Packaging constructivist Science teaching in a curriculum resource

Peter AUBUSSON[1] and Kevin WATSON[2]
[1]Science and Technology Education
Faculty of Education
University of Technology, Sydney
PO Box 222, Lindfield 2070, NSW, AUSTRALIA
Email: Peter.Aubusson@uts.edu.au

[2] School of Social Ecology and Lifelong Learning
University of Western Sydney
Locked Bag 1797, Penrith South DC NSW 1797, AUSTRALIA
Email: k.watson@uws.edu.au

Received 2 September, 2002
Revised 17 January, 2003

Contents

Abstract

This paper outlines research that assessed the effectiveness of a curriculum package combined with a professional development program in promoting constructivist science teaching. Six high school science teachers from three schools attended professional development workshops and attempted to implement a science curriculum package which included an emphasis on a constructivist approach (the 5Es) and cooperative learning. The findings suggest that teachers were the critical factor in curriculum innovation, that professional development and the curriculum package influenced implementation, and that a hierarchy of skill and knowledge acquisition is associated with constructivist teaching. In some cases, the curriculum package seemed to improve teaching and learning, in other cases good teaching and learning were hindered.

Introduction

This paper reports the trial implementation in secondary schools of a science curriculum package in an Australian State, New South Wales (NSW). The trial was a collaborative project among the Australian Academy of Science (AAS), NSW Department of Education and Training (DET) and University of Western Sydney (UWS). The package trialed was a USA curriculum project (BSCS, 1994), *Investigating Patterns of Change*. The curriculum package claimed to employ a constructivist approach to learning and teaching using five phases, known as the 5Es (Engage, Explore, Explain, Elaborate and Evaluate) (Bybee, 1997). The engage phase is designed to promote interest and motivation. During this phase the emphasis is on activities to arouse curiosity, puzzle students and raise questions for further investigation. The Explore phase provides students with, usually similar, practical experiences. During this phase students continue to raise questions, listen to the views of others and begin to investigate different phenomena. Students are encouraged to express and share views while value judgements about views are suspended. In the explain phase students explain their findings to others and their ideas are subjected to greater scrutiny. During this phase, the teacher introduces relevant scientific explanations. By the end of the explain phase students should have developed greater understanding of phenomena under investigation. The emphasis in the elaborate phase is on students applying their new understandings, developed during previous phases, to a range of familiar and unfamiliar situations. During this phase, students can see how fruitful their new ideas are. This phase is important as it allows

students to see how well their ideas work in a range of contexts. The evaluate phase is the final phase. Here students' understanding is assessed formally and students are encouraged to reflect on and question the ideas which they have developed. (For a more detailed outline of the 5Es, see Bybee, 1997). Each lesson taught involves aspects of each phase, and each phase should be evident in the planning and implementation of the unit as a whole (Bybee, 1997).

It would be simplistic to suggest that the BSCS curriculum project was based solely on constructivist principles. A range of popular trends and broad movements in science education has influenced them including: Science, Technology and Society approaches; the teacher proof curriculum projects with their origins in the post-sputnik era; the 'big ideas in science' view of school curriculum and the nature and history of science and its implications for science education. In addition, views on assessment, language development, cooperative learning, learning styles, problem solving, the interests of students and what students should know (see introductions to BSCS) have all influenced the development of the package (BSCS, 1994). Consequently, the BSCS package is a product of varied, interrelated and complex influences using a constructivist teaching approach where 'students construct rather than absorb new ideas and where learners actively generate meaning from experience' (Bell, 1993, p. 23). One reason for the trial of the package was the success of the AAS sponsored Primary Investigations curriculum package (Swanage & Lane, 1999), which is also based on a similar constructivist (5Es) approach.

Constructivism as a theory of learning (Richardson, 1997) has been an influential movement in science education research over the past two decades (Matthews, 1998; Tsai, 1998). A fundamental principle of constructivism is that people construct meaning and therefore have 'knowledge' based on their life experiences (Fensham, Gunstone & White, 1994; Driver, Asomo, Leach, Mortimer & Scott, 1994). As a result, students bring prior knowledge to the classroom that is resistant to change because it is powerfully explanatory since it is based on personal, real life evidence and therefore influences the learning of related concepts. If students bring alternative (less scientific) views to the classroom, the task of the teacher is to promote student consideration of alternative ideas which make better sense of the world (Carr, Barker, Bell, Biddulph, Jones, Kirkwood, Pearson & Symington, 1994). The teacher is requiring students to change their concepts from those they have formulated through experience to others that more closely resemble the accepted scientific view (Skamp, 1998). Strike and Posner (1992) formulated a set of conditions under which this sort of conceptual change (learning) could occur. In brief,

these conditions are that the student must perceive dissatisfaction with the conceptions they currently hold, that the new or replacement conceptions must be intelligible and appear plausible and that the new conceptions should suggest the possibility of a fruitful program of future investigation.

There have been a number of studies that have incorporated a constructivist perspective on teaching and learning. These include the *Project for Enhancing Effective Learning (PEEL)* (see eg. Baird and Northfield, 1992), the *Learning in Science Project in New Zealand* (see eg Osborne & Freyberg, 1985) and the Leeds University science projects beginning with *Children's Learning in Science* (CLIS) in the UK (See eg, Scott, Dyson & Gater, 1987; Millar, Leach & Osborne, 2000). There have been varied efforts to design curriculum support materials, which incorporate a constructivist perspective on teaching and learning and assist teachers to implement this approach (Windschitl & Andre, 1998; Rhagavan, Sartoris & Glaser, 1998). However, these curriculum initiatives do not provide support materials intended to be a complete teaching/learning package. The BSCS project is informed by similar constructivist views of learning to those which underpin these other projects. The phases of the 5Es teaching approach are similar to steps or stages specified in recommended teaching approaches in other projects. For example, the learning and teaching practices in the 5Es approach are very similar to the four steps recommended in the LISP Interactive Teaching Approach (Osborne & Freyberg, 1985), where the phases are preliminary, focus, challenge and apply. They are also akin to the five stages of the CLIS project, orientation, elicitation of ideas, restructuring ideas, application of ideas, review and change in ideas (Scott, Dyson & Gater, 1987). What is unusual about the BSCS project is that it represents an attempt to incorporate its constructivist teaching approach (5Es) into a complete curriculum package with a text book and teacher resources to enable teachers to implement constructivist teaching in their science classes.

A Queensland study of the implementation of the 'Earth science' section of *Investigating Patterns of Change*, reported that teachers found some of the materials inappropriate for students. However, the introduction of new teaching methods, particularly cooperative learning, did result in, at least, short-term improvement in student attitudes to the learning of science (McRobbie, Watters & Diezmann, 1999). The 5Es instructional model was also used in a primary science curriculum package, Primary Investigations (AAS, 1994), which was first introduced in Western Australia. This package has been used extensively by teachers in a number of Australian states to promote learning in science (Swanage & Lane, 1999). A contributing factor in its success was the extensive

use of professional development associated with the introduction of new materials (Venville, Wallace & Louden, 1998).

A point made in PEEL (Baird & Northfield, 1992) was that teachers needed both time and support if they were to implement constructivist teaching approaches. The need for extensive professional development, including interaction with peers, to assist teachers to develop constructivist approaches has been identified in reviews of teacher development particularly in the PEEL and LISP projects (Bell & Gilbert, 1996; Loughran & Northfield, 1996). Furthermore, it was recognised that teachers do not simply shift from their initial teaching styles to implement constructivist approaches but gradually built an approach where they work with students ideas; ascertaining student understanding, intellectually engaging with students ideas and encouraging students to question and challenging these ideas (Bell & Gilbert, 1996; Loughran & Northfield, 1996). Other studies have emphasised that change in the classroom cannot be brought about by the imposition of curriculum directives, and that teachers must control the pace and direction of development (Bencze & Hodson, 1999; Fullan, 1991). A curriculum package alone cannot guarantee change in the classroom. It is also likely that, by itself, professional development in the use of teaching strategies may not be enough. An investigation of the use of conceptual change teaching strategies by life science teachers found that the teaching strategies were useful but could not be implemented without appropriate curriculum materials (Smith, Blakeslee & Anderson, 1993). Thus, both appropriate professional development and the selection of an appropriate curriculum package are likely to be necessary factors for the successful implementation of curriculum initiatives. Consequently, the research question investigated by this study is, does the BSCS curriculum package combined with a professional development program enhance teaching and learning in lower secondary science.

Methodology

The researchers, in conjunction with the NSW Department of Education and Training, identified the schools, teachers and students to participate in the study. 'Purposive sampling' was employed to achieve a 'representative sample' of schools across the Sydney metropolitan region with 'typicality' (Cohen & Manion, 1994, p. 89) of the schools and the willingness of two teachers in each school to participate in the study being the main criteria for selection. The materials were to be trialed in three schools with two science teachers from each school participating. The sample (see Table 1)

included two coeducational schools and a single sex school drawing students from a range of socioeconomic and cultural backgrounds.

Table 1: *Participating Teachers Identified by Pseudonym*

	Teacher Qualification	Teaching Experience	Class Taught	School Type	School Size
Bronwyn	BSc Dip Ed	12 years	year 8	comprehensive	1000
Elaine	BSc Dip Ed	5 years	year 8	boys	300
Frank	BSc (Hons) Dip Ed	24 years	year 7	comprehensive	1000
Gina	M App Sc PhD Dip Ed	11 years	year 8	boys	300
Harry	BSc Dip Ed	6 years	year 8	comprehensive	900
Jon	Dip.Teach BSc MEd	22 years	year 7	comprehensive	900

One hundred and seven students took part in the data collection providing samples from their work books, participating in interviews and agreeing to have lessons viewed by researchers and video taped. The student sample was diverse and typical of schools in the Sydney metropolitan region.

The topic selected for teaching was 'Matter' as presented in BSCS Level B, Investigating Diversity and Limits, Unit 3: 'Why are things different?'. This topic was selected because it does not use excessive North American examples and is normally covered as part of the year 7 or 8 science program in NSW schools. The curriculum project materials were made available for teachers to examine before the first professional development session. A list of the materials supplied is shown in Table 2.

Table 2: *Package Materials Provided to Teachers*

BSCS Package	pages
Student text book unit	42
Teacher Edition consisting of:	114
o Introduction	20
o Annotated student book & teachers notes	94
o Teacher's Guide and Resource Book consisting of	79

o Cooperative Learning background	11
o Creating and sustaining teams	7
o Learning Styles	11
o Background Information	3
o Charts of Outcomes	3
o Extension activities	3
o Assessment Evaluation and Student Learning	25
o Black Line Masters	16
Total	**235**

The first of three professional development days, to support the research project was held in week 1 of term 3, 1997. This was followed by eight weeks in which the BSCS program was taught. The additional two professional development days were held in week 5 and week 8 of the teaching phase of the project. At the first professional development day the purpose of the research project was described. The teachers discussed constructivism, cooperative learning and the 5Es. Teachers' views of constructivism and cooperative learning were elicited by asking each teacher to write down their understandings of each of these terms followed by a general discussion that encouraged teachers to talk about their views. In this way teachers learnt from each other and may have modified their views. The 5Es were described and discussed. Teachers were asked to plan their first week of teaching. Throughout the day a cooperative learning approach was modelled with researchers acting as facilitators in eliciting answers to questions asked by teachers.

Each teacher was visited at least twice by one of the university researchers between the first and second professional development days. At these visits, classes were observed and conversations and interviews were held with both teachers and students to collect data and to support the teachers in their trial of the curriculum materials. Classroom observations were made using a predetermined protocol to assess how teachers were using the curriculum material - if they were following the strategies outlined by the project support notes. Observations were also made of student interactions using a predetermined check list to assess how they were engaging with the material presented in class and to find out if they perceived any differences in the way they were being taught. Student and teacher interviews, employing a semi-structures interview schedule, were

used to triangulate the data collected from classroom observations and to provide detailed views on the teaching and learning experiences.

By the second professional development day two teachers had decided to leave the project. Their reasons are discussed in detail later in this paper. During the researchers' visits to classes and in interviews with teachers, it became apparent that the constructivist elements of the curriculum materials had been ignored by all but one teacher (Jon). Hence, on the second professional development day, the researchers concentrated on constructivism. The teachers themselves, however, were mainly concerned with either the difficulties or successes they were experiencing with the implementation of cooperative learning. This led to extended discussion of cooperative learning, including distinguishing cooperative learning from group work. This was achieved by modelling cooperative learning approaches to some of the suggested experiments and activities. In addition, teachers shared anecdotes about their experiences, selected activities were modelled and analysed to identify the ways they employed constructivist approaches, teachers were given an interim summary of the researchers' findings. These findings were discussed and the teachers planned the final weeks of their units.

A researcher visited each teacher at least twice between the second and third professional development days. On the third professional development day, the teachers were asked to bring students' books and videotapes of their lessons as a stimulus for discussion. It was on this day that the teachers, lead by Jon, began to concentrate the discussion on constructivism and the 5Es.

At each professional development day teachers were encouraged to talk about the experiences they had in their teaching and to identify effective teaching and learning which had occurred, as well as problems which had arisen. The professional development sessions were based on the assumption that teachers could learn from each other, drawing on their different expertise to describe and analyse their work to inform each other (Venville, Wallace & Louden, 1998). The main role played by the researchers was to promote this analysis and discussion and to act as colleagues with different expertise. Often this involved modelling approaches, offering views on the theoretical and philosophical basis of the project materials and drawing on examples from the project materials to illustrate how these views could be put into practice.

The data was reviewed throughout the data collection phase to identify patterns and trends (Erickson, 1986). This ongoing iteration of analysis influenced the questions students and teachers were asked in subsequent interviews and conversations, as well as

shaping the design of the professional development program. The validity of this type of research is strengthened when a variety of overlapping data sources are collected and analysed. These included: formal interviews, informal conversations, lesson observations, observations at professional development days, survey of students' views on matter (pre and post implementation) and collection of artefacts. The interviews, conversations and observations, were analysed using the process recommended for interpretive studies (Erickson, 1986). Results are presented as short case reports for each teacher to illustrate the different ways in which they and their students used and responded to the curriculum project materials. In this way, evidence is presented to compare the impact of the package in different classes, to evaluate the extent to which they enhanced science education in each case and to identify trends. Where two teachers worked closely together in a school and the effects of the package was similar, case reports on these teachers have been combined. The pre and post surveys of student views were analysed using SPSS. No significant differences were found between pre- and post-scores on the surveys and this data is not discussed further in this article.

Case Studies

Bronwyn and Frank

Bronwyn and Frank taught at the same school. They came to the project looking for new, different and innovative ways of teaching. Neither teacher had heard of constructivism at the start of the project. They found the BSCS material hard to read and implement. They found it difficult to follow the BSCS material and implement the program as it was intended. Both argued that the support materials were complicated and Bronwyn explained that the BSCS packaged sequence of activities was 'restrictive' and the project materials were 'complicated and time consuming to look through'. They chose not to use any of the BSCS resource materials, other than the textbook and the parts of the teachers guide essential to understanding the student textbook. Bronwyn and Frank found it necessary to consult with each other extensively throughout the project because the package was so difficult to use.

Bronwyn had used group work extensively in her teaching but not cooperative learning. Frank had never taught using group work, other than for practical work. After the first professional development day, he rearranged the rows of tables and chairs and put his students into groups. After the first week he said 'the group work was going well'. The students were 'looking forward to science' and 'although the class was noisy at first, the

kids learnt to settle down quickly and get on with their work'. The allocation of group roles worked better than he had expected because students knew what they had to do and Frank found he could relax and 'let the kids take more responsibility for their own work'. The students said that they liked working in groups because 'you learn more because there's more than one brain'. 'It's more fun' and 'I like science more'. Frank described the learning as 'piecemeal' and considered the students were learning more about cooperative skills than they were about matter.

Frank did not consider the 'text user friendly for teachers let alone students'. After two weeks Frank gave up getting the students to read in class. Frank, like Bronwyn, considered that 'the rate of progress (compared with previous work) was slow'. He found that 'developing strategies for getting through the reading in an interesting way was taking up a lot of time'. Because the rate of work was so slow, Frank felt 'the continuity of what the kids were learning was becoming a problem'.

As time went on, Bronwyn became more efficient in getting from the project what she wanted. The problems Browyn and others in the project initially experienced decreased as they became more familiar with the BSCS resources and as a result of discussions they had with other teachers who were trialling the package. The teachers provided both general encouragement to each other and suggestions about how to use the resource. She would talk to other participants and exchange ideas and materials during and outside professional development sessions. Bronwyn was positive about affects of the BSCS package on her class. Through increased interaction with her students, Bronwyn considered she was developing 'a greater rapport with the kids in the classroom'. It was not until towards the end of the project that Bronwyn began to see the relevance of constructivism in the whole process. Early in the project Bronwyn valued the engage phase activities, particularly the discrepant events. (Discrepant events are surprising, counter intuitive and unexpected events which arouse student interest, raise questions and lead to further investigation (for an extensive discussion of discrepant events see eg, Liem, 1987). One discrepant event used was the bouncing of two seemingly identical soccer balls, one indoor and one outdoor. When both were dropped one bounced the other did not. Bronwyn said she had 'taken discrepant events into other classes and they really liked them'. It was after this that Bronwyn began to look for the 5Es in the program materials. It was as if recognising the value of one part of the 5Es, the engage phase activities, led to an interest in the whole 5Es framework. During the final professional development session Bronwyn commented that she was 'not into the 5Es yet. (She was) still concentrating on the basics, the tools of cooperative learning'. However,

she was starting to 'use the 5Es, which is a scaffold for constructivism'. According to Bronwyn, she began to view the 5Es as a systematic way to put into operation a constructivist approach to teaching and learning but had not yet developed a clear understanding of what contructivism was.

Frank also eventually began to value of the 5Es approach to teaching as outlined by BSCS. However, his initial concern was to get the students to work well in groups. It was only after he began to feel confident with students working in small groups that he began to think about the 5Es. During the second professional experience session, Frank said he was 'thinking about the 5Es and cooperative learning every lesson' but not once did he mention constructivism in discussions until the last professional development day. By the end of the project the students commented that nothing was being written on the blackboard any more. They also commented they were writing less in their books. They thought this was good.

The students liked using the textbook. They said it was 'good because it's got everything in it you need. You don't have to go to the library and find other books'. Thus the textbook had some impacts which could be considered to be poor learning behaviours. Bronwyn's students said they sometimes had done group work, in previous topics, but students were consistent in the claim that 'we don't normally do as much group work as we do now'. They also argued that they were 'discussing things more, helping each other more and solving problems together'. The students said that they enjoyed science more when using the BSCS package, 'it gives us the advantage of exploring other ways and ideas'. 'We learn more because we discuss things. It opens up your brain. It's fun. It's more like normal'. Students explained that they were learning 'how to think' and commented that science is 'now as good as other subjects'. Frank argued that the amount of practical work had not increased but the students said that 'it had increased a lot'. A few students were critical of the BSCS science experience. One student complained 'this is better than what we usually do in science but I still don't like it'. Another commented that science was more fun and interesting although some of the activities 'taught them little'.

Harry

Harry felt he might learn something to improve his classroom practices by participating in the project. He wanted to teach well and learn as much as he could to become a good teacher. Harry was determined to implement the BSCS program as intended. This meant he interpreted the teachers' notes carefully so that he 'would not make a mistake'. This he did even when his own view conflicted with the teacher's notes. For example, Harry was

not used to his students working in small groups so this was a significant change for him. He rearranged the tables in the room. As recommended by BSCS, he placed the students in structured ability groups based on information obtained from their previous science teacher. Students wanted to work in friendship groups. This generated resentment among students and became an obstacle to their learning.

Harry said 'the students complained about their groups' and 'liked working with their friends'. Harry was determined to have students work in their structured ability groups and would not allow changes. The result was that 'some groups did not work together' and some 'individuals did not pull their weight in their group'. The classroom climate generated meant that 'some students took the opportunity to do very little work'. Harry felt uneasy when he talked to the other teachers in the project because he could see that most of them were positive about and enjoyed using group work. He spoke with a member of the research team, as he was keen to find a solution to the problem in his class. However, he considered it would not be possible to change the groups to friendship groups since this was not what the program required.

Harry 'knew about constructivism but only played it lip service' but now he was 'coming to grips with it'. He considered that the students were learning little. Harry's class was a mixed ability class which while not highly motivated, did not typically experience difficulties with reading materials in science. Yet, one of the reasons for this was the 'trouble the students were having with the language in the textbook'. Harry said it took too long to get through a small amount of work. The students also claimed they had not learnt much in the topic. Harry spent a great deal of class time disciplining students who were misbehaving. This disrupted the class as a whole and decreased the amount of time students were engaged in learning.

Some students said there were more experiments in science throughout the project than they were used to in other science lessons. Other students said there were fewer experiments. All students interviewed said there was a lot more 'theory' than in their last topic. The students said the textbook was good because they did not have to write as much. One of Harry's high achieving students said that 'science was all right if the group felt like working, but this did not happen much'. She said that 'we should have made sure this (the group) was okay before we started (the topic)'. One student summed up the thoughts of many, 'I don't like science. It is boring and I won't use what we learn...I only like working with my friends and the experiments but even they are not going to benefit me when I leave school'.

Jon

Jon had been using constructivist approaches in his teaching for about two years and was keen to learn about the 5Es as another way of implementing a constructivist approach. His class was used to working cooperatively with allocated group roles in a friendly and supportive atmosphere. The class was already taught using constructivist principles and the students thought science was important, fun and interesting.

Jon found the program more difficult to implement than he had expected. The amount of preparation and reading the students had to do were a burden. This was in addition to reading through the teacher's notes to find out what was required for each lesson. Jon thought it was important to carry out the program faithfully and he followed the directions outlined by the teacher's notes, even when he considered there was a better way of doing it. Consequently, he thought the program was inefficient. Jon considered the 5Es approach 'too time wasting, for the concepts gained by the kids'.

Students said the teaching in the classroom during the project was 'basically the same' as usual. The students often used the word cooperation when talking about group work. When asked what they had been learning in this topic student's answers ranged from no answer to 'what's inside materials and how to work properly together in a group'. 'How to use your brain and think, judge things and work things out'. When asked if they liked doing all this thinking one student said, 'No, it is hard, but it is okay if we work in a group. It makes it easier. If we're wrong we've got others to help us. We learn more because we can talk about it more and we get to understand'. The students also liked having a textbook because 'you can see it'.

Only in Jon's class did an examination of student books indicate differences between the BSCS topic and previous science topics in that the amount of recording had decreased. The nature of what the student recorded had also changed. Students wrote more about their own ideas and opinions. Less information was being covered in the time available than Jon expected. In order to move through the project materials at his expected rate, Jon found there was less time to spend on students recording information in their workbooks. The program inhibited Jon's natural constructivist style of teaching because he felt restricted in changing parts of the program when he thought there was a better way of doing it because 'if you're going to implement a program and research its effectiveness, you have to implement the program and not something else'.

Elaine and Gina

Elaine and Gina attended the first professional development day, but on returning to their

school declined to use the text materials (BSCS). Their reason was that the reading and conceptual levels were too high, a view supported by the head teacher and the school's remedial reading teacher, who tested the difficulty of the text. The head teacher rated the overall appeal of the text as low, and accordingly it was not even used as resource material. The teachers, especially Elaine, were clear that they had joined the project to get some materials to use in the classroom. They felt they did not have the time to adapt or interpret materials. In discussion neither teacher spoke of constructivism or cooperative learning, or learning in general. Their main concerns, in discussions with the researcher, were classroom control and developing literacy. There were no changes observed in their classes.

Discussion

Of the six teachers reported, four were enthusiastic and keen to try the BSCS project materials with their classes. Elaine and Gina were initially willing to participate but were not keen on the package, considering it unsuitable for their students. The impacts of the package on the quality of teaching ranged from none (Elaine and Gina) to marked changes, such as using cooperative learning and beginning to employ constructivist teaching (Bronwyn and Frank). For Jon and Harry, the situation was complicated by their perceptions of their role as participants in a research project. Both saw their role as trialing a research package exactly as prescribed. Their attempt to maintain their research rigour restricted their use of the curriculum package. They did not adapt or use the materials in ways they might normally. For Harry this was destructive. By contrast, Jon coped ably with this problem. Hence, the fact that they were engaged in research may have inhibited potential benefits of the package.

The evidence suggests that those teachers who sought new approaches to enhance their teaching were more likely to achieve this. However, it was difficult for teachers to develop an understanding of constructivism and appreciate its implications for teaching, let alone employ constructivist approaches such as the 5Es, until they had mastered some of its building blocks including teaching strategies. Teachers perceived it necessary to implement cooperative learning teaching strategies before implementing constructivist approaches to teaching and learning, such as the 5Es. The development of this teaching-learning strategy seemed a necessary prerequisite before teachers were prepared to examine constructivism and its implications for their teaching. Bronwyn and Frank did not even begin to consider constructivism until after they had organised and

established cooperative learning groups. Harry never managed to establish cooperative learning and did not move on the consider constructivism. Only Jon, who was already familiar with a constructivist approach, was not stalled by the need to implement cooperative learning in his class.

The mass of information in the curriculum package was too much for most teachers. The information, which was provided to support the implementation of the project materials, rather than promoting implementation, had the unanticipated outcome of alienating some teachers. Teachers had difficulty using the BSCS text. They found it impossible to use without reference to other support materials in the package. Those who persevered with the project eventually implemented cooperative learning, began to consider the 5Es and considered constructivism and its implications for teaching. The BSCS curriculum package also necessitated teachers working closely together in their schools and seeking mutual support as they attempted to deal with the difficulties arising from the use of the package. This interaction may have assisted teachers to develop greater insights into the teaching and learning principles than they would if they had worked alone. This was most evident with Frank and Bronwyn who worked as a team in their school from the start of their project but all participants commented on the importance of meeting with other teachers to share ideas about the resources and to be encouraged by their peers.

Almost all students in all classes (except Harry's who did like the cooperative groups into which they were placed) said that they liked their science experiences and claimed they learnt more when using the curriculum packages. Students also thought the nature of teaching and learning had changed. Students in all classes claimed, for example, that they did more practical activities and more group work. One of the main factors cited by students to explain their improved attitude to school science was the greater opportunity to work in groups, particularly when they could work with friends. Some teachers were less convinced that the teaching had changed and were concerned that students may be learning less in the time available. The difference between student and teacher perceptions of the impact of the package requires further research to explore the reasons for these differences.

Factors influencing the success of the implementation

A range of factors influenced the success of the attempted implementation of the BSCS package and its constructivist approach. These factors included

- Previous learning experiences, particularly with cooperative group work and exposure to constructivist teaching.

- The amount of material provided to support the teacher. In this study teachers considered there was too much to cope with.
- Teachers' perceptions of what was meant by trialing a resource. For example, Browyn and Frank were more willing to adapt the package to their needs in contrast to Jon and Harry who considered it important to use the activities with minimal alteration.
- Students' interest in and motivation to learn science. There seems to have been an interaction between the trial of the package and students' interest and motivation. In some classes (particularly Browyn's and Frank's) the trial of the package seemed to increase student interest and motivation. In contrast, students' lack of interest and low motivation may have made it difficult to implement the approach effectively in Harry's class. This possible interaction between students' motivation, interest and the pedagogy of the package requires further investigation.
- Students' ability, particularly in language, as some students found reading the text too demanding.
- The duration and type of professional development. One of the main problems experienced by teachers, other than Jon, was that it was very difficult to quickly develop a clear view of constructivist learning theory. This led to a mechanistic implementation of the 5Es teaching approach and an emphasis on the cooperative learning strategy, which they more readily understood and found attractive.

Conclusion and implications

This study substantiates the view that teachers are a critical influence on the quality of teaching and learning that occurs in their classrooms. If teachers are willing and are positive about trying new initiatives, the chance of successfully employing an innovative curriculum and its teaching approach is increased. However a range of factors interact to influence attempted innovation. In this study these included, students' attitudes and previous learning experiences, teachers' perceptions of their role and the size of the teaching resource teachers were to use.

Teachers should feel free to draw on their contextual knowledge and experience to make professional judgements about their teaching rather than simply follow a sequenced set of activities. This is not to say that curriculum packages should not incorporate pedagogy or a sequence of activities. Rather, there should remain provision for the teacher to make a significant contribution - identifying opportunities for learning, adapting activities and

activity sequences to respond to students' views and ideas that surface as a result of their learning experience.

For the teachers in this study, as it would seem with many innovations, things sometimes get worse before they got better. In their attempt to understand and implement an innovation, teachers learned to use new knowledge and skills. Often success was not achieved in the first attempt. Understanding the pedagogy of cooperative learning and implementing it required time - time to develop the necessary expertise and skill. According to the teachers, the professional development program helped teachers to develop such expertise.

The extent to which this curriculum package promoted engagement with its constructivist theoretical framework has implications for its implementation. As the student text was difficult to implement, teachers had to engage with its underpinning philosophy to use it well. This, in turn, promoted an evolving understanding of constructivism among some teachers. For others, the perceived difficulty of the materials simply caused them to avoid using the curriculum package. Before spending vast amounts of money on developing curriculum packages to improve science teaching, research needs to be conducted to determine not only how to design curriculum packages with a sound constructivist underpinning but to determine how to encourage teachers to engage with its theoretical framework. Providing large amounts of information only resulted in information overload. Although the inherent difficulties in using the BSCS materials resulted in some teachers beginning to think deeply about cooperative learning and then the 5Es approach, it seems unwise to recommend that curriculum packages simply be made difficult to implement.

Perhaps the most important implication from this research is that within an innovation requiring significant change, there may be a hierarchy of needs that should be recognised and worked through before teachers implement a constructivist approach. Aubusson (2002) argued that science education progresses through stages like biological succession and stagnates at different climaxes, depending on factors in the science education environment operating within systemic and school communities. Such a hierarchy of stages, through which change progresses, could be identified in this study. It was only after teachers organised their classrooms for group work and promoted team work through cooperative learning strategies that they began to engage with teaching and learning approaches that embodied constructivist ideas. The rate at which teachers progressed varied and the 'climax' type of teaching, which teachers reach may also vary. However a longer study would be required to explore this further.

It was only after using cooperative learning and the 5Es in a step-by-step fashion that teachers were prepared to consider the constructivist theory underpinning it. It would appear that there was a need for teachers to see that a theory is practical and useful to them before the theory, and its ramifications for their teaching, was worthy of further attention, reflection and analysis. It is as if teachers need to experience success with components of the approach and engage in conversations that confirm successful teaching before a deep understanding of the whole teaching approach develops.

References

Aubusson, P. (2002). An ecology of science education. *International Journal of Science Education*, **23**, (27-46).

Australian Academy of Science (1994). *Primary investigations A science program for primary Schools*. Canberra: Author.

Baird, J. R. (1998). A view of quality in teaching. In B. J. Fraser & K. G. Tobin (Eds) *International handbook of science education* (pp. 153 - 167). Dordrecht: Kluwer Academic Publishers.

Bell, B. (1993). *Children's science, constructivism and learning in science*. Geelong: Deakin University Press.

Bell, B. & Gilbert, J. (1996). *Teacher development: A model from science education*. London: Falmer Press.

Bencze, L. & Hodson, D. (1999). Changing practice by changing practice: Toward a more authentic science and science curriculum development. *Journal of Research in Science Teaching*, **36**(5), 521-539.

BSCS (1994). *Investigating Patterns of change: Middle school science and technology*. Dubuque, IO: Kendall Hunt.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices*. Portsmouth: Heinemann.

Carr, M., Barker, B., Bell, B., Biddulph, F., Jones, A., Kirkwood, V., Pearson, J. & Symington, D. (1994). The constructivist paradigm and some implications for science content and pedagogy. In P. J. Fensham, R. T. Gunstone & R.T White, (Eds) *The content of science* (pp. 147 - 160). London: The Falmer Press.

Cohen, L. & Manion, L. (1994). *Research methods in education*. London: Routledge.

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

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd edition) (pp. 119-161). New York: Macmillan.

Fensham, P. J, Gunstone, R. F. & White, R. T (1994). Science content and constructivist views of learning and teaching. In P. J. Fensham, R. F. Gunstone & R. T. White (Eds.) *The content of science* (pp. 1 - 8). London: The Falmer Press.

Fullan, M. G. (1991). *The new meaning of educational change*. Columbia, New York: Teachers College Press.

Liem, T. L. (1987). *Invitation to science inquiry*. Chino Hills: Science Inquiry Enterprises.

Loughran, J.J. & Northfield, J.R. (1996). *Opening the classroom door: Teacher, researcher, learner*. London: Falmer Press.

Matthews, M. R. (1998). Introductory comments on philosophy and constructivism in science education. In Matthews, M. R. (Ed.) (1998). *Constuctivism in science education*; A philosophical examination. Dordrecht: Kluwer Academic Publications.

McRobbie, C. J., Watters, J. J. & Diezmann, C. M. (1999). Implementation of an instructional sequence based on constructivist principles. Paper presented at the annual conference of the Australasian Science Education Research Association, July 10-12, 1999.

Millar, R., Leach, J. & Osborne, J. (Eds.) (2000). Improving science education: The contribution of research. Open University Press.

Raghavan, K., Sartoris, M. L. & Glaser, R. (1998). Why does it go up? The import of the MARS curriculum, as revealed through changes in student explanation of a helium balloon. *Journal of Research in Science Teaching*, **35**(5), 547-567.

Richardson, V. (Ed.). (1997). *Constructivist teacher education*. New York: Falmer Press.

Skamp, K. (Ed.). (1998). *Teaching primary science constructively*. Sydney: Harcourt Publishers.

Smith, E. L, Blakeslee, T. D. & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning in science. *Journal of Research in Science Teaching*, **30**(2), 111-126.

Solomon, J. (1994). The rise and fall of constructivism. *Studies in Science Education*, **23**, 1-19.

Strike, K. A. & Posner, G. J. (1992). A revisionist theory of conceptual change. In Duschl, R. and R. J. Hamilton (eds.), Philosophy of science, cognitive psychology, and educational theory and practice (pp. 147 - 176). Albany: SUNY.

Trowbridge, L. R. & Bybee, R. W. (1990). *Becoming a secondary school science teacher*. 5th Edition. Columbus: Merrill Publishing Company.

Swanage, M. & Lane, N. (1999). Primary investigations. April, 1999, 1-7. [Online] http://www.science.org.au/pi/intro.htm.

Tsai, C. C. (1998). Science learning and constructivism. *Curriculum and Teaching*, **13**, 31-52.

Venville, G., Wallace, J. & Louden, W. (1998). A state-wide initiative: The primary science teacher-leader project. *Research in Science Education*, **28**(2), 199-217.

Windschitl, M. & Andre, T. (1998). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. *Journal of Research in Science Teaching*, **35**, 145 - 160.