at the beginning of the lesson. During group work, the students engaged in discussions, but mostly the work was individual. Rhian provided attention and guidance to individuals and groups throughout.

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. She included 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' as a focus for stimulating each student's thinking about the concepts.

Explanation

A pattern can be observed in Rhian's beliefs and attitudes to science. At school she believed she was a successful science student 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.

It was evident that Rhian possessed other attributes such as a desire and will to improve her teaching of science. Although no mentor program was available for beginning teachers, the school environment in which she found herself as a beginning teacher supported her intentions. The climate of the school was positive in that both the Principal and Deputy Principal 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 had also 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 could be seen in the PSTE score (56) at the mid-point of her second year of teaching. This positive change in her beliefs about her ability to teach science may be substantiated by her response to an open-ended item in the questionnaire that probed for changes in beliefs about teaching science, "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 related to her initiatives 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 factors influencing Rhian's growth appeared to be the successful teaching experiences with the children, and the level of support and reinforcement she received, which was manifested through the activities of her principal and fellow teachers.

Case Report: Kirren

Profile

Kirren was a Year 7 teacher at a large elementary school in a suburb of Brisbane.

In the first interview with Kirren, she recalled that her experiences in upper elementary school involved mainly copying 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 an integrated, general science course, 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 several years before returning to study Year 11 and 12 biology at a secondary college for adults. She enjoyed biology because it had plenty of practical, hands-on work.

Kirren recalled the core science 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. She drew attention to a number of positive features of that assignment:

> I interviewed my cousin on her understanding of temperature, and cold and hot, all that sort of thing. I enjoyed actually interviewing a child because she surprised me. At that stage you have no idea of what perceptions children have of science, or anything really. 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 (sic) 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’ at the thought of teaching 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 “All copy work. All of it was on overhead transparencies and you’d whack (sic) 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 (sic) out to uni (sic) and get all these 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. 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 experiments.

When 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 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, all right, why did this happen? 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 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. She 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 a conclusion. The approach, which involved much discussion, took some time to develop, but led to improved reporting of science activities. However, 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 strongly 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 think about, and link ideas together, and she continued to persevere with including as much language as possible in her science program. Getting students to understand concepts 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."

The lack of appropriate resources remained a problem for Kirren and she often make them herself out of odds and ends, or actually purchased items herself for use in the classroom. The most positive experience in science for Kirren was observing the students' excitement while doing activities and using equipment. The worst experience was making students sit down and copy material from the overhead transparencies in preparation for Year level tests.

Teaching Practices

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 the introduction enabled 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, the students were invited to test numerous objects around the classroom. When the students reported back as a group, the teacher emphasized both their written and oral use of language and grammar. 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.

Explanation

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 completing 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 on STEBI-B of 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. The 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 in field experience sessions.

Kirren may have had high expectations of what good science teaching was from the preservice course and was apprehensive about meeting these ideals. When confronted with the reality of science teaching in her new school, which she saw was well below her high expectations, she resolved to provide better experiences for the students. The challenge to improve the program appeared to be achievable for her. From her story, it is evident that she took the initiative, challenged her co-teacher, and gained the tacit support of the Principal, to implement her own strategies that were based on her preservice experiences. In response to an item on the questionnaire, Kirren replied that 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 to teach science but 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 a repertoire of effective strategies. The possible implication here is that whilst one may experience personally successful events, without external reinforcement and acknowledgment 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. 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.

Case Report: Ellen

Profile

Ellen was a Year 4 teacher in a small country town situated 100 km north-west of Brisbane.

She had studied science in upper elementary school, two science courses to senior level in high school, and 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, and work on electrical circuits. 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. They did a lot of exciting things there but, for example, diagrams of circuits were always done straight off the board. There were no light globes, there were no wires, there were no boards there. No concrete stuff (sic) was taken out, unless it was magnets. The only concrete materials used well are 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 had seen no supervising teacher working on topics involving, for example, chemicals or heat energy, and also very little engagement of students in construction or practical work.

Ellen's immediate concerns, when commencing teaching, related to problems with the aggressive behaviors of one child, which tended to dominate her day. The child was eventually suspended from school. Ellen's concerns were then directed to coping with learning difficulties shown by almost half her 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, or university lecturer observing her teaching. However, after several weeks this became a concern that she had to resolve:

> 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 (sic) so, started them, and after I got into those I picked an English, a Science and a Maths (sic) unit that I'd done on prac (sic). I just felt a lot more confident after that.

Ellens' use of lessons that she had implemented previously as a preservice teacher proved to be an effective coping strategy for her. 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 (science) before I go into a unit."

When 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 (sic) don't necessarily realise it's science. For example, the other day we were talking about the leaves and someone noticed that something was going brown. I went down the road at lunch time and got celery and we did the water going through the tubes and we chopped it up, and we did it as group work, we did it as me demonstrating it. I try and get a lot of colour, a lot of equipment. We'd usually have some sort of discussion time as part of a morning session.. Each morning there's a problem-type question, maths, 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. At the moment we're discussing the difference between results and conclusions, so we're doing observing and predicting.

In the second interview, Ellen maintained 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. She admitted that without that support "We would have done a lot of nice little colouring in 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 (the group) 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 has 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 .

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. For example, one child, a slow reader who rarely contributed to any writing activity at all, had completed and labelled an illustration. She believed that additional work was required to get the students to write clearer explanations of their observations.

Ellen believed that her preservice program had helped her ability to explain scientific ideas to students. She acknowledged that content can be found, or known, by the teacher but it is the ability to "bring it down to the student's level" that was important. She also expressed concerns about the teaching and evaluation of students of diverse ability in science, and she saw it as problematic that students received remediation in mathematics but not science.

Teaching Practices

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 by an inflated balloon. 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 work sheet. In acknowledgment 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.

Explanation

Ellen's background provided her with the basis for feeling confident about teaching science and a high sense of self-efficacy on entry to university (PSTE 50; STEBI-B, Table 1). Her practice teaching experiences did not contribute credible models of science teaching that 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 decreased at the midpoint of her program but was restored to high levels on graduation (PSTE 52; STEBI-B, Table 1). Ellen's observations of teaching in mathematics and other areas may have demonstrated to 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; STEBI-A, Table 1). Her reliance on already prepared resources played an important role during the initial difficulties she experienced with her class and provided the essential foundation to implement a worthwhile program. Like Rhian and Kirren, she made the effort to gather the necessary resources for science teaching from outside the classroom. 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. In response to an item on the questionnaire, 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.

Discussion and Implications

The sense of self-efficacy of the three beginning teachers reflected in their PSTE scores on STEBI-A can be contextualized by comparison with a previous study of teachers in a single school. deLaat and Watters (1995) reported on the range of teaching practices and science teaching self-efficacy levels of experienced teachers in a large suburban elementary school. 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 PSTE scores on STEBI-A for the beginning teachers in this study fell within one standard deviation approximately of the mean PSTE for the whole school study conducted by deLaat and Watters.

Analysis of the interview, video and audiotape, and field note data indicates that all three 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; Ellen); suitable analogies were used (Rhian); links with students' interests and experiences were achieved (Kirren); and the use of students' ideas (Kirren). The tasks and activities used by the teachers were appropriate. Each teacher demonstrated flexibility in catering for a variety of student abilities, and in adjusting her science program to meet unusual situations that arose in the classroom. In each case, the classroom climate was conducive to individual and group discussions and frequent, constructive exchanges between the respective teachers and students occurred. 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 that allowed students to engage in the sharing of ideas, questioning, argument, and identifying problems. The implication is that contemporary theory underpinned the beginning teachers' planning and implementation of science programs. However, it was apparent that there was a need for more overt and continuous recognition by peer teachers, school principals and university science educators, of their efforts in developing appropriate practices for the effective teaching of science.

Bandura (1995) asserted 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. All three 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; 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 students (Rhian; Kirren); observing the enhancement of students' learning and skills (Rhian; Kirren); positive experiences with students (Ellen); and success with group work (Rhian).

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. For Rhian and Kirren, it is evident that the students' feedback has been sufficient to change their low personal science teaching self-efficacy at graduation to a relatively high science teaching self-efficacy, or beliefs 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 their fellow, more experienced colleagues and the school administrators. Ellen did acknowledge the support of the school science coordinator in regard to the provision of resources for teaching science.

The virtual isolation of the university from any contact with the beginning teachers meant that no positive feedback was provided by this sector of the science education community. It could be argued that the links between the researchers and teachers developed during this study influenced teachers' self-efficacy. This argument can be refuted because, as stated previously, a balance was maintained between researcher intrusion and the natural situation, and no critical analysis of the teachers' planning and/or implementation of science lessons was provided at any stage of the study. Further, a deliberate decision was made to avoid intensive and prolonged observations in the classroom. The researchers did not encourage a focus on science, however, the data revealed a sustained commitment to the teaching of science, by all three beginning teachers, throughout the school year. However, some small contribution to teachers' self-efficacy by the research design and procedures adopted cannot be dismissed entirely.

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 would avoid teaching science.

Rhian and Kirren 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 intended that she would be a co-learner with her students. 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 students and her. 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 evident in the STEBI-A and questionnaire data collected in her second year of teaching.

Self-efficacy beliefs, therefore, do not appear to account fully for a beginning 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. Experiencing success appeared to be a major contributor to the effective teaching of science by the beginning teachers. Thus successful experiences are a key element in enhancing beginning teachers' science teaching self-efficacy and developing an extended commitment to the implementation of science programs that are grounded in contemporary science education theory.

Tentative assertions concerning approaches needed to enhance teachers' science teaching self-efficacy are now discussed.

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 the preservice teachers was a measure of their anticipated confidence in teaching science and any gains they made may have been based on their success in learning science content and methodology. All three 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 did 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 meant that the preservice teachers were unable to implement strategies that would facilitate their development as effective teachers of science, hence they did not achieve early success in teaching science using those strategies. 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, the preservice teachers were not be able to perceive the effectiveness of their teaching behaviors and practice in science and, therefore, did not receive a stimulus to growth in their own confidence and expertise to teach science in an effective manner. Of further concern was the lack of opportunity to observe science teaching in schools. Without opportunities to observe effective and credible teachers of science and model their own behaviors on experienced teachers, vicarious experiences that contribute to developing self-efficacy were also absent. Thus, without positive feedback from supervising teachers, school principals, and university supervising staff, the development of self-efficacy in preservice programs was left to strategies built around persuasion in the Science Education course, and internal motivational characteristics of the preservice teachers 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.

Convincing preservice teachers that they will be able to become effective teachers by persuasive guidance 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 science education course may contribute marginally to enhancing self-efficacy as our previous studies suggest, but do not represent genuine experiences that firmly establish a sense of self-efficacy (Watters *et al.,* 1995; Watters & Ginns, 1997b). The impact of the strategies used in the course often became subsumed by other pressures of the preservice program. 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 may be lost.

The Science Education course did involve preservice teachers 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. Given that the opportunities to observe and to teach science in field experience sessions were random and beyond the control of the university science education staff, there were limited opportunities to apply the knowledge acquired from working with elementary school students in clinical situations. Therefore, more tangible connections between science education courses and field experience sessions are essential.

Preservice science education courses must have a greater impact on the development of teachers' beliefs about their ability to teach science. Collaborative learning experiences, reflective journal writing, and problem based assignment tasks employed in subsequent offerings of the Science Education course have been shown to be effective strategies for this purpose (Watters & Ginns, 1999). The effect of these strategies on the teaching of science in elementary schools has yet to be studied. Authentic practices that enable preservice teachers to engage with students in demonstration teaching, or with peers in microteaching, would be desirable. The economics, logistics and practicality of these latter 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.

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

There are 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 an important role to play in reinforcing good practice and acknowledging explicitly effective teaching of science. All three of the beginning teachers did receive some form of general support from their Principals or colleagues. This support was welcomed and all participants acknowledged the impact of this support on maintaining their overall confidence as teachers. However, the beginning teachers' feelings of success in implementing science programs were generated mainly by positive feedback from their students. Little, or no, specific feedback was provided by principals and experienced peer teachers about the beginning teachers' science programs. In fact, few principals would recognize the importance of contemporary approaches to teaching science. Specialist science teachers could play an important role in filling this void. Schools 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.

University science teacher educators must be aware of, and support, preservice teachers' ability to cope with practical experiences in science and science teaching by designing courses to either maintain or enhance their sense of science teaching self-efficacy. It is also vital that similar support mechanisms extend into the induction year of teaching and beyond. With the increasing recognition that teacher education is an ongoing process from preservice through to inservice, it is now an opportune time for science teacher educators to play an active role in the beginning years of teaching by working collaboratively with experienced teachers and Principals. University teacher educators, experienced teachers and school administrators should, therefore, combine their expertise and efforts to foster beginning teachers' sense of science teaching self-efficacy and their use of effective science teaching practices.

Conclusions

By studying the practice of three beginning teachers, we have gathered data that have enabled us to examine changes in their beliefs about science teaching during the period of induction and adaptation to the teaching system. This period 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, can frame the development of preservice courses that are grounded in contemporary theory, include learning experiences that are relevant and authentic, and address the nexus between theory and practice. In order to enhance preservice teachers' beliefs about their ability to teach science, it is evident that 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 extensive practice required to develop the understandings and skills that are essential for planning and implementing effective science programs. Haury (1988) has demonstrated that the development of courses designed to have a positive effect on the affective domain is an achievable objective.

Beginning teachers need to able to recognize, reflect and draw upon successful experiences and interactions with students, in difficult and stressful times. Therefore, they need the continuous support of peer teachers, school principals and science teacher educators to identify and analyze successful teaching episodes in order to enhance their professional development. If this support is freely available, it may develop in beginning teachers a long-term commitment to the effective teaching of science.

References

Abell, S. K., & Roth, M. (1991, April). *Coping with constraints of teaching elementary science: A case study of a science enthusiast student teacher.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Lake Geneva, WI.

American Association for the Advancement of Science. (1993*). Benchmarks for Science Literacy: Project 2061*. New York, NY: Oxford University Press.

Appleton, K. (1997). *Teaching science: Exploring the issues.* Rockhampton, Qld: Central Queensland University Press.

Australian Science Technology and Engineering Council (ASTEC). (1997*). Foundations for Australia's future: Science and technology in primary schools*. Canberra: AGPS.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1995). Exercise of personal and collective efficacy in changing societies. In Bandura, A. (Ed.), *Self-efficacy in changing societies* (pp. 1-45). New York: Cambridge University Press.

Borko, H., & Putnam, R. T. (1995). Expanding a teacher's knowledge base: A cognitive psychological perspective on professional development. In T. R. Guskey & M. Huberman (Eds.), *Professional development in education: New paradigms and practices* (pp. 9-34). New York: Teachers College Press.

Bybee, R. W. (1993). *Reforming science education: Social perspectives and personal reflections.* New York: Teachers College Press.

Curriculum Corporation. (1994). *A statement on science for Australian schools.* Carlton, Vic: Curriculum Corporation.

deLaat, J., & Watters, J. J. (1995). Science teaching self-efficacy in a primary school: A case study. *Research in Science Education, 25*(4), 453-464.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: a preservice elementary scale. *School Science and Mathematics, 90*(8), 694-706.

Ginns, I. S., Watters, J. J., Tulip., D. F., & Lucas, K. B. (1995). Changes in teachers' sense of self-efficacy in teaching science: A study of Australian preservice elementary school teachers. *School Science and Mathematics, 95*(8), 394-400.

Greenwood, G. E., Olejnik, S. F., & Parkay, F. W. (1990). Relationships between four teacher efficacy belief patterns and selected teacher characteristics. *Journal of Research and Development in Education*, *23*(2), 102-106.

Guba, E. G., & Lincoln, Y. S. (1993). *Fourth generation evaluation.* Newbury Park, CA: Sage Publications.

Haury, D. L. (1988). Evidence that science locus of control orientation can be modified through instruction. *Journal of Research in Science Teaching, 25*(3), 233-246.

Huberman, M. (1995). Professional careers and professional development: Some intersections. In T. R. Guskey & M Huberman (Eds.), *Professional development in education: New paradigms and practices* (pp. 9-34). New York: Teachers College Press.

Kruger, C., & Summers, M. (1993). *The teaching and learning of science concepts in primary classrooms: Two case studies.* Unpublished paper, Primary School Teachers and Science (PSTS) Project, Oxford University Department of Educational Studies.

National Science Teachers Association. (1992). *Scope, sequence and coordination of secondary school science: The content core, a guide for curriculum designers, Volume 1*. Washington, DC: National Science teachers Association.

Neale, D. C., Smith, D., & Johnson, V. G. (1990). Implementing conceptual change teaching in the primary school. *The Elementary School Journal, 91*(2), 109-131.

Riggs, I. M., and Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*(6), 625-637.

Shulman, L. (1987). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Sternberg, R. J., & Horvath, J. A. (1995). A prototype view of expert teaching. *Educational Researcher, 24*(6), 9-17.

Taylor, P. C. S., Fraser, B. J., & White, L. R. (1994, April). *CLES: An instrument for monitoring the development of constructivist learning environments*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Watters, J. J., Ginns, I. S., Enochs, L., & Asoko, H. (1995, November). *Preservice primary teachers' sense of self-efficacy. International perspectives on the teaching and learning of science and mathematics.* Paper presented at the Annual Meeting of the Australian Association for Research in Education, Hobart, Tas.

Watters, J. J., & Ginns, I. S. (1997a). An in-depth study of a teacher engaged in an innovative primary science trial professional development project. *Research in Science Education, 27*(1), 51-69.

Watters, J. J., & Ginns, I. S. (1997b, March) *Peer assisted learning: Impact on self-efficacy and achievement*. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Watters, J. J., & Ginns, I. S. (1999, January). *Setting the environment for life-long learning: Collaborative and authentic learning experiences in primary teacher education.* Paper presented at the International Research Network (PACT) Conference, Hong Kong.

Weiss, I. R. (1994). *A profile of science and mathematics education in the United States: 1993.* [A report for the National Science Foundation], Chapel Hill, NC: Horizon Research Inc.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. *The Science Teacher, 58* (September), 52-57.

Yin, R. K. (1994). *Case study research: Design and methods.* Thousand Oaks, CA: Sage Publications.