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Using a Constructivist Approach to Enhance Conceptual Understanding of Science: the pre-service training of Fiji primary school teachers[1]

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Science teaching in Fiji is often very formalistic and didactic. This is in part due to an extremely competitive examination system, but work by Muralidhar (1989) has also indicated that at the primary and lower secondary level, teachers' content knowledge of physical science is often lacking. This in turn impacts on the teachers' confidence, and often results in a teacher-centred approach in which there is little deviation from the set text. This paper outlines an innovative science programme which was developed and trialled with Fiji pre-service primary teachers in an attempt to improve their content knowledge of physical science. It also reports some of the student teachers' views on the various teaching strategies employed during the programme.

Introduction

Science and technology are promoted as major contributors to national development (Dunne & Rennie 1990). Consequently, improved science education has been placed high on the agenda of tasks to be tackled in many developing countries (Kahn 1990), although progress has often been limited. In fact, Elkana (1981) claims that the enormous investment in teaching science in developing countries has basically failed, while Hewson (1988) describes how efforts to teach science in developing countries often result in rote learning of strange concepts, mere copying and a general lack of understanding on the part of local students. These generalisations can be applied to science education in Fiji. In a year long naturalistic study of upper primary and middle school science, Muralidhar (1989) described a situation in which students were given little opportunity to carry out practical activities in science, and an

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extremely didactic form of teacher exposition was the predominant method of instruction during science lessons. Muralidhar concluded, amongst other things, that teachers' limited understanding, particularly of aspects of physical science, often resulted in their rigid adherence to the text book and the omission of certain activities or topics.

Although many of the problems associated with science education in developing countries have been documented (e.g. Ingle and Turner 1981), Baker and Taylor (1995) assert that few attempts have been made to understand how non-western students might better learn science.

The significance of this study is that it addresses the gap in the research identified by Baker and Taylor by providing student teachers in Fiji with learning experiences based on a constructivist epistemology. This approach to the teaching and learning of science is highly regarded and strongly recommended by many science educators (e.g. Millar 1988; Summers 1992). While the effectiveness of this approach in improving the student teachers' science knowledge was assessed quantitatively and shown to be associated with statistically significant improvement, this paper reports their views on the teaching strategies and how they compared with those experienced during their schooling. The fact that these people will comprise the next generation of primary school teachers in Fiji underlies the importance of this study of their perceptions about the appropriateness of constructivist-based teaching strategies. The comparative views of the two major ethnic groups in Fiji, indigenous Fijians and ethnic Indians, was also of particular significance, given their cultural diversity and well-documented differential performance in science and other school subjects in public examinations at all levels of education in Fiji.

Methodology

Shaeffer (1986:5) made this important observation in the context of developing countries:

> In much of the developing world, educational research is largely empirical and quantitative, characterised by the development of standardised tests and questionnaires, the production of data from large samples of schools and individuals, and the analysis of these data by a variety of statistical methods.

One consequence of this, according to Vulliamy (1990), is that some research questions have rarely been addressed at all, despite their potential relevance to both the process of policy making and to the more theoretical study of schooling in the developing world.

With these considerations in mind, this research project was conceptualised to include a combination of qualitative and quantitative methods with the results from each method being used to inform later methods (Greene, Caracelli and Graham 1989). It comprised four phases: an elicitation phase, a prevalence phase, an experimental phase, and an evaluation phase. This paper reports findings from the evaluation phase in which semi-structured interviews included questions which asked students to make explicit their views on the teaching strategies employed throughout the intervention. In particular, feedback was sought on which strategies they found most effective, and their views when they compared the instruction they had received during the intervention with their previous experiences of science, at the college as well as at school.

Procedure

Participants in that part of the larger study described here were pre-service primary teachers in the second (final) year of their course. There were 13 indigenous Fijians (9 female) and 14 ethnic Indians (7 female). They comprised an intact class taught science by the author for the entire period of the intervention phase of the main study. The author has extensive experience teaching science in developing countries, including Fiji, and was a visiting researcher at the college for the entire year. He designed the teaching

sequences and conducted the interviews that provided the principal data source for this paper.

The teaching sequences (Figure 1) were informed by the theoretical perspective of authors such as Vygotsky (1962) and Solomon (1987) who claim that the social context can make an essential difference to the learning process and advocate taking advantage of the social nature of learning to foster knowledge construction. While it is at odds with much current practice in Fiji schools, the view of learning as a largely social activity appears to be appropriate for indigenous Fijians who have a strong oral tradition and who tend to be collaborative rather than competitive in nature, despite considerable western influence. Ethic Indians are more competitive in nature and tend to succeed in the public examination-dominated education system in Fiji.

The teaching strategies employed drew extensively on those described by Summers and Kruger (1994), who made considerable use of analogies in an attempt to build on teachers' existing ideas. They also attempted to encourage active, collaborative learning in which views were expressed, exchanged and developed through discussion and social interaction, while at the appropriate time they confronted teachers with the currently accepted scientific view of a particular concept (Summers 1992).

As it was important for the students to become aware of their own ideas about a science topic, some time (normally 10-15 minutes) was spent eliciting and discussing students' views at the beginning of each new topic, before proceeding with instruction. While they were initially reluctant to reveal their own ideas about a science topic prior to instruction, the students become more comfortable with this procedure and it became unnecessary for the instructor to prompt discussion by reference to examples of alternative science concepts reported in western science education literature.

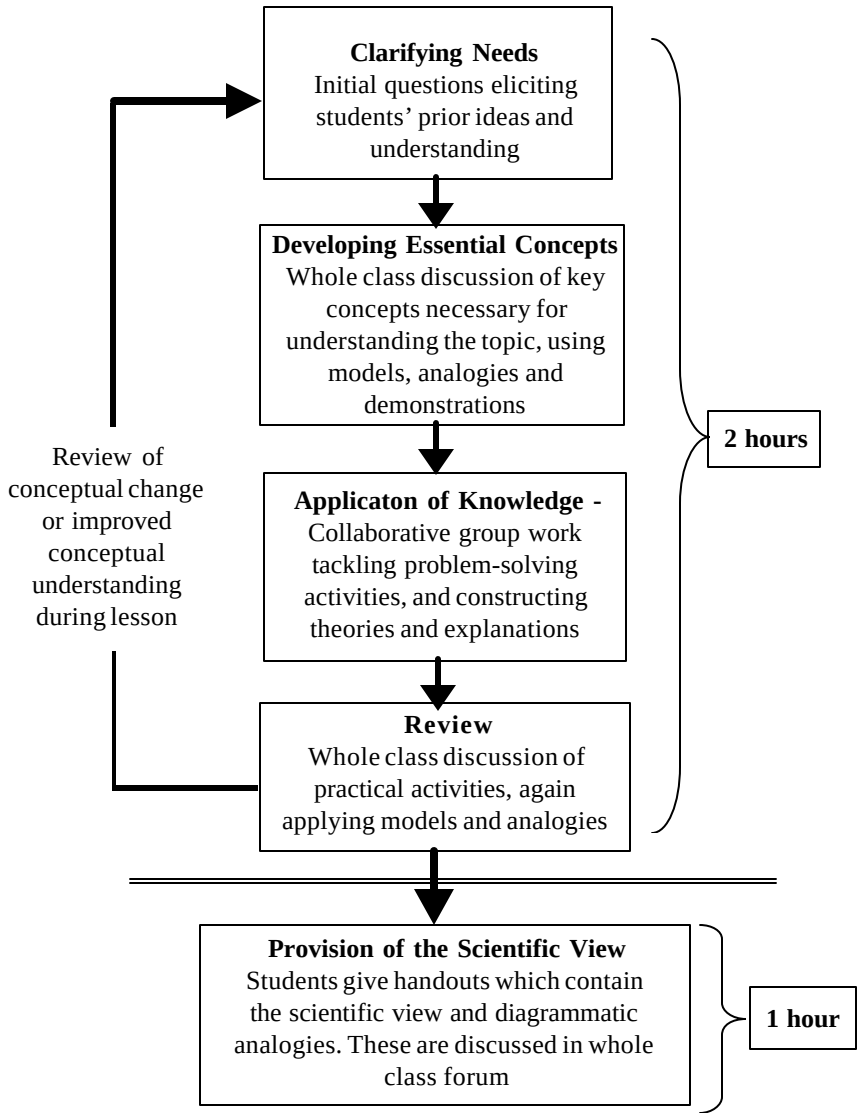

Figure 1. **A flow chart of the sequence of a typical weekly experimental session comprising a two-hour (double) followed by a one-hour (single) class**

The analogies used were mainly diagrammatic in form and largely taken from the work of Pendlington, Palacio, and Summers (1993). They were frequently used in the initial class discussions in an attempt to assist the students to develop concepts that would allow them to work on the problems presented later in the session. (See Fig. 2.)

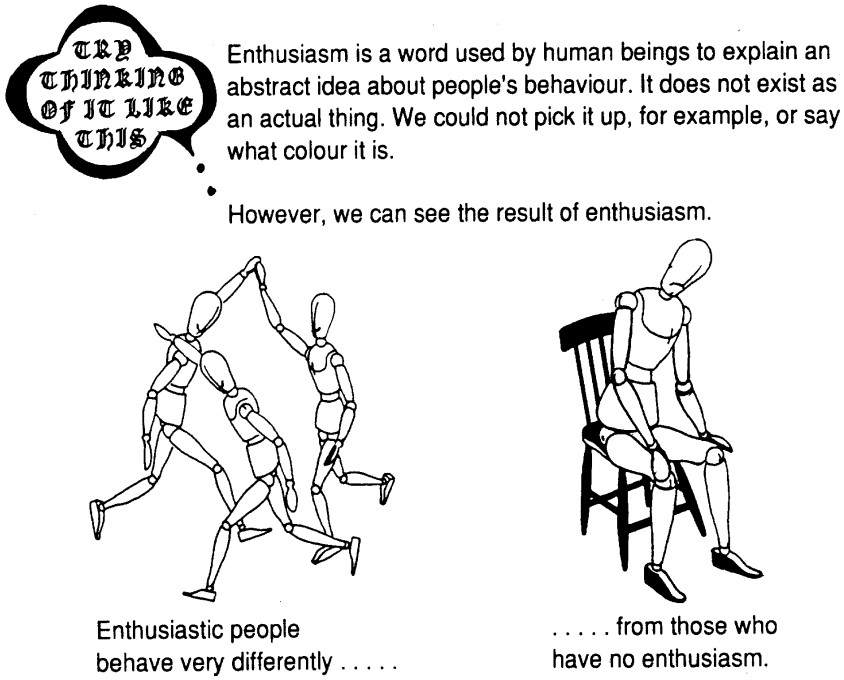

Figure 2. **An example of an analogy used in the interventions, that presents enthusiasm as analogous to energy (Pendlington et al., 1993).**

Similar use was made of models, in particular a commercially produced Kinetic Theory or Particle demonstration apparatus. This provided the students with a strong visual representation of how particles behaved in different conditions. The students were shown how to construct a low cost version of this model that they could use for themselves throughout the intervention.

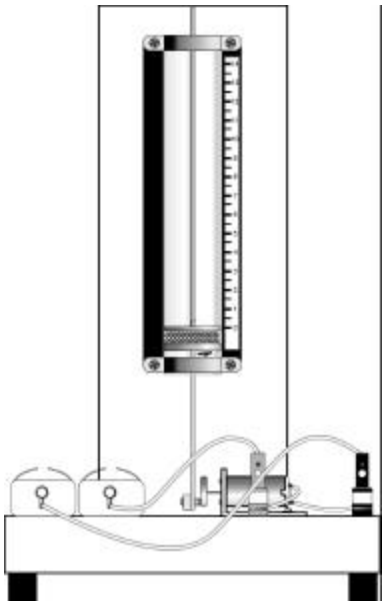

Figure 3. **A diagrammatic representation of the commercially produced Kinetic Theory model used with the experimental group.**

Other models, such as a "cannonball model" that helps students to visualise the transfer of energy between particles, were also constructed by the students.

It was demonstrated in analyses yet to be reported, that the constructivist-based approach to teaching resulted in statistically significant increased knowledge of the science concepts by the students in this class compared with another class taught the same unit by the author using a more conventional, didactic approach. However, we were interested to determine the students' answers to the question "to what extent is your increased understanding attributable to the particular teaching strategies employed by your teacher?" These were elicited in a series of post-instruction interviews, supported by observations of students during all lessons, audio-taped records of verbal negotiations of meaning during group activities, and impromptu interviews with students during the course

of the teaching programme. The interviews probed all aspects of the teaching approach, including the initial focus on the students' understanding at the commencement of lessons, the novel use of analogies and physical models, extensive involvement in group activities and the use of concept mapping. Students were also asked how the constructivist-based teaching programme compared with their previous experience of science instruction.

Findings

Overall, this programme, although based on pedagogy developed in a western context, appeared to be appropriate for use in Fiji. Certainly the students who undertook the innovative programme made significantly greater gain scores on a post-test than a group taught the same content, in the same time period, but in the traditional manner. A series of post programme interviews also revealed a qualitative improvement in their understanding. However, an interesting but difficult question was the extent to which the growth in the student teachers' understanding of specific concepts could be attributed to particular teaching strategies used during the trial programme. As Summers and Kruger (1994) point out, the only evidence available in connection with this question comes from the subjects' perceptions. These were elicited in a series of interviews conducted after the teaching programme had been completed, along with the students' views on how this trial programme compared with their previous experience of science instruction. (In the sections of discourse that follow, the students have been given pseudonyms. The race and sex of each individual is presented at the end of each segment of discourse).

Contrast with school and the college science programme

Many students who took part in the final interviews reported that they had been taught science at school in an environment that offered them little opportunity to do practical work.

Researcher: When you were at school learning Basic Science did you get a chance to do much practical work?

Prakash: Depends ... but mostly the teacher just writes the answer.
Researcher: So the teacher wrote the answers on the board?
Prakash: If they were not able to cover the syllabus then they just write the answer on the board and we learn it.
Researcher: Even if you don't understand it?
Prakash: (laughs)
Yes.
(*Indian male*)

Some contrasted their experiences of school science with the trial programme conducted at the college.

Seremaia: This was really different from school.
Researcher: In what way?
Seremaia: In school most of the time you didn't do experiments … the teacher tells us what the result will be like so we just sit down there and absorb everything from the teacher.
Researcher: Was that because of lack of equipment?
Seremaia: Not really, the teachers could have made more effort … improvised.
Researcher: Did you perform any experiments?
Seremaia: If I'm correct maybe only one.
Researcher: In one year of Form 7 (Year 13)?
Seremaia: In one year yeah
(*Fijian male*).

Other students contrasted the trial programme with the normal teaching procedures at the college.

Researcher: The style of teaching that I used during the six week programme, was that the same or different to the style of teaching you normally receive at the college?
Nisha: It's quite different.
Researcher: In what way was it different?
Nisha: Because before we just didn't used to go into depth about anything. We just learnt about it briefly on how

to do the experiments and things … we didn't learn actually why it happened, we learnt only that it happened.

Researcher: So are you saying you didn't learn the explanations?

Nisha: No, no, not in any detail, we learnt it in brief.

Researcher: In brief … did you find it helpful to learn things in more depth?

Nisha: Yes sure.

(*Indian female*)

Elicitation of preconceptions

Despite early concerns that students might be intimidated or offended by a teaching approach which made public inadequacies in their current knowledge of science, most students stated that they found it valuable to discuss their preconceptions and were not uncomfortable when these proved to be different from the scientific view. Some tended to blame their misconceptions on the poor teaching they had received at school. Most claimed to be 'happy' when they found out their views were 'wrong', as they felt it was important to have the correct scientific view if they were going to teach science themselves.

Researcher: OK, so you said you had one idea and then we discussed it and you discovered that the scientific idea was different from yours?

Laisani: Yeah.

Researcher: How did you feel about that?

Laisani: I feel happy because the idea that I think is different and it's wrong from the scientific idea.

Researcher: You felt happy?

Laisani: Yes because it improves my knowledge of science.

(*Fijian female*)

Introduction to constructivisim

Prior to teaching the unit about matter and how it changes, two one-hour class sessions were devoted to an introduction and

discussion of constructivist views of learning, supporting research and implications for changing practice in science classrooms. However, the response to this strategy proved to be rather disappointing. Most students claimed they had no recollection of this theory. Some confused it with analogies, and even after considerable prompting about the ideas children bring with them to science lessons only a few could amplify this further.

Researcher: At the very beginning when we discussed something called Constructivist Theory, did you understand that?
Meriani: Yes that's all about analogies and all.
Researcher: No before the analogies I mentioned that we often have ideas about science before we …
Meriani: Oh before we even get into a science lesson.
Researcher: Yes.
Meriani: Like teachers they sometimes think that students come without any knowledge of science but actually they do have some.
Researcher: Did you understand that idea?
Meriani: (laughs)
Yeah because like although they have conceptions about science mostly they are the wrong ones … for example like you say your mum tells you not to sit next to the fire because your spine will melt.
(*Fijian female*)

Given the generally poor recall of the constructivist view of learning it seems unlikely that there was the kind of metacognitive development in terms of better understanding of their own learning process that was claimed by Summers and Kruger (1994), who were working with experienced teachers.

Use of models and analogies

Students contrasted their introduction to particle theory at school with that employed during this unit at college. Only one student could recall being taught about particles by way of analogy at school. He had a clear recollection of his teacher's approach:

Vinod: Well I just remember one thing about when I was taught about particles. The teacher used to break up pieces of chalk to show us the powder and the big pieces and the small pieces.
(*Indian male)*

None of the students had ever encountered a particle demonstration even though all had been introduced to the concept of the particular nature of matter during high school. This was presented in the set school text as a series of diagrams that some students found difficult to understand.

Salote: In high school they had particles in this shape … circles and we couldn't understand much and there was something written in the circles.
Researcher: I see … you did this in form 4?
Salote: Yes.
Researcher: And there was something written in the circles?
Salote: When we looked at the pictures we could see that the particles moved apart when they were heated … we didn't know they gained and lost energy.
Researcher: What did you think happened to the particles when the substance cooled?
Salote: I didn't know.
(*Fijian female*)

The students claimed that the strong visual representation provided by the model used during the lessons at the college was helpful in improving their understanding of particle behaviour and in particular the relationship between particles and energy.

Researcher: Why did you find the particle model particularly helpful?
Salote: Because you can actually see the particles move … you can see how they lose energy.
(*Fijian female*)

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Meriani: Well for example like I could see … when we apply energy I can really know that the size of the particles and the number of remains the same even though energy was … there's loss of energy or there's gain of energy the particles remain the same.
(*Fijian female*)

Students claimed they also found the analogies particularly effective because they were able to link them to their everyday experiences, and a number of students evoked specific taught analogies when discussing this aspect of the instruction. One mentioned an analogy in which migration was linked to evaporation.

Sheetal: There's lots of people and then they migrate eh from, for example, Fiji to America, then the other poor are left so they need more money … I mean if they work hard and get more money then some more migrate … and it's the same with the acetone … it needs more energy … some of them evaporates the others are left … they need more energy.
(Indian female)

Although not a perfect explanation, this Indian student had grasped the idea that energy is required for evaporation to take place. This was a particularly apt analogy for Fiji where the migration of wealthy Indians to western countries is commonplace. A number of students remarked that they would try to employ analogies in their own teaching where possible.

Collaborative group work

Group work was generally well received by the students who claimed that they found it beneficial to share their ideas when attempting to develop explanations for the outcomes of the practical activities. Fijian students readily connected this kind of learning experience to their cultural background.

Researcher: Do you like working in groups or do you prefer to work individually?
Merelesia: I like working in groups.
Reseacher: Why is that?
Merelesia: So that I can share the ideas, I can eh share the ideas with others and the others share ideas with me.
Researcher: Did you think this was a suitable way for Fijians to work?
Merelesia: Yes.
Researcher: Why would that be?
Merelesia: Because Fijians rely on each other and eh they are very good in sharing.
(*Fijian female*)

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Evivi: We share our knowledge … our skills and we are never scared of asking one another questions … any type of question.
(*Fijian female)*

While Indian students agreed that their society was more competitive and individualistic, they too claimed they enjoyed the experience of group work. One student was able to reconcile competitive instincts with a collaborative group learning environment.

Sanjay: Even if you want to compete, group work can help … if I want to compete and know more then I have to involve myself into a discussion with other people in my group.
(Indian male)

However, group work was not viewed as a panacea by all students, as a small number stated that although they found it beneficial they were critical of the fact that not all their colleagues participated.

The use of concept maps

Concept mapping was a new learning strategy for all students, and was introduced by the author prior to, and during, the early stages of the unit. Many of the students interviewed described how concept

maps could be used to help gauge their understanding of a topic. However, this strategy received a mixed response with only about half of those interviewed stating that they found it of benefit. One Fijian student produced a number of concept maps voluntarily.

Milika: It's (concept mapping) … it was rather difficult in the first place … the one we did at the end of last semester … comparing it with the one we did more recently … like I've found that I've made many more connections this semester than I've written last semester … that shows me that I have learnt more this semester.

(Fijian female)

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Researcher: Did you find it [concept mapping] an interesting idea?
Meriani: It was interesting … first we quarreled with my friends about what would happen…the relationships between those … those … what?
Researcher: Concepts.
Meriani: Those concepts … but it was interesting finding the relationship and how they would interact.

(Fijian female)

However, other students found the concept mapping procedure difficult and of little value to them, particularly those who failed to understand the potential learning benefits of this strategy.

Researcher: How did you find drawing the concept maps?
Kalisi: I found that difficult.
Researcher: Has any other teacher done that with you?
Kalisi: No.

(*Fijian female)*

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Researcher: Can you explain to me the idea behind drawing a concept map?

Vinod: I mean they will be using arrows and the arrows will be going to the right place and maybe there's misunderstanding and they'll put it another way.
Researcher: How did you find the concept mapping?
Vinod: It was quite confusing.
Researcher: Why was it confusing?
Vinod: When it has many links it's like eh many arrows going to one place and some having just one or two … I didn't find it very useful … I didn't like it.
(Indian male)

Although there was evidence from some of the sequential concept maps developed by some groups of students that they were producing more links between appropriate concepts, a sufficient number found this strategy difficult and of limited value to suggest that more training in the use of this technique was required. Initial training had been given, but because of time constraints it was not possible to give the students sufficient practice to master the technique. However, the positive responses of some students suggest that this strategy could prove to be effective in a constructivist-based learning environment in the Fiji context. Further research in this area in Fiji is clearly desirable.

Conclusion

To date the most significant piece of research into science education in Fiji has been that conducted by Muralidhar (1989). He identified many of the existing problems. The research reported here, which is part of a larger study, has attempted to build on Muralidhar's findings by trialling a science programme based on a constructivist view of learning rather than the more usual transmissive approach to science teaching so prevalent in Fiji. Many of the strategies employed, such as the use of analogies, proved to be entirely novel to the pre-service teachers, and certainly neither the students nor the science education lecturers at the college were familiar with constructivist theory. Thus, this overall approach was highly original in the context of the teachers' college.

The outcome of the trial was very promising, not only because it appeared to give the students of both ethnic groups an improved understanding of an area of science often considered conceptually difficult, but also because the students were generally able to identify those strategies which they had found most beneficial, and to articulate why this was the case. The fact that both Fijian and Indian students benefited from the science programme is particularly significant as, traditionally, Fijians have not performed as well as Indians in science, especially at the secondary and tertiary levels (Stewart 1983; Tavola 1992; Macpherson and Taylor 1994). Research into other areas such as general ability (Chandra 1975) and language competence (Elley and Mangubhai 1979) has failed to explain this difference.

However, one of the more plausible suggestions put forward by Nabobo and Teasdale (1994), is that of a total disregard for Fijian ways of learning in the formal school system. Certainly, it is possible that the formalistic, didactic style of teaching evident in many of the classrooms in Fiji may be at odds with the oral tradition of the Fijian culture where discussion is the predominant mode of information sharing.

The approach to learning adopted in the programme which was implemented at the college put a strong emphasis on discussion and the negotiation of knowledge in an effort to help the students construct a better understanding of scientific concepts. Clearly this approach was more in accord with Fijian ways of learning, and may go some way towards explaining the positive outcomes achieved. However, it should also be pointed out that although Indians students have in general fared better in Fiji's extremely competitive education system, those who took part in the trial found the strategies involved generally beneficial. Thus, despite the fact that this pedagogy, which derives from a constructivist epistemology, was developed in a western context, it appeared to cross both national and cultural boundaries quite successfully.

It is hoped that some of these strategies will be adopted by the college for the future training of student teachers in science. However, whether the students themselves will employ any of these strategies in their own teaching is less likely as, when they enter the teaching profession

in Fiji, they will be exposed to a very tightly prescribed curriculum and an extremely pervasive examination culture which often acts as a major impediment to any innovation in science teaching at the primary level. As one student pointed out.

> Mostly you prepare children for examinations and what happens for example in the external class 8 exam … if the teachers they try to change or they want to use some different ideas in their way of teaching then the children might suffer … because the pattern here is that mostly the exam questions are taken straight from the text book and we have to teach what we are given.
> *(Indian male)*

A major challenge for science educators in Fiji will be to develop a system of assessing students which does not encourage a style of teaching and learning based largely on teacher expositions, rote learning and a strong reliance on the prescribed text. This will be no small task as class sizes in Fiji are large and science departments often poorly resourced. Perhaps an even more challenging obstacle to change is the problem that many people in Fiji equate education with passing examinations and hence attempts to modify the examination system or familiar teaching strategies are very likely to be extremely unpopular politically.

The current system acts to stifle innovation and thus appears to deprive many students of the type of teaching that not only helps make science interesting, but also provides them with experiences that lead to meaningful learning. This is particularly unfortunate because, as research by Twoli and Power (1989) indicates, the school and teacher characteristics play a more significant role in shaping science attitudes and achievement in developing countries than in developed countries where home background is a more significant factor.

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