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What are the Qualities of a Good Explanation?

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What are Explanations?

Much has been written about the role of explanations in science (e.g., Achinstein, 1983; Hempel, 1966; Harre, 1988) with much less written about explanations in science teaching (Dagher & Cossman, 1992, Horwood, 1988; Martin, 1970). Horwood (1988) makes a distinction between 'explanation' and description and illustrates by examples that, at the junior high school level at least, the two terms are often considered, at last by students, to be synonymous (Wong, 1993). At higher levels of secondary education, there is an expectation that the underlying mechanism of mitosis, for example, should be given in a question that asks for an explanation of mitosis. Further explanations involve 'explain how' and 'explain why' and the hearer or reader expects to learn about specific causes.

Suitable explanations in science are the essence of understanding any phenomena under investigation even though the research literature devotes little attention to teacher explanations (Shulman, 1986). Explanations can be presented from the logic of teaching (Smith & Meux, 1970), from a philosophy of science perspective (Hesse, 1970), or from an educational perspective (Martin, 1970; Ennis, 1986). However, in discussions about explanations, authors usually do not describe the nature of the science content being taught. Few studies have focused on the actual content, rather the content has been the convenient vehicle for examining teachers' explanations.

In this paper, we examine the overt features of science content knowledge and review the types of explanations available to teachers to explain this content. Very little research has been performed into the nature of explanatory frameworks, therefore there is little consolidated theory in this domain. In this paper therefore, a theoretical overview is developed that describes our research on the philosophy of explanation, the analysis of science content and of teachers' preferred explanations.

Properties of Content

White (1994) argues that the properties of the science content (see Figure 1) both limits and should influence the types of explanations used by teachers. For instance, abstract concepts like atoms and magnetism involve a high proportion of images and models that are most often presented as analogical models. Both the teacher's and the students' common experience, interests, preferences and culture interact in determining which explanations are most appropriate in a given situation. It may often be the case that multiple or mixed explanations are necessary to cater for the individual student differences present in any one class.
Openness to common experience
Presence of alternative models with explanatory power
Presence of common words
Demonstrable Versus Arbitrary
Extent of Links

Abstraction
Complexity
Mix of types of knowledge
Social Acceptance
Emotive Power

Figure 1. Properties of content that influence teaching procedures (From White, 1994, pages 256-262)

In brief, the terms in Figure 1 are described by White as follows:

Openness to Common Experience. Certain content like forces and motion, or light can be experienced by students and so interpretations are developed to account for instances that are often not in keeping with scientific explanations. How to explain content such as forces compared to solar system astronomy presents teachers with specific challenges.

Abstraction. Different content has different levels of abstraction such as displacement compared to acceleration. The more abstract the concept, the less likely that learners will have direct experience of it and so will not hold prior conceptions. How to take these differences into account when offering explanations also challenges for teachers.

Complexity. Some content comprises many components while others have few, for example, sound (many) compared to density (few). The need to explain the connections most likely requires different teaching approaches.

Presence of Alternative Models with Explanatory Power. One of the challenges for teachers is to know when best to use one model to explain a concept rather than another. Research suggests that the use of multiple models can be effective.

Presence of Common Words. Science teachers continually face the challenge of how to use common words such as 'animal', 'flower' or 'force' that have different meanings in science. How are these common words to be best used in teachers' explanations?

Mix of Types of Knowledge. An important property of content is the emphasis it puts on knowledge of different types such as propositions, images, episodes, and procedures. For example, explaining atomic structure presents many challenges. How do teachers decide when to use their preferred explanations?

Demonstrable Versus Arbitrary. Some content is organised in a demonstrable way such as flowering and non-flowering plants. Others are somewhat arbitrary such as physical and chemical change and are very difficult for the students to work out by demonstrations. How do teachers decide the best explanations in these situations?

Social Acceptance. Many topics of science such as creation and evolution, population control and consumption of fossil fuels are contentions. How are teachers to decide the explanations to offer and with what level of personal commitment?

Extent of Links. Content is often presented in science classes in a disconnected way. For example, the topic of cellular respiration is often presented at the beginning of a biology textbook but photosynthesis is presented much later without any reference to the earlier chapter. How should teachers decide which content needs to be connected and how should these relationships be explained to integrate these concepts?
Emotive Power. Different topics are more likely to arouse more interest than others. Are there different approaches for explaining the content if students' interests are different?

Analogical Explanations

Several of the above factors that enable teachers to create conditions in which students can learn by constructing their own knowledge are directly related to teachers' understanding of the science content. Related to teachers' content knowledge is their content-specific pedagogical knowledge which includes the use of those analogies that can effectively communicate concepts to students of particular backgrounds and prerequisite knowledge (Shulman, 1986). However, analogies are not used by science teachers as often as might be expected (Dagher & Cossman, 1992; Treagust, Duit, Joslin, Lindauer, 1992) in spite of the existence of useful analogies in the textbooks used in science classrooms. In addition, research suggests that when analogies are used in science classes they are frequently not presented in a manner which enhances their effectiveness. Recent research has shown that teachers can substantially help students in their understanding of concepts if analogies are presented in lessons in a systematic manner that is meaningful to the students (Glynn, 1991; Treagust, 1995). It seems most likely that the vast majority of science teachers have no formal training in the use of analogies and hence it is not surprising that analogies are not used in explanations as often as they could be.

A teacher's knowledge of science content in relation to the level of competence of his or her teaching has been largely ignored by researchers (Shulman, 1986). In our own work, however, we have observed the importance of subject matter knowledge when teachers introduce analogies to help students understand the phenomena under question. For example, the introduction of the car cooling system analogy for homeostasis and the fluid mosaic model to represent semipermeable membranes could not have been presented and used effectively in lessons with senior high school classes without very good content knowledge of the teachers concerned.

One of our current research programs is examining the contribution that analogies and models make to teachers' explanations and indicating in which ways the explanations are related to the nature of the science content. For example, explaining unfamiliar concepts by comparing them to familiar objects and processes is the very basis of analogy but an analogy will only bolster an explanatory framework if a genuine systematic similarity exists between the analog and the target.

Explanatory Frameworks

Explanations are usually framed in ways that reflect the style and individuality of the speaker or writer. The 'teacher as an artist' simile succinctly describes what may happen when a creative teacher crafts an elegant and concise explanation in a challenging situation. How do expert teachers draw creative word pictures that both appeal to and inform a diverse group like a class of students? Artists and craftsmen are distinguished by their styles and it is just as likely that expert teachers use an artistic style or creative format within which they logically develop their explanations, arguments and questions. Many educational writers call these structures "explanatory frameworks" but fail to explain what the term means. The idea of
frameworks for conceptions (Toulmin, 1972) and explanations seems to be a popular post-modern notion that draws on schema theory for its justification. The "framework" metaphor evokes an image of a three-dimensional matrix where the nodes are schemata or conceptions and the interconnections could be the logical or aesthetic ribs upon which an argument or explanation is detailed and "fleshed-out."

A theory that is specifically scientific and which makes supportable predictions is an "explanatory framework" (Solomon, 1995, p. 16). Solomon reasons that a good explanation takes into account the audience and context and appears to be 'correct.' She gives this example.

In science the explanation will not satisfy if it is, for example, in terms of human agency. When Bohr produced his famous explanation for the lines in the spectrum of hydrogen, which had been observed but not explained for half a century, it would not have done to attribute them to impurities in the hydrogen, nor to how the observer had carried out the experiments. A suitable explanation would need to start from Rutherford's sun-and-planet image of an atom which was familiar and acceptable to his scientific audience. This is just what Bohr did. Then he added to this his new concept of electrons in stationary orbits. The existence of spectral lines followed from the application of well-known principles of energy and frequency. The whole argument of the explanation fell comfortably within the context of contemporary physics. (p. 16)

When crafting explanations, scientists, teachers and students are not free to use just any sort of explanation, acceptable explanations need to agree with the scientific consensus on the subject. A second important feature of an explanatory framework is its holistic agreement. Bohr satisfied both of these conditions by applying his new ideas to the previous scientific consensus and out of it, synthesised a powerful new theory.

Solomon also points out that metaphors, analogies and models are important components of explanatory frameworks. Explaining unfamiliar concepts by comparing them to familiar objects and processes is the very basis of analogy but an analogy will only bolster an explanatory framework if a genuine systematic similarity exists between the analog and the target. Many scientists have supported their explanations by analogy (Lorenz, 1974; Oppenheimer, 1955) and other scientists (e.g., Kepler, Van't Hoff, Pasteur) have even used analogy as a source of scientific discovery. Thus, science often uses models as analogies, indeed, it is often difficult to differentiate between an analogy and a model in science. This is why this paper chooses to use the term, analogical model for the analogies and models that are used in chemistry.

Factors Which Influence Explanations

Broadly speaking, we are concerned about teachers' explanations that impart knowledge and promote student understanding. We believe that how these explanations can be analysed in a meaningful manner depends, to a large extent, on the theoretical analysis of the content of the science. In this regard, it is our contention that an investigation into the relationship between the content being taught by teachers and the manner in which they go about explaining it can have useful outcomes for improving classroom practice and students' learning.
When experienced teachers decide to explain difficult concepts in a particular way, they are usually influenced by a variety of factors related to the content, the teacher and the students. Some of these factors are listed in Figure 2. The teacher and student factors are recognised as being very important for learning and for successful teaching, but in this paper we do not address all of them but rather attempt to examine the content factors in terms of the explanations preferred by science teachers.

In an interesting discussion on the process of developing science content in constructivist teaching, Carr et al. (1994) show how teachers can use constructivist principles to enable them to explore the nature of the science content with their students. Questions debated are: 1) Does nature contain a definition of the concept which can be uncovered through appropriate experiences?, 2) How does a scientist develop a statement of a concept?, 3) Is there a single explanation for a phenomenon which teachers should aim for?, 4) Can science always provide an answer to a question?, and 5) When a 'better' explanation is proposed, how do scientists decide to accept it? (p. 151).

Answers to these questions illustrate the complexity of the task at hand in providing explanations in the science classroom. Also, the questions point out the difficult burden placed on science teachers because school science can only be provisional knowledge leading towards the scientist's construct. In most cases the scientist's constructs are inaccessible to students - the properties described earlier by White give some indications of what these might be and why they are inaccessible - so transitional concepts should be addressed in a comprehensible manner.

In responding to question 3, Carr et al. proposed that the level of explanation depends on the purpose of the exploration and the background of the students for whom the explanation is provided. They also emphasised that it is "inappropriate for classroom interactions to convey the impression that here is a single correct explanation of any phenomena or a single definition of any concept (p. 156)." In responding to question 5, Carr et al. point to the need to let students know 'the rules of the game' for the development of ideas in science. Teachers should encourage students to recognise that whether or not a proposed explanation is better than others is related to the notions of elegance, parsimony, and greater connectedness as well as those of plausibility, intelligibility and fruitfulness.

In his discussion about the role of explanations in science, Horwood (1988) refers to the work of Roberts (1982, cited in Horwood, 1988)) who developed the concept of curriculum emphases in science which are defined as a set of coherent messages to the students about the nature of science contained implicitly within the curriculum. Three of the seven emphases refer to explanations, which he labelled "the 'correct' explanation", "the structure of science", and "the self as explainer" emphases. In brief, the duty of the teacher in the first emphasis is to explain things to the students using explanatory statements approved by the research community; in the second emphasis, the teacher explains things but the explanations are subject to scrutiny and are available for change; in the third emphasis, the teacher gives credence to the students' intellectual activity as explainers.
## CONTENT FACTORS

- The nature of the content (material or process; specific or general)
- Importance of the concept within the course (examinable, central or peripheral)
- Micro/macro content levels
- Process/matter content attributes
- Is the explanation deductive, inductive or causative?
- Teleological and anthropomorphic explanations
- Is the information a law, a theory or hypothetical?
- Relational or instrumental knowledge
- Alternative conceptions (already present or could arise during teaching)
- Related experiences and problems
- Relevance to the topic in hand

### TEACHER FACTORS

- How the teacher understands knowledge (constructivist, positivist, objectivist)
- Teacher's subject matter expertise
- Teacher's pedagogical expertise
- Teacher's rational preferences
- Teacher's conception of "what is science?"
- Teacher's explanatory style (direct, comparative, Socratic)
- Teacher's aesthetic preferences
- The education-control dilemma
- Teacher's philosophical position - technical, practical, emancipatory

### STUDENT FACTORS

- Student age
- Student ability
- Student background
- Knowledge in the subject
- Student knowledge in other areas
- (Potential source of analogies and metaphors)
- Student's conception of "what is science?"
- Available time and resources
- Group dynamics
- Motivational and interest factors
- Reason for choosing the subject
- Cultural influences
- Student language skills

*Figure 2. Factors that may influence teachers' explanations.*

### What are Explanatory Frameworks?

Just as artists and craftsmen have particular styles, it is therefore likely that expert teachers use an artistic style or creative format within which they logically develop their explanations, arguments and questions. When crafting explanations, scientists, teachers and students are not free to use just any sort of explanation, acceptable explanations need to agree with the scientific consensus on the subject. Effective explanations also need to accommodate the content, teacher and student factors enumerated in Figure 2. Finally, an explanatory framework needs to agree holistically with science and experience and conform to the rules of explanation. These rules, or better, philosophical considerations, have been discussed for almost 50 years by science philosophers. Explanations can therefore consist of a variety of forms as shown in Figure 3:

<table>
<thead>
<tr>
<th>Acceptable explanatory qualities</th>
<th>Unacceptable explanatory qualities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precise</td>
<td>Intuitive</td>
</tr>
<tr>
<td>Complete or comprehensive</td>
<td>Vague or incomplete</td>
</tr>
<tr>
<td>Science theory-driven</td>
<td>Folk theory-driven</td>
</tr>
<tr>
<td>Empirical</td>
<td>Human action</td>
</tr>
<tr>
<td>Logico-deductive</td>
<td>Teological</td>
</tr>
<tr>
<td>Inductive</td>
<td>Idiosyncratic</td>
</tr>
</tbody>
</table>

### Types of scientific explanation

<table>
<thead>
<tr>
<th>Deductive-nomological</th>
<th>Deductive statistical</th>
<th>Inductive statistical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holistic</td>
<td>Complete</td>
<td>Partial</td>
</tr>
<tr>
<td>Theoretical</td>
<td>Relational</td>
<td>Empirical</td>
</tr>
<tr>
<td>Pragmatic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 3. Types of explanations and applicable descriptors*
Three of the most significant explanatory types are 1) deductive-nomological, 2) inductive-statistical, and 3) deductive statistical (Ruben, 1990). These terms can be explained thus:

**Deductive-nomological.** Explanation that uses deductive reasoning constrained by known general laws (e.g., Newton's Laws, inheritance laws, etc.). It is a rational, law driven, step-by-step generation of knowledge where the applicable scientific laws are preserved and obeyed. In such situations, laws are often more powerful than theories.

**Inductive-statistical.** This is *inductive* because the interpretation is the most consistent pattern or generalisation that can be derived from the empirical data. If the generalisation is found to be valid in every case (no exceptions) the relationship may become a law. It is called *statistical* because of the lack of a deductive cause-effect links between the relevant law(s) and the outcome; therefore, the interpretation is probably true in most case or most of the time (i.e., there is a high probability of the law holding but it is not certain).

**Deductive-statistical.** Deductive reasoning that is applied to probabilistic law driven situations. As in the previous case, the relevant laws do not hold incontrovertibly. It is the law(s) that are probabilistic. The interpretation is not induced from the data, rather the data is interpreted in a rational and logical step-by-step way to derive the best-fit knowledge.

Despite explanations being part of daily human interactions, effective explanations are constrained by numerous factors. These include content attributes, teacher and student characteristics and philosophical considerations. The purpose of this paper is not to confuse the issue but to sensitise teachers to the existence of a variety of influences that may compromise or if considered, enhance the quality of their classroom discourse.

**References**


Comparative Study of TEE Chemistry Papers of China and Western Australia

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Abstract

The article examined the Tertiary Entrance Examination Chemistry Paper of Western Australia and China in 1995.

As a summative assessment, the TEE is an important standard for year-12 secondary students as well as for their schools. In Western Australia, all of the students in the State use the same TEE paper. Similarly, in China all of the students in the whole country use the same TEE paper.

Preparation of the TEE papers are both based on the syllabuses. They are similar in China and WA. So, to some extent, the TEE papers reflect the standards and levels of secondary chemistry education in both countries.

Comparing the TEE chemistry papers of China and WA, we can find that their structures are similar in many ways. Multiple choice, short answers and calculations are common components of them. However, their contents show somewhat different stress on basic theories of chemistry and properties of chemical substances: China emphasises the latter and WA lays stress on the former. Furthermore, China pays more attention to testing the ability of problem-solving and integrated understanding of students. WA pays more attention to a strong foundation of basic chemical theories and covers a wider range of knowledge.

Introduction

The Tertiary Entrance Examination is a big event both in China and Western Australia.

As a summative assessment, the TEE is an important standard for year-12 secondary students as well as for their schools. In Western Australia, all of the students in the State use the same TEE paper. Similarly, in China all of the students in the whole country use the same TEE paper. The numbers of students who take part in the TEE are about 4,000 and 600,000 each year in WA and China, respectively.

Preparation of the TEE papers are both based on the syllabuses. They are similar in WA and China. So, to some extent, the TEE paper reflects the standards and levels of secondary chemistry education in both countries. It is for this reason that I am interested in a comparative study of the TEE papers of WA and China. I would like to analyse the TEE papers in terms of their structure and content.

Comparative Structure of the TEE Papers

The structures of the TEE papers of China and WA are very similar. (See Table 1.) Multiple choice, short answers and calculations are the common components of them. In the TEE paper of WA there is an addition part - extended answers - that does not appear on the TEE paper of China.
### Table 1.

**Comparative structure of the TEE Papers**

<table>
<thead>
<tr>
<th>part</th>
<th>Format</th>
<th>No. of Questions set</th>
<th>No. of Questions to be Attempted</th>
<th>Marks Allocated absolute*</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>Multiple choice</td>
<td>30</td>
<td>All</td>
<td>56</td>
</tr>
<tr>
<td>WA 1</td>
<td>Multiple choice</td>
<td>26</td>
<td>All</td>
<td>30</td>
</tr>
<tr>
<td>China</td>
<td>Short answers</td>
<td>7</td>
<td>All</td>
<td>32.7</td>
</tr>
<tr>
<td>WA 2</td>
<td>Short answers</td>
<td>14</td>
<td>All</td>
<td>35</td>
</tr>
<tr>
<td>China</td>
<td>Calculations</td>
<td>2</td>
<td>All</td>
<td>11.3</td>
</tr>
<tr>
<td>WA 3</td>
<td>Calculations</td>
<td>5</td>
<td>All</td>
<td>25</td>
</tr>
<tr>
<td>China</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WA 4</td>
<td>Extended answer</td>
<td>3</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

* Total score is 150 in China and 200 in WA

We all know that as a summative test carried out on such a large scale, the TEE has to be a fair, reasonable one. In other words, it must be objective, and have a high reliability and validity. It is for reasons of reliability that both countries select the multiple choice, the short answer, and the calculations as main types of question formats in the TEE paper. Those sorts of questions usually are referred to as objective test questions because they limit the choice of the person who marks them. In fact, in China as well as in WA the multiple choice questions are machine-scored. They both use a separate Multiple Choice Answer Sheet. The short answers and the calculations usually can be scored using a template that keeps the common standards for marking. In this way, the reliability of the TEE papers has possibly been achieved.

But everything has advantages and disadvantages: the objective questions are powerful to maintain fairness when scaling them; but it is hard for the multiple choice, the short answer, or the calculations to assess the students’ ability of expression and coping with integrated subject matter. On the other hand, extended answers can achieve these goals, so there are 10% of all marks allocated to the extended answer in the TEE paper of WA. Unfortunately, there are not any of this type of question included in the TEE paper of China at present, even though some experts argue for using it. One reason might be that it is hard to mark because so many students take the TEE in China. In Jiangsu province alone, there are around 60,000 students who will sit in the TEE room every year. In WA there are about 4,000 students take part in the TEE Chemistry exam each year. Another reason might be that the dominant idea in secondary science education of China is still knowledge transmission. Students are expected to answer questions that have a certain answer instead of an open end. To answer an extended question is thought too difficult for year-12 students.

When we consider the marks allocated in the TEE papers, we will find they are very similar for the short answers in both countries. However, they are quite different for the multiple choice and the calculations. For the former, China vs. WA are 56% vs. 30%; for the latter, China vs. WA are 11.3% vs. 25%. If one takes account of the number of the TEE students in China and concerns about the convenience of machine-scoring, one would understand why such a high degree of marks is allocated to the multiple choice. The other rationalisation might be that WA TEE redistributes 10% marks from the multiple choice to the extended answer. By analysing the questions in the multiple choice one can find that there is nearly no calculation in the WA’s TEE. On the contrary, many calculations are involved in the multiple choice section.
of the Chinese TEE. Roughly speaking, nearly the same percentage of marks is located in the calculations in both TEE papers.

**Comparative Content of the TEE Papers**

To compare the contents of the TEE papers of China and WA, the contents have been divided into three categories: the language of chemistry, the basic theories of chemistry, and the properties of chemical substances. The language of chemistry involves names, formulae, electron dot diagrams, structural formulae of chemical substances, and equations for reactions, etc. The basic theories involve structure of atoms, chemical bonding, redox reactions, chemical equilibrium, electrochemistry and so on. The properties of chemical substances include physical and chemical properties of elements and compounds. Of course, there are some contents that do not fit any of the three categories. For example, the mole concept is treated as a tool of calculation rather than as theoretical knowledge. Calculating the marks allocated for each of the categories, the result is shown in the Table 2.

**Table 2. Comparative content of the TEE papers**

<table>
<thead>
<tr>
<th></th>
<th>Language of chemistry</th>
<th>Basic theories of chemistry</th>
<th>Properties of chemical substances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>marks allocated</td>
<td>marks allocated</td>
<td>marks allocated</td>
</tr>
<tr>
<td>China</td>
<td>28</td>
<td>49</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>18.7%</td>
<td>32.7%</td>
<td>25.3%</td>
</tr>
<tr>
<td>WA</td>
<td>38</td>
<td>88</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>44%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table 2 shows that the language of chemistry carried almost the same percentage of marks in both the TEE papers. However, the marks allocated to basic theories in the Chinese TEE paper are obviously lower than in the WA by about 11 per cent. Oppositely, the marks occupied by the properties of chemical substances in the Chinese TEE paper are higher than in the WA paper by about 15 per cent.

These results might tell us a number of things. Firstly, the language of chemistry is seen to be an important part of content in secondary chemical education in both countries. The language of chemistry is a tool for communication of chemists as well as between teachers and their students. The language of chemistry for learning chemistry is just like 1, 2, 3, is for learning singing. Secondary chemistry can be regarded as the first stage of chemistry. To be able to correctly apply the language of chemistry will give students a good starting point to learn more chemistry. In addition, it is a hard task for many students to represent chemical substances or chemical reactions in symbolic form or in jargon rather than in everyday language.

Secondly, China put more emphasis on the students mastering the properties and reactions of chemical substances; the marks allocated China vs. WA are 25.3% vs. 10%. WA pays more attention to the students' grasp of basic theories of chemistry; the marks equal 32.7% and 44% for China and WA, respectively. Many conceptions demanded in the TEE of WA are not taught in Chinese secondary schools. Ionisation energy, electronegative of an element, equilibrium constant and standard electrode potential are the instances of these. On the other hand, the preparation and properties of nitrobenzene and the reaction between NH₃ and NO are only included in the Chinese TEE paper and syllabus.
Comparative Requirements of the TEE Papers

It seems true that the Chinese TEE paper requires higher problem-solving skills and integrated understanding of knowledge, but WA calls for a wider range of knowledge and applications. For example, to test the properties of ions, the following question is taken from the Chinese TEE:

Each of the following examples is a set of four water-solutions. In which one of the sets could all four solutions be distinguished from one another by reactions between themselves only.

A. hydrochloric acid, potassium hydroxide, potassium sulphate, potassium carbonate;
B. sodium chloride, hydrochloric acid, ammonium chloride, potassium hydroxide
C. barium chloride, calcium chloride, sodium sulphate, potassium nitrate
D. potassium hydroxide, potassium carbonate, magnesium sulphate, potassium hydrogen carbonate

To answer this question, a student has to remember many facts including propositional knowledge (name of the compounds, solubility of the compounds) and procedural knowledge (designing a rational procedure). Similar questions in WA’s 1995 TEE exam were Question 13 of Part 1, and Question 8 of Part 2.

The demand in solving the WA questions are less than for the above question from the Chinese paper.

Below is a copy of question 13 Part 1 of WA’ TEE:

Each of the following examples is a set of three water-solutions. In which one of the sets could all three solutions be distinguished from one another by colour alone?

(a) ammonium dichromate, diamminesilver(I) chloride [Ag(NH₃)₂Cl], sodium bromide
(b) calcium chloride, mercury(II) nitrate, potassium chromate
(c) cobalt nitrate, cobalt sulphate, sodium carbonate
(d) copper(II) sulphate, silver nitrate, zinc nitrate
(e) nickel sulphate, potassium dichromate, zinc chloride

Some Chinese educators believe that asking students to solve a problem in a new situation that differ from the one students have been familiar with can test the quality of their understanding. They also believe that the more variables the student is able to cope with the richer knowledge the student possesses. So in the Chinese TEE students were asked to draw an electron dot diagram for CH₃⁺ instead of H₂O or even NH₄⁺, and to write a structural formula of an organic molecule which is a product of reaction between (CH₃)₂CH⁺ and a solution of sodium hydroxide. However, this reaction does not occur in the syllabus or textbook.

Moreover, there were some questions harder than those described above, such as the following one.

Two organic compounds A and B have different formulae. They all consist of carbon, oxygen and hydrogen or any two of them. No matter in any ratio that they are mixed, as long as the total number of moles of A plus B is fixed, burning them completely will consume a fixed amount of oxygen gas and produce a fixed amount of water. So the formulae of A and B might be__________

Indeed, some students can do those questions as a result of depth of understanding. But some are successful only because of over-hard training. This training makes them study in school from 6 am to 10 pm. Even though government and experts strongly oppose this practice, the effect of their protests is very limited. Too many year-12 students face too few universities. This is a big problem in China. The students are forced practice the problem-solving skills again and again and lose the opportunities to broaden their range of chemical knowledge. From this respect, China could learn from the system of chemical education in WA.

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Catherine Milne
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Social Justice and Science Stories

A number of papers have been published recently that present rationales for the existence of many sciences rather than one unique science (Ogawa, 1995), of the need for multicultural perspectives in science (Stanley & Brickhouse, 1994) or the need for anti-racist science education (Dennick, 1992, Hodson, 1993). All these authors critique, to a greater or lesser degree, the type of science that continues to be portrayed in school science text books and which is often presented as 'the science' in science classrooms. Historically, the prevailing representation of science in school science tends to consist of a science that is conducted by white, middle class or wealthy, European males. Stanley and Brickhouse (1994) describe this as an implicit commitment to a universalist notion of science. Such a notion protects science against incursions from multicultural perspectives because it consists of beliefs that support the existence of one true science. Universalist science is characterised by a number of fundamental beliefs. Firstly, that there is a direct correspondence between reality and our observations of that reality. This notion is called naive realism. Secondly, that there exist universal truths or scientific facts that can be uncovered by the application of one true scientific method. This notion provides a protective belt against the multicultural push for a relativistic view of science. Finally, that scientific knowledge is value free and that the beliefs and values of scientists, and of the culture to which they belong, have no influence on the type of research that is conducted or the knowledge that is produced.

I do not believe that this is an accurate portrayal of contemporary science but it tends to be the type of portrayal that informs the science that is presented in schools. If we wish to have a socially just form of science we need to acknowledge both the contribution of people from a broad range of backgrounds to the development of science and the dynamic interaction between science and culture. If we wish to develop science curricula with a social justice perspective we need to appreciate the social context in which scientific knowledge evolves. I argue that this is not a move to rampant relativism in science because appreciation of a variety of views does not automatically mean that anything goes with respect to recognising new knowledge. Some forms of knowledge are more valued than others. Conversely however, belief in relativism does not ensure that marginalised voices will then be heard in science. Instead, acceptance of multiple perspectives allows us to present a richer picture of science. As Helen Longino (1988) argues, "scientific knowledge - although not the product of some uniquely truth producing method - is nevertheless a specific form of knowledge" (p. 574). If this means that we can no longer posit a misleading and simplistic universal notion of science then we should instead present a richer, more interesting and more representative picture of science.

An examination of the following questions might sensitise us to the need for multiple perspectives if we are to develop a socially just science curriculum. What is valued in science, who values it, and where is it valued?...
valued? These questions might be useful to consider when we examine the type of science represented in science text books and popular literature especially the type of science represented in the stories that they tell.

Stories in Science?

Some of you might wonder what sort of stories I am talking about. You might argue that science is mainly about facts not stories. You might say that it is facts and theories that are taught in school science, while stories are used purely as anecdotes by the teacher or the text to make science more interesting for students. You might further argue that stories are not an integral part of science because they are about fiction not facts. Some readers might think that they could possibly accept the importance of 'accounts' in school science because accounts are used to link facts together within a time frame. These accounts help us to explain concepts or processes to students but they are based on facts and, therefore, these accounts could never be described as stories. For example, 'the life cycle of a gnat' could constitute an account or a description because it combines all the facts about the life of a gnat into a temporal frame but it is not a story.

However, I wonder is it possible in our account to include all the facts about a gnat's life that are available to us at that time? If it is not, who decides which facts to include and which to leave out? What implications do the selection of facts have for the meaning that we impose on the account? I argue that once ideas are presented selectively in science no longer are we telling 'the facts'. We are instead telling a story. In the following sections of this paper, I examine some of the stories that have been presented either in texts or in popular literature and suggest how we could retell these stories from a more socially just perspective. As teachers and educators, we need to be aware of both the power of story and of the philosophical assumptions that underpin stories, particularly as these assumptions might be at odds with our emerging views on the constructed nature of scientific knowledge and of the contribution of marginalised groups to this construction.

Stories are used extensively in school science because students (ie., novices) are believed to lack knowledge about science (ie. 'situated' knowledge) so text books and teachers use stories to help students make sense of the grand narrative of science. Thus, stories are used to help students organise their knowledge into explanatory frameworks which serve them as interpretive 'lenses' from which to comprehend their experiences in science. Even stories about the natural world reveal the author's values and attitudes (Pagano, 1991). Stories and narratives are used in school science because they are believed to facilitate learning. Consequently, narrative structure in school science serves to assist in the construction and transmission of a particular notion of the culture of science. However, I hope that narrative can also assist to transform school science. Because science stories reveal implicitly something about the nature of science, they serve to legitimate particular philosophical frameworks in science which may not be consistent with contemporary developments in philosophy of science or educational practice. Do these stories help us to move towards social justice in school science?
Politically Correct Science Stories?

According to Dennick (1992), multicultural science education provides a science curriculum which recognises the contribution to the development of science of other cultures apart from white, Western European cultures. He argues that a Eurocentric perspective in representations of science leads to a misrepresentation of the existence of scientific knowledge construction in countries like China, India and Egypt that historically was consistent with 'genuine science' practiced by Europeans. In other words, universal science tends to posit that only Western Europeans 'do' science. He argues further that the contribution of Islamic scholars to the development of science in Europe has been either ignored or misrepresented as merely translations of ancient Greek texts.

In recently published text books there has been a move to recognise the contribution to the development of science of women and people from other cultures, and to remove the gendered focus of textbooks. For example, a human biology text book commonly used in Western Australia evolved from being called Man in perspective (1979-1989) to Human perspectives (1990-1995).

This move comprises one section of an historical continuum. In the beginning, women and other marginalised groups were not the subjects of stories presented in science textbooks. Firstly, there emerged the "affirmative action" photographs (Brush, 1985) in which women scientists, in particular, could be observed but were not referred to in the text of the book. Then, in recently published textbooks, we find examples of what I have called politically correct science stories. I use the term 'politically correct' because, although I hope that these stories have emerged in texts as the result of a more enlightened appreciation for the role of marginalised groups in science, I wonder if their inclusion is a political rather than an ethical decision. Let me illustrate what I mean by examining the implications of two stories that demonstrate a move towards a more politically correct perspective in their tales of the development of vaccination. The first story in Figure 2 comes from Biology for the Individual: War Against Disease which was published in 1974.

Look round your class - if you were all living in 1780, ten people in a class of thirty would be dead from smallpox by now.
But at least everyone knew that you couldn't catch it twice. So parents sometimes gave mild attacks of smallpox to their children deliberately. Unfortunately, no-one knew for certain how to produce a 'mild' attack of smallpox.
So many children died from being given 'mild' smallpox.
Fortunately, a British doctor called Edward Jenner became interested in finding a way to prevent smallpox. He heard that girls who milked cows often caught a mild disease called cowpox. After they had caught cowpox, they never seemed to catch smallpox. So, in 1796, Jenner tried the experiment on the next page.

(Reid & Booth, 1974, p. 29)

Figure 2. A 1974 story about vaccination

Contrast this story with one about the same topic published in 1994 and presented in Figure 3.

The old Turkish women who ingrafted their families were in fact injecting some smallpox viruses into the blood. This stimulated the body to produce antibodies to combat the foreign particles and destroy them. These antibodies remained in the blood and protected the people against further attack by the smallpox virus.
Some years after Lady Mary Wortley Montagu ingrafted her young daughter, Edward Jenner developed a safer, more effective way to protect people against smallpox. He once overheard a milkmaid say to another patient that she could never catch the disease because she had the cowpox. Jenner never forgot that remark and on the 14 May 1796 he vaccinated a small boy, James Phipps, from the cowpox pustule of a milkmaid, Sarah Nelms.

(McAllister, 1994, p. 239)

Figure 3. A 1994 story about vaccination.
I note some developments towards a more socially just perspective in these two stories about vaccination that were published twenty years apart. Firstly, in the story by Reid and Booth (1974) only the males are identified while in the story from McAllister (1994) all major participants in the vaccination story, males and females are identified. Secondly, the more recent story acknowledges the contribution of a non-Western European group to the development of conceptions about vaccination. Finally, the contribution of Lady Mary Montagu to introducing ingrafting to English shores is noted in the more recent story. Perhaps these stories indicate a development towards recognising the contribution of women and other groups to the development of science and also a greater sensitivity towards recognising, where possible, the contribution of all people, not just the males, to a particular episode in science.

However, we can read a different version of this story in Margaret Alic's Hypatia's Heritage.

Milkmaids had long known that exposure to cowpox provided immunity to smallpox and variolation [a type of immunisation against smallpox] had been practiced in China, India and the Middle East for centuries, but it took a brilliant and intrepid Englishwoman, Lady Mary Wortley Montagu (1698-1762), to introduce the practice to Britain and the rest of Western Europe. In 1717 Lady Mary travelled to Turkey with her husband, the British Ambassador at Constantinople. There she first witnessed variolation. . .

On her return to England, Lady Montagu had her daughter inoculated and she succeeded in interesting Caroline, Princess of Wales, in the procedure. Under Lady Mary's direction experiments were conducted, first on half a dozen condemned prisoners, and then on six orphans. The experiments were successful and the Princess had two of her daughters inoculated. The practice spread rapidly throughout the country despite vehement opposition from both the medical profession and the Church. In a rebuttal to these attacks, Lady Mary published anonymously her Plain Account of the Inoculating of the Smallpox by a Turkish Merchant. Since variolation did occasionally result in severe disease (fatal in perhaps 2-3 percent of cases, as compared with 20-30 percent with naturally contracted smallpox), the popularity of inoculation declined, but not before the practice had spread to continental Europe and North America. (Alic, 1986, pp. 89-90)

This story indicates that perhaps Lady Mary Montagu's pioneering work in this area of science deserves more recognition than it is given at present in text book science stories that examine the development of vaccination. Edward Jenner did not miraculously think of vaccination all by himself but his awareness of the complexities and difficulties of vaccination were aided by work from earlier scientists and from community practices. Alic's story implies that Lady Montagu was a greater devotee of scientific practices than was Edward Jenner. After all she conducted multiple tests!

Implications for Teaching Science

From a purely social justice perspective, we need more stories in school science which recognise the role of women and other marginalised groups. An examination of the history of the development of science presents evidence of situations where a woman's contribution has been ignored, subsumed or stolen. Consider, for example, Lady Mary Montagu and inoculation or ingrafting, Anne Conway and vitalism (Alic, 1986), Lise Meitner and nuclear fission (Brush, 1985; Rossiter, 1993), Inge Lehman and the existence of an inner and outer core in the Earth (Brush, 1980).

In science stories the contribution of non-Western science has also been ignored or subsumed. For example, Hurons living where Montreal is now situated, were able to show French explorer Jacques Cartier a cure for scurvy in 1535 but Scot James Lind is recognised as the discoverer of the cure for scurvy which he proposed two hundred years later (Priess, 1993). Ibn-al-Nafis contradicted Galen's claim that blood seeped
through pores in the septum of the heart in 1242, however, the discovery of pulmonary blood circulation is
normally attributed to Michael Servetus (1553) or Realdo Colombo (1559) (Kohn, 1989). According to
Sardar (1980), Islamic science was characterised by an appreciation of the relationship between the subject
being studied and the appropriate scientific method which lead to an emphasis on using an appropriate
method from one of many scientific methods. They were not constrained by the need to apply 'THE scientific
method'. Islamic science also emphasised the need to understand and not to dominate the material being
studied.

Joseph Needham (1969) in *The grand titration* argues that Chinese scientific thought was based on
acceptance of a prototypic wave theory rather than a particle theory of matter that dominated Western
scientific thought from the 17th to the 19th century. In contrast to Western scientific thought, Chinese
scientific thought was essentially algebraic rather than geometric and was dominated by an organicist world
view (Pepper, 1970) in which the parts are integrated into a whole rather than a mechanistic and reductionist
world view which dominated Western thought. He argues that such a perspective inclined Chinese thinking
"a priori to field theories" rather than the notion of action and reaction. Thus although Chinese science might
not have demonstrated the theoretical underpinnings of Western science, it was based on theoretical
structures. Chinese scholars carried out scientific investigations based on careful examination, awareness of
the use of controls in experimentation, accurate measurement, systematic observation and meticulous
recording and communication (Dennick, 1992). According to Needham (1969), a lack of written material
about the processes that scientific artisans conducted can be attributed to social factors in China which
discouraged the publication of technical details.

Women are ignored in stories in other ways as well. According to Brush (1985), there is a tendency
for some text book authors to neglect to identify the scientists involved in a particular momentous discovery
as female, leading most readers of the text to infer that the discoverers were male. Stories continue to under-
represent the involvement of people other than rich, white males in the history of scientific development.

Teachers need to be ever vigilant of the tendency of textbooks to construct science from a particular
perspective. The story presented below illustrates this difficulty:

**Daily Life of the Neanderthals**

The hunters probably formed bands of about a dozen, while the women gathered berries, roots, and other
plant food. Women probably also had the job of preparing hides for clothes, although the men would have
skinned the animal. ... Tool making would have been carried out by the men in the group and may have
been done at special sites where the stone was available. There is no direct evidence for this division of
labour between men and women, but the study of present-day hunter-gatherer communities supports it.

(Newton & Joyce, 1995, p.141)

One wonders on the need of this text book to speculate on the roles of women and men in
Neanderthal society in this way and, if there was a need, then perhaps there is also value in considering other
alternative descriptions of these roles. The presentation of these scenarios in text books gives them certitude
that they do not deserve. As teachers we could encourage students to be critical of the interpretation supplied
in this story and encourage them to be involved in reconstructing this story from a different perspective.
If, as teachers, we want our classrooms to be socially just then we need both to consider the implicit messages in knowledge construction of the type demonstrated in *Daily life of the Neanderthals* and to acknowledge the contributions of other cultures to the evolution of science in all its variety.

**Conclusion**

All the stories presented in this paper represent a particular reading of the narrative of science. In most cases these stories under represent the involvement of people who are not white, middle class and Western European in the construction of science. Although there have been attempts recently to ameliorate somewhat this oversight, these attempts still seem to be captivated by universalist notions of science. As a consequence, they continue to present a gendered view of science ignoring the dynamic and powerful interaction between science and society.

As teachers, we need to be mindful of the implicit messages that underpin these stories and all science stories. What sort of story about science do we want to present to our students? We need to be conscious of how we organise and interpret events in science and of the prominence that we give to particular science stories. What we tell and how we tell it is a revelation of what we believe about the nature of science. Perhaps if we wish to involve students more in thinking about the enterprise that we call "science" we would do well to tell stories that celebrate the involvement of all in the development of scientific knowledge, rather than being tokenistic about this involvement. If we want students to learn to be critical about the stories that are presented in school science and if we want our science curriculum to be a socially just one, we need to encourage them to generate alternative stories that utilise other perspectives. If we do not provide this opportunity to our students, we may remain locked into a confining myth about what constitutes science. Consequently, science will continue to be uninvolving and uninspiring for many of our students and we will continue to encourage a lack of reflection about the nature of science and acceptance of a universalist notion of science.

**References**


Portfolio Assessment in Lower School Science

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**Abstract**

Craigie Senior High is trialing portfolio assessment with all year eight science classes. The following points are the expected positive outcomes from using portfolio assessments.  
1. To capture and capitalise on the best each student has to offer.  
2. To focus on what the student knows and can do.  
3. To be ongoing part of their science classes that the student can use as a reference and/or reflection of their endeavours.  
4. To guide the teacher as to what is needed in the teaching.  

Our focus has changed to reflect developmental learning and problem solving skills rather than just factual recall of scientific concepts. The assessment profile now includes a wider range of learning evidence. This has also introduced science staff to outcome based education and helped stimulate "best practice" in science education.

**Introduction**

*What is a Portfolio?*

To use this assessment tool in the classroom it is important that we define what a portfolio is, however views about portfolios and portfolio practices are diverse. From ACER (Australian Council for Education Research) it puts portfolios into the following categories:

1. **Working portfolios**  
   A Working Portfolio is the equivalent of the artist's studio; the sketches, the notes, the bits of stimulus, the half finished drafts and the completed works. The best of Working Portfolios become an interactive context for ongoing instruction and feedback: a central curriculum and formative tool.

2. **Documentary portfolios**  
   Documentary Portfolios are collections of students work assembled specifically for assessment. They contain not only final products of student work, but also evidence of the processes that students use to develop those products.

3. **Show portfolios**  
   Show portfolios are purposeful selection of a limited amount of material designed to reflect the best of student work. They are used for a number of educational purposes including selection, certification and classroom assessment.

At Craigie Senior High our science portfolio is a mixture of the documentary and show categories and some educators would argue that our year eight model is not a portfolio as we do tell the students what materials must go into the collection. Despite this criticism, I am a believer that we need to model what is expected in such a collection of work. Then give more freedom to the students as they encounter more science in years nine and ten. There is no one "portfolio", there are many portfolios for different educational.
contexts and purposes. I like using ACER's simple definition of a portfolio as; "a collection of artefacts of students learning experiences assembled over time"

Background

In 1995 I was selected to participate in an innovative professional development plan called the Secondary Science Teacher - Leader Training Project run by the Education Department of WA, Science Teachers Association of WA and Curtin University of Technology. The aim has been to establish state of the art practice in science education. The workshops have been conducted throughout 1995 and 1996 and set over an extended time frame for the participant to be reflective on the information gained. Some workshops included:

- What is the nature of science and learning? Different views of science
- How do people learn? Constructivist teaching
- How to include everybody. Gender and race issues
- How to connect teaching with learning. Strategies in teaching
- How to do research into your own teaching. Action research
- A portfolio approach to teaching. Developmental learning
- What is outcome based education? Using this approach to teaching
- How to involve others. Role as a science teacher leader

This has increased my knowledge and awareness of the major changes and current focus in science education. For the last two years I have taken a leadership role for my school trialing the latest methodologies in science education; becoming familiar with up to date research findings; developing curriculum materials based on constructivism principles; and communicating findings and methodologies to other science staff. I have conducted action research in my classroom as a means of helping me to collaboratively examine my teaching. This has given me an insight on how my students see me as their teacher and what areas I can critically look at to improve the learning environment on classroom interactions. Also using the resources developed by Dr. Mark Hackling (Head of Science Education - Edith Cowan University) I have been collecting and reviewing examples of students work using open ended investigations. This has given me first hand experience with using outcome based assessment materials.

Sharing my experiences with the staff at Craigie Senior High School I have used the portfolio assessment as a way of getting other science teachers involved in improving science teaching and learning. With my guidance the science department has done a critical analysis of the year eight science curriculum in the context of "Best Practice" to move towards a more relevant and useful science program. Changes have also included introducing group projects and competitions to improve students skills in problem solving and to generate positive healthy collaboration in their learning to enhance the enjoyment of their studies. This has had some success as many students have enjoyed the activities however others have done very little. This is an area that the science staff consider important and with some modification, (mainly timing) competitions within the school will continue in 1997. Providing an opportunity for "fun" to be put into the science curriculum for every student is an essential ingredient to the program.
Year Eight Portfolio Outline for Craigie Science

To develop a more relevant curriculum, and exploring better teaching practice the shift in methodology has been facilitated by the small changes to the course. Portfolios are been used as part of their assessment for all year eight students so that all science teachers can critically assess their worth. It has been agreed that the portfolios are to be purposeful collections of students work selected to provide evidence of their progress towards developing good scientific method in their learning. The extra dimension to assessment and positive student involvement in producing portfolios will hopefully improve this fundamental concept in science education. Teachers have been encouraged to use teaching strategies that assist in enhancing problem solving skills and explore assessment tasks that provides evidence of developmental progress in learning. This has increase teacher interest with Outcomes Based Education and they have been asked to adopted the following principles for effective learning in Science;

1. Taking account of students' views.
2. Recognising that students construct their own understanding.
3. Provide a supportive learning environment.
4. Learning in practice.
5. Engaging in relevant and useful activities.

To make use of the well developed resources in the school the science teachers have not changed the year eight units but restructured them. Assessment outlines have changed to include a component of showing developmental learning and problem solving skills rather than just a heavily weighted profile of factual recall of scientific concepts. The resources that are in the school (ie. tests, practical activities, worksheets etc.) are still used but their importance has changed so that teachers can experiment with a wider range of evidence of learning.

As such, the science staff are learning more about Outcome Based Education and clearly are shifting the focus of the assessment profile at Craigie Senior High School. This has generated enough enthusiasm for the staff to look at changing the structure of the year eight science program to a more "Thematic" approach science in 1997. Over time and more experimentation with O.B.E. it is envisaged that the experiences in the science classroom also complement learning in other curriculum areas. As teachers feel more confident with a "Thematic" approach to learning goals this is an area that needs to be developed by the whole school over the next few years.

Setting up and management of the Portfolio has been a minimal task. The portfolios are A4 display files which cost around $1.50 and were placed on the book list for year eight in 1996. The files are kept in the science classrooms and are not to be taken home. At different stages of the year students have taken the portfolio home for parent comment, but usually kept in particular areas within the classroom. During a lesson a student may access the file to finish off incomplete tasks or maintain a journal.
Portfolio Goals

The following points are the expected positive outcomes from using portfolio assessments in the science classroom.

1. To capture and capitalise on the best each student has to offer.
2. To focus on what the student knows and can do.
3. To be an ongoing part of the their science classes that the student can use as a reference and/or reflection of their endeavours.
4. To guide the teacher as to what is needed in the teaching.

Assessment Profile

Apart from trying different strategies in the classroom the assessment profile of the year eight students was changed. In the past the assessment has been heavily weighted on tests in the profile (up to 80%). For this year the assessment profile for each unit does change but a general outline is:

1. Tests 50% (never more that this)
2. Assignments, reports etc 20%
3. Skills tests 10%
4. Portfolio 20%

The assessment of the portfolio is an area that needs to be developed but at this stage the use of it is seen as a three way information platform. Firstly by the student to reflect on their learning by the marks given and producing new individual goals for enhancing future work. Secondly to be used by teachers to look at the work produced by the students and then reflect on what types of experiences are needed to develop science learning. Also I see the role of assessing student outcomes through carefully produced work tasks placed in the portfolio as a future direction in its evolution. Thirdly for reporting to Parents, the portfolio does give an insight to how the student is progress in their studies. The displayed work can give excellent account of how the student is performing with hard evidence to show to the parent. This year at Parent information evenings the portfolios have been used very effectively to show student's achievements over an extended period of work. Comments by parents have been very positive as it has provided them with very good feedback. Parent involvement is being achieved by looking at the areas their child has weaknesses and/or strengths in their science learning. Discussions then lead to what strategies can be used for improvement and/or development.

Portfolio Contents

Within each science unit the students have to include the following in their portfolio:

1. Goal sheet.
   The students are give an outline of the unit of work that will be done over the term. Here the student looks at what the outcomes of the science unit are and appraises it with their own knowledge.
Students then produce their own goal sheet on what outcomes they need to develop over the unit of work. This worked well at the start of the year however in later topics due to specific science jargon it was found that students were just copying down all the outcomes without using it to guide new learning. For 1997 this will change to a series of general questions on the topic for which they can write down their understanding of the science in question before the start the unit. Other questions will guide them to add what they hope to gain from the learning encounter.

2. Assessment grid

The students are to fill in a grid of their marks of any assessments made over the unit. Here they are asked to reflect on the teachers assessment and consider if it is a good or bad mark, or why they think a particular mark was given. At this stage students have not been able to re-submit work however this is an area that the science staff will consider in future years.

3. Two practical write-ups.

The students are to place two of their experimental write ups in the portfolio which are marked as part of the portfolio. The practical report is chosen by the teacher in the units early in the year. This has been done to model what is expected in the display. In later units the students may pick their own two practical write-ups that they feel show their best work. Also as part of the Craigie S.H.S. Development Plan, the literacy component focus has been to monitor that “Students will be able to write in appropriate text forms for each subject area”. The Science department has been able to monitor this in year eight over an extended time frame assessing developmental learning from the display of experimental write ups in the portfolios.

4. Unit reflection sheet.

At the end of the unit the students are asked to fill in a reflection sheet on what they learnt from the unit and any experience they felt was important in their learning. This sheet is very structured for the first units, then less structure is used on the sheets later in the year. This again is modelling what is expected in this document. It is envisaged that students can develop their own way of reflecting on particular science learning experiences in years nine and ten. With the change to general questions on their goal sheet for next year it is hoped that this can be used to help students in producing the reflection sheet, adding in any new knowledge from the learning experiences.

5. Journal.

This is a exercise book that students keep in their portfolios and are asked at times to write down individual experiences about different science concepts and their perceptions on why things happen. This book is not assessed formally but is given a small weighting to the portfolio mark to make sure that it is included. Its major use for the students is to develop their literacy skills and can be used by the teacher to reflect on what types of learning are taking place in the classroom.

Concluding Comments: Future Directions

Evidence so far using Portfolio assessment has shown that it has given the students some “ownership” of the science classroom. Some students have included a major assignment or a poster in the
portfolio that they wish to display as a part of their best work. Some students have also included title pages for different sections of work to enhance their exhibit. This has helped in fostering positive work habits in science and many students have been eager to complete or "update" work in their portfolio if they have some spare time during a class. For 1997 the science curriculum and the portfolio will be updated for next years intake, moving towards O.B.E. Present year eight students will continue their portfolio in 1997. After this year of mainly modelling the portfolio it is hoped that the students have more input into what goes into their portfolio for assessing in years nine and ten. For the teachers using it as an assessment tool it has produced teacher discussion about "Best Practice" in science teaching and this by itself has to be good for science learning at Craigie Senior High School.

Reference

Managing Equipment in Primary Science: New Skills for Experienced Teachers

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I come to this study as a teacher of 12 years service in both primary and secondary education. In my role as science coordinator at my local primary school I facilitated teachers’ trialing and implementation of a new curriculum program called Primary Investigations (Australian Academy of Science 1994). Working with experienced teachers it became clear that they held a set of beliefs and experiences about science teaching and learning. Experienced teachers have a wide range of pedagogical knowledge of teaching but the lack of content knowledge and pedagogical content knowledge in science inhibits their attempts to teach science. Many of these problems, including the lack of science content knowledge, have been well documented by Symington (1980), Yates & Goodrum (1990), DEET (1989) and Appleton (1991). Teaching is a complex process and teachers’ change slowly, unwilling to let go of their established patterns of teaching. Calderhead (1988) found that teachers faced with change in their teaching practice feel discomfort if the change differs from their accustomed method of teaching. Wallace & Louden (1993) found teacher discomfort with change is a particular problem for primary teachers, experienced and expert in other fields, having to teach science. Teachers in primary schools are expected to be expert in several fields but how can one person be equally effective in all areas, especially in science, if they had only studied biology as students? In 1989 a Federal Government study (DEET 1989) established that science education in primary schools in a state of ‘crisis’. Jeans & Farnsworth (1992) established that teachers, when asked to rank the importance of subjects they taught, gave science the highest score. While many teachers’ acknowledge science is important Shulman (1986) found they were unsure about how to incorporate new science programs into existing frameworks of teaching practice.

Many studies have focused on beginning teachers but what about teachers in the field who find themselves working with new programs to upgrade their expertise in a teaching area? The purpose of this study is to examine how two experienced teachers, comfortable teaching in other subject areas, introduced a new program of elementary science into their teaching practice. An interpretative methodology, defined by Erickson (1986) as “the immediate and local meaning of actions, as defined from the actors’ points of view” (p.119), incorporating a constructivist perspective was utilised in the study. The constructivist perspective is given by Guba & Lincoln (1989). The study was conducted in two primary classrooms, one year two the other year five, in the state of Western Australia. Data were collected over a ten month period. Each of the classes was observed each week and regular interviews conducted with the teachers and students. The data consisted of field notes and interview transcripts and were used to construct several narrative vignettes of science teaching featuring the teacher and students. The vignettes were also used as interview triggers to gain understanding of the way in which these teachers engaged with the new science curriculum. These analyses were also shared with each of the participants as member checks to improve the authenticity of the data.
Lynley, the year five teacher, feels it is the duty of teachers to make sure students have a deep understanding of all aspects of science and technology to help them cope with their changing world. Lynley remembered a museum trip with her father as influencing her view of the importance of science. Her formal learning was in biology but she had always shown an interest in the physical sciences. Wallace & Louden (1992) suggest the importance of teachers' biography shows that, “few teachers have a strong basis of science content knowledge or pedagogical content knowledge” (p.512). Lynley preferred to teach older students because they are independent and easier to communicate with about interesting topics. Lynley was aware that her science content knowledge was inadequate and welcomed the new program as a way of increasing her content knowledge.

Leslie, the year two teacher, is a focus teacher in First Steps language which is a whole language program developed by the Ministry or Education, Western Australia. Leslie regarded me as her personal mentor in the new program because I had previously taught year two science. She agreed to participate in the new science curriculum because she felt unhappy with the way science was taught in the existing curriculum. Leslie had not taught science during the last five years because the previous schools had provided a science specialist. Leslie believed science was important and that it provided students with meaningful activities associated with the themes she was covering in language. Leslie's formal learning in science was biology. She was comfortable teaching science at a grade two level because she was unsure of her content knowledge when teaching higher grades. Appleton (1992) found that primary teachers lack confidence in their roles as teachers of science.

The new program relies on the supply of equipment to provide hands-on experiences for small groups. Both teachers had different backgrounds and experiences of science lessons and each viewed collection of equipment differently. A major contributor to the lack of science lessons was the difficulty in obtaining and organising materials according to Jeans & Farnsworth (1992). Leslie, being a junior primary teacher, was familiar with the need to supply equipment in her lessons and the school allocated a teacher's aide to help with the vast array of equipment necessary. Science was not her preferred teaching area but she had agreed to the new program if the science coordinator supplied her equipment. Lynley has the responsibility of supplying her school with equipment for the program but this is familiar to her as she has previously coordinated kits of equipment for a district science program. Both teachers experienced difficulties with equipment for a variety of reasons. This study uses vignettes of lessons to document reasons why experienced teachers have difficulties with equipment.

**Bottle Divers**

Today's lesson was based on bottle divers, which elaborated the concept of systems and the skill of analysis of a system by helping to identify the interactions within that system. A bottle diver is constructed using an eyedropper suspended in water, in a sealed 2 litre Pep bottle. When the sides of the bottle are squeezed the eyedropper descends due to a change in pressure. After my arrival at school Lynley and I moved to the staffroom to make an operational bottle diver for demonstration purposes. On examining the eyedroppers in the school supply we realised many had perished rubber tops which were hard to remove. As
the students may need to insert a piece of wire to the eyedropper to ensure it's descent during the experiment, this became a problem.

"I used an eyedropper from home last night and it didn't cross my mind that these would be perished," said Lynley. "It just shows you how little some of the equipment is used around here."

"How will the students manage if they need wire?" I asked.

"Well, I didn't have to put wire in mine last night," said Lynley, "so I'll tell them to try the system without the wire and if they find they need the wire they will have to come to me to remove the rubber. They are really old aren't they?"

Finding the best eyedropper Lynley showed me how, by squeezing the sides of the bottle, the eyedropper descended to the bottom of the bottle. No matter how hard the bottle was squeezed nothing happened. Lynley checked for air leaks around the lid and the water level to see if less water would help. Finally a piece of wire was added to the eyedropper as suggested in the teachers' resource book. After each alteration the diver still resisted the pressure on the side of the bottle. We watched the clock tick around to the lesson time and felt the panic rising.

"When I did this last night it worked the first time," she said. "I should have kept it for the demonstration."

"If it worked once it must work again." I replied. "Let's go through the steps in the book one at a time and check we have done everything properly."

We read the through the instructions yet again, checked our equipment, left out the piece of wire, changed the eyedropper, lowered the water level and got desperate. As we struggled to make sense of the bottlediver I turned to the last piece of information available to us. The diagrams! There had to be a clue to the system through the diagrams. Like a jigsaw puzzle we checked each picture and then I saw it.

"There it is!" I cried. "The water level shows the eyedropper sitting just under the water level, the black line, and not above it."

We squeezed the bottle to pop the eyedropper out the top, made a mess, filled the eyedropper with a little more water and made sure it was just below the water level. Yes! it worked perfectly and did no harm to my credibility as the science expert.

Lynley addressed the students seated on the floor at the front of the classroom. She discussed the systems they had been working referring to a discussion she had with Judy, a girl in the class.

"Judy says many things working together creates a system of movement or a system that works," said Lynley. "If one of those parts doesn't work what happens to the system?"

"It breaks down," added Judy.

"It breaks down, good girl," said Lynley. "All right, so again today were going to be looking at a system. A special system and were going to try and relate this system to things that we use in our world today. Technologically, other things have been based on the principle that we are working with today. So we are going to be looking at a system. We are just going to look at this...."

"The thing in the bottle!" sang out Len.
"Good Len," Lynley acknowledged. "A very simple system. I want you to watch it carefully. What can you see in the system? What is involved in the system? What have I in my hand?"

The students describe the items used in the bottle diver. Satisfied that the students were aware of the parts of the system Lynley went on to demonstrate how it worked.

"All right," said Lynley. "I want you to watch the eyedropper in the bottle, just watch it. (she squeezed the bottle and the class went, Oh!) All right...lets have another look."

The class was suitably impressed and focused on achieving the magical bottle diver. Lynley went through the team skills and roles and the need for the group to listen to the student reading the instructions. The groups moved to their desks to read through the activity and gather the materials. Once they had accomplished this Lynley again called them to attention to discuss the need for care when operating the eyedroppers.

"Now some of these," she began. "Boys are you listening? Rodney you don't know if you need it yet dear." She went on, "Your eyedropper may not need a small nail but today you have a piece of wire, all right. To take the rubber off the glass stem it should come apart. Now if you have difficulty in taking the top off yours would you please give it to the speaker to bring to me so that I can help you. I don't want you to tear the rubber top if it can be avoided. Don't you try and do it Dennis, would you bring it to Mrs. Pearson or myself."

"Can you take the top of the eyedropper off?" asked Dennis.

"You may not need to yet," I replied. "Do you want to try it without taking it off first. Try it without, read your instructions. If you need to put the nail in, which you may not, come back and I will help you but it's pretty well stuck and I don't want to move it unless we absolutely have to."

Lynley knew that she had time to organise the material and having problems at the last minute did not help. Being an experienced teacher she was able to overcome these obstacles but this meant explaining the lack of good eyedroppers. The students became concerned about the need to use the wire (nail) because it had been mentioned and it was shown in the diagram in their student book. Not allowing students the opportunity to manipulate the materials to investigate the phenomena could be seen as the worst aspect of prescriptive curriculum. Once the students began their experiment they focused on achieving the end result shown by Lynley and needed constant prompting by Lynley and myself to focus on what was happening within the system.

The following story of a lesson using magnets, to classify objects according to a criteria, raises other issues about the use of materials. Leslie had been assured by the school of assistance in assembling science materials. Leslie had shown the teachers' aide the list of requirements given in the master list at the back of the teachers' resource book. The teachers' aide had finalised preparation of material for the lesson. The magnets available from school supply were bar magnets of dubious magnetic strengths. In the preparation section for the lesson the teacher is requested to use small round ceramic magnets to disguise the nature of the magnet. The magnet story illustrates what can happen when the collection of equipment is left to the last minute and how lack of content knowledge about magnetic properties hindered the initial learning of students. Both Jeans & Farnsworth (1992) and Wallace & Louden (1992) emphasise a lack of time for the
preparation of equipment and also how teachers concede that equipment is a major constraint in teaching science.

**Magic Sorters**

The second lesson in science for the year two class asked the students to sort objects into two groups by selecting their own criteria. The teacher was to give the students a ceramic magnet, a small round magnet used for fridge magnets, so they could put the objects into groups according to whether they stuck or didn't stick to the magnet. While the children were at recess I watched Leslie sort through the material and noticed that the magnets were long bar magnets and some were very old.

"The magnets look very old Leslie, I wonder if they still work?" I asked.

"The science coordinator, gave them to me," Leslie replied. "I know she had trouble getting hold of them but I assumed she knew which ones to get."

"If you check the teachers' resource book it asked for ceramic magnets." I replied. "This is so the children can't identify with the shape and properties of the magnet before they start sorting."

Leslie reiterated her initial response, "This was all Jessica could find in the school." and added, "My Monday is very busy and I didn't get time to sort the material. Jessica agreed to help us out with the material otherwise I would find it too hard."

We tested the magnets and discovered some were indeed weak but there was no time or alternative sources within the school to change them. The rest of the materials were arranged in an icecream container including the badges for the roles the children had in the group work. The children returned after the siren and sat on the mat with expectant eager faces.

"Thank you class," Leslie said. "Last week we worked in teams to make a fish. Mrs Wilde (teachers' aide) has put a copy in your books and made a display of them on our back wall."

Having made links with last week's work Leslie went on to explained to the children that instead of paper shapes they would sort out a set of different objects into different groups. For the next 5 minutes the teacher went over the rules for the groups and the team work and team jobs collect material and return it safely and speakers who seek help for the group.

"Okay, this is what is going to happen." began Leslie. "a student from each group needs to collect an icecream container which has eight different items inside. I want you and your partner to decide one way of sorting those little bits and pieces. Share your ideas and come up with one way of sorting those objects in the icecream container. After you get a little bit of time to do that we are going to stop and share our ideas."

The children moved off and after an initial discussion about who would do what part they were able to sort the objects using a variety of criteria. The teacher called them back to the blue mat after a while and asked the students to share the reasons for the groups they made using their eight items.

"Well," Crystal replied, "we sorted ours from the ones that we can recycle and ones that can't."

"I thought that was a very interesting one." said Leslie. "I don't think I would have thought of that interesting one. Thank you Crystal."
The teacher congratulate the class on the different ways they'd sorted the material and went on to describe the next part of the lesson.

"Wowee!" said Leslie, "We have got some really interesting ways haven't we. I'm going to come around to your groups now and I'm going to give you something, some very special little thing that your going to use to help you sort all those objects in maybe a different way."

Darcy had worked out that it was hard, Nancy said it was metal. I 'accidentally' dropped a paper clip onto the magnet which stuck and the children thought it might be a magnet.

"Ah!" Darcy sang out.

"Oh! what did I do?" I asked.

"It's a magnet." replied Darcy incredulously.

"It's a magnet because they just do this," said Nancy. "They don't pick it up and fall down again it just picks it up because magnets can pick things up, if it picks this one up. Oh! it can't pick this one up, but it's metal."

"I'll make it," said Darcy. "I'll make it go in."

"Now you have done it," congratulated Nancy.

Obviously the magnet was not strong but Darcy was able to balance the paperclip well enough to get a result. The bell rang and the children were asked to stop and listen. The teacher gave them a sheet to help record the information by circling around the words, 'yes' or 'no', beneath the pictures of the items. During this recording activity a group of two boys had completed the sheet quickly but it transpired that only Mark had done the work. Andy had been busy sharpening his pencil. Mark had created his groups using a weak magnet and when Andy borrowed a stronger magnet it became clear that the groups organised by Mark were inaccurate. At my suggestion the boys worked through the activity again checking Marks answers.

"It's different," Mark said. "I'll have to cross out that one."

"Yes," I agreed. "Put a cross through it and then you might like to explain to your teacher that you had trouble with your magnet. What do you think then Andy?" I asked. "It works a lot better doesn't it?"

The majority of groups were able to arrive at the conclusion that some items would stick to the magnets and others would not.

Magic sorters, like the bottlediver story, relied on the supply of appropriate material. As was the case in both stories the supply of material was left to the science coordinator, a member of the teaching staff, with varying levels of expertise in this field. There was an assumption that the materials had been seen in the science stores and were therefore judged to be adequate. Leslie had only agreed to 'give it a go' if she had support in collection of materials. To make the task easier the teachers' resource book had a master list of materials needed for each lesson and Leslie gave this to the teachers aide to help in her preparation. The reliance on prescriptive curriculum enables teachers with limited expertise to conduct successful lessons.

Shulman (1986) points out that teachers must not only understand answers to questions but they need a deeper understanding of the science concepts to pose subsequent questions to enrich the students' understanding. The gaps in content knowledge and pedagogical content knowledge are revealed by the underestimation of the importance of specific equipment which is essential and preferable to others.
A Conversation About the Stories

The stories were shared with the two teachers for reflection and comment about what they saw as the issue within the lesson. Both teachers commented on how the reading of the story made it all come back to them and both teachers acknowledged that the equipment had been a difficulty. When the reflections and commentaries were discussed with the teachers it became clear the issue of equipment acted as a lens through which the teachers' understandings of content knowledge and pedagogical content knowledge of science was disclosed. The issue of explicit materials and teaching science places a reliance on cookbook experiments. This form of assistance for teachers revealed weaknesses in teachers' limited content knowledge of science. Although seen to be essential in supporting the reluctant teacher the cookbook should be viewed as a tool in developing understanding of science concepts for the teacher as well as the students. These three major areas will be discussed in light of the data collected through the vignettes.

Content Knowledge and Management of Equipment

In Magic Sorters the lesson relied on the use of a ceramic magnet to enable the students to sort items into two groups. Leslie had limited experience teaching science but she'd been assured that the schools' science coordinator would supply all materials needed for each lesson. The science coordinator's strengths lay in language and administration, not science. Leslie recalls her preparation for the lesson.

"My first vivid memories were of the frenzied last minute search for the magnets, a vital piece of equipment for the lesson," Leslie recalled. "The magnets weren't in the place they were meant to be so I went on a wild goose chase around the school looking for them."

Leslie's lack of experience meant she had not appreciated the difficulties inherent in using poor magnets and how this would alter the students' perceptions of their beliefs and abilities in science. The students initially grouped the items according to a criteria they chose, for example, round or not, blue or not etc. The lack of a functioning magnet meant, for many students, a lesson which created a sense of frustration and disappointment. Nancy knew what a magnet did but could not describe it well. When the magnet did not react as she knew it should it meant her original thoughts were not reinforced and her belief was shaken.

"Oh! It can't pick this one up, but its metal," said Nancy.

Mark had worked hard to complete the activity without the help of Andy who had wandered off. He had to correct his work when Andy checked his original answers with a good magnet.

"It's different," Mark said. "I'll have to cross out that one."

Leslie had not considered that for some students this was their first experience using a magnet and they would make judgements and discoveries about magnets based on faulty material. Yes, they would be able to sort the items but the experience with the magnets would promote alternative concepts because of this weakness. An activity that was designed to be a simple motivating look at sorting was frustrating and disappointing for some students in the class.

The bottle divers story shows that Lynley acknowledged the need to ensure that students have the appropriate equipment. Lynley had made a working model of the bottle diver the previous evening as she
went over the lesson plan in the teachers’ resource book. But she, like the students, had been able to reconstruct the model without fully understanding the principles of air pressures. Shulman (1986) investigated how teachers dealt with textbooks they found problematic due to a lack of content knowledge about the subject.

"Two valuable aspects learned from the preparation and teaching of the "BottleDiver" lesson were," stated Lynley, "One, the importance of total preparation and two, to have complete awareness of the concept to be taught. Having successfully and easily trialing the bottlediver at home, was no presumption that this is what would happen at school. My 20 minutes at lunch time was not enough time with the school equipment."

We looked for clues in the steps set out for the experiment in the teachers’ resource book. As a last resort we looked at the diagrams to see where the eyedropper should be. We both relied on the 'cookbook' strategies to overcome our lack of content knowledge about air pressure. Lynley realised she would have to look at ways of increasing her content knowledge of science. I was thankful to be able to solve the puzzle and have my content knowledge taken for granted. After the lesson I searched through the teachers resource book and found that it provided some additional information to assist my understanding.

"When the bottle is squeezed the volume of the bottle decreases so more water is forced into the eye-dropper. As a result, the eye-dropper becomes heavier and sinks."

A note in italics, adjacent to the lesson steps, instructs teachers not to expect the students to be able to explain why the eye-dropper rises and falls but that it is enough for the students to view the bottle diver as a system.

Lynley felt frustrated with her attempts at teaching the students the real science of air-pressure but this had not been the intent of this particular lesson. It was enough that the students followed the steps to produce the bottle diver and recognised a system could be influenced when they interacted with it. Lynley’s reflections on the overall lesson reveal how concerned she was about the need to have a good understanding of the concepts being taught in science lessons.

"Teachers need to be aware of the students outcomes, the important steps of the lesson and inherent pitfalls." said Lynley. "They need to experience failure in the experiment themselves to understand the pitfalls, strengths and weakness that can occur in such a simple, straight-forward exercise. Understanding scientific principles is best learnt through trial and error."

Lynley and I had not understood the importance about the placement of the eyedropper under the water level with reference to air pressure acting on the level of water in the bottle and in the eyedropper.

Pedagogical Knowledge Transferred to Science Lessons

Pedagogical knowledge transfer can be identified in both vignettes. Calderhead (1988) and Shulman (1986) look at the interdependence of knowledge base and how teachers transfer pedagogical content knowledge from subject to subject to develop a generic pedagogical knowledge of teaching. Leslie was able to maintain the steps of the Magic Sorters lesson by adopting strategies she used in language lessons. These strategies included the grouping of students on a mat at her feet for whole class discussions which set the
pattern of the beginning and end of the lessons. During the start of the lesson the students were given the main ideas of the lesson.

"I want you and your partner to decide one way of sorting these eight objects. Share your ideas and come up with one way of sorting those objects in the icecream container. After you get a little bit of time to do that we are going to stop and share our ideas," she said.

Discipline management was transferred through the use of positive reinforcement of good behaviour when students were on the mat. There was also the ringing of a bell to call the students to attention ready for the next step in the lesson.

Lynley employed similar strategies. Although the students were older they too were sat at the front of the class for discussions and redirection. It was during this time that the roles and rules of group work were reinforced and special instructions about the use of equipment was delivered. Like Leslie, Lynley used positive reinforcement to discipline the students and she also used questioning of students to redirect their attention to the activity. Both teachers were able to compensate for their lack of content knowledge by transferring practised strategies for managing students from other subjects to the science setting.

Explicit Materials and Management of Equipment

In the study the teachers worked from a set of curriculum materials which explicitly laid out lesson sequences, structure, extensions, equipment and evaluation procedures. The explicitness of the experiments in the teachers' resource book was a valuable tool in the teachers' planning of the lessons and use of equipment. The teachers' resource book offered information about equipment, special preparation instructions and the quantities of materials required. Goodrum, Cousins & Kinnear (1992) found that although structures programs assisted teachers' understanding there were limits on the teachers' understanding of how students think. The teachers' resource book proved to be a benefit but also a limitation for both teachers because when good quality materials was not available the success of the lesson was jeopardised.

Typically, during science, Leslie read directly from the teachers' resource book during the lessons and carefully followed each step. This strategy was in contrast to her practice in other subjects where her programmes used ideas from numerous sources and had been modified over the years to suit her method of teaching. The teachers preparation notes, at the beginning of the lesson, defined the type of magnet. Leslie was unaware how important this information was to the collection of material and leaving this part of the lesson preparation to others resulted in inadequate materials on the day. Teachers in primary schools are under pressure to prepare for a curriculum full of subjects, teaching as many as six subjects a day according to Wallace & Louden (1992).

"This was all Jessica could find in the school," she said. "My Monday is very busy and I didn't get time to sort the material. Jessica agreed to help us out with the material otherwise I would find it too hard."

Lynley memorised the lesson plan the night before and seldom referred to the teachers' resource book during the lesson. She was able to remember the sequence of the lesson and the questions needed to prompt the students thinking. When Lynley had to use wire instead of a nail some students focused on the need for wire because this had been emphasised in the instructions. Lynley and I spent much of our time
encouraging the students to read their student book and follow the procedure and not just recreate the working model. Oral instructions is used in many subjects and the students were reluctant to refer to a student book for science instructions.

Although they had prepared for the lesson within the limitations of the time and available resources both teachers had experienced difficulty with materials. Leslie was unaware of the discrepancies between the list of materials in the master list and the refined list given in teachers preparation notes. Leslie had assumed the supply of materials seen in the science store room was adequate but this proved to be otherwise. The introduction of alternative materials caused the students confusion when they read their student book.

Conclusion

This paper examined several issues in relation to experienced primary teachers' use of equipment in teaching science. These issues included the connection between content knowledge and use of equipment, transfer of skills from other subjects and the benefits and limitations of explicit curriculum materials. These issues suggest several implication for the way in which teachers' knowledge is transferred from one subject to another and the way that knowledge develops in response to a new field of teaching.

Knowing why a piece of equipment is essential to the outcome of the lesson relies on teachers' understanding of the concepts. The year two teacher's perception of the lesson was centred on the students sorting items into two groups. The magic sorter was only there to give them another criterion for this sorting. When supplied with a set of magnets, with poor magnetic qualities, the significance of the inadequate magnets was not clear to her. The teacher was unable to appreciate the difficulties inherent in using poor magnets and how this would alter the student's scientific understandings. In the case of the year five teacher, she assumed that the material described in the teachers' resource book would be available at the school. She also assumed the equipment was a particular standard, with good quality eyedroppers and nails appropriate to the task. Having successfully trialed the bottle diver at home she was surprised when the demonstration bottle diver would not work. Neither of us understood that the system would only work if the eyedropper was submerged beneath the water level in the bottle. Thus, the teaching of science required a complex array of knowledge about the availability, suitability and quality of materials and the application of these materials to the pedagogical situation.

To a large extent the teachers were able to compensate for their lack of content knowledge by transferring pedagogical knowledge from other subjects to the science setting. The teachers were able to conduct successful lessons and complete all the steps suggested in the teachers' resource book. Their teaching experience helped them make decisions about alternative strategies and equipment when presented with inadequate equipment. The year two teacher chose to ignore the poor quality of the magnet and assumed that the students would be able to sort the groups somehow. The year five teacher substitute the wire for the nail and warned the students about not removing the rubber tops of the eyedroppers. Both teachers transferred discipline strategies from other teaching areas through the use of positive reinforcement of acceptable behaviour and whole class grouping for discussions and dissemination of instructions.
Explicit materials are a valuable tool for teachers with limited knowledge and confidence in a particular subject. Both teachers have limited experiences in learning and teaching science and consequently their content and pedagogical knowledge was underdeveloped. Explicit materials help to compensate for teachers’ lack of science knowledge but student outcomes are not always assured. When the new program was introduced the teachers were offered the opportunity to peer tutor the lessons they would conduct with their students. The concepts at each year level would then be developed and understood, rather than being presented with a set of lessons. Both teachers’ were unable to access this process and did not develop their understanding of the concepts. The year two teacher used the teachers’ resource book as a constant reference by placing it on her lap during the science lesson. She was unaware of the need to check the material suggested in the master list with the preparation notes at the beginning of the lesson. The year five teacher memorised the sequence of the lessons without relying on the teachers’ resource book during the lesson. When the material differed from that stated in the teachers’ resource book and the student book, she had to spend valuable time explaining the lack of equipment to the students. This led to the students focusing on the equipment rather than creating a functioning bottle diver to demonstrate how a system works. Explicit materials need to be explained and refined to allow for the teachers perspectives which are created by their past experiences of learning and teaching in subject areas. Too often this is done at the expense of the students as the teacher tries to stay one step ahead.

Epilogue

When we were planning and writing this paper, we gave considerable thought to the ‘voice’ and whether it would be written in the first or third person. The vignettes and discussions are written in the first person throughout for the sake of authenticity but the paper was jointly planned and constructed by both authors contributing their ideas from their own perspectives.

References

The term "gender-inclusive" has become well known in Australian education over the last decade. In the preparation of the statements for the eight learning areas in Western Australia, an inclusive (including gender-inclusive) approach was mandated. Writers were required to make explicit in their document evidence that they had taken inclusivity on board. Thus, officially, Western Australian schools will be expected to provide a gender-inclusive education in science, mathematics and technology, as well as in all other learning areas.

If we are intending to promote "gender-inclusive" practice in science and technology education, we need to know what is meant by this term. We might define the term gender-inclusive to describe curricula and learning environments which

(i) incorporate, value and extend the prior experiences and learning; the current interests, needs and concerns; and the preferred learning and assessment styles of both females and males; and

(ii) challenge the dominant ways of thinking about science, mathematics technology and about the kinds of knowledge and behaviours that are valued and legitimated in those classrooms (Rennie & Parker, 1996).

A conceptual definition such as this requires some operationalisation to imagine what a gender-inclusive classroom will look like. Helpful descriptions for science can be found in Gianello (1988) and Hildebrand (1989), for example, and more generically in the National Action Plan for the Education of Girls, 1993-1997 (Australian Education Council, 1993). As the first part of the above definition suggests, many of the strategies are not specific to science and can be applicable to other subject areas. The second part takes a more socially critical view of the curriculum and the way it is enacted in the classroom. In this paper, the definition is used to explore the extent to which the curriculum and learning environment in a Year 2/3 class is gender-inclusive.

**Background to the Study**

My collaboration with Jan, the teacher whose classroom is described in this paper, was part of a National Professional Development Project in Technology and Enterprise coordinated by the Mathematics and Science and Technology Education Centre at Edith Cowan University. Here, the focus is one small section of the Term 2 program in Technology and Enterprise in Jan's Year 2/3 classroom. Children were working on a technology task to design, make and appraise a model pirate ship in the context of a pirate theme developed by the class. It is not an easy class to teach; there are 31 children, including 12 with special needs.

The data on which this paper is based include field notes from several visits to the school and Jan's class, interviews with Jan, sometimes audiotaped and transcribed, informal conversations with some of the
children, a videotape recording of one class, and inspection of children's work. To give a flavour of Jan's classroom and to place the discussion which follows in context, the following vignette has been constructed from field notes and the videotaped record of a Technology and Enterprise lesson in the third week of second term.

Description of the Lesson: Building Pirate Ships

Despite the rain outside, it is warm and friendly in Jan's classroom. Models of pirate ships, in various stages of completion, occupy the centre part of the two clusters of desks. Some notes about magnets, a set of compass points, and some work on grids, using mathematics to create maps to find buried treasure, fill the chalkboard. Colourful paper fish suspend from the ceiling. In a corner, a table with beach sand, shells, flotsam and model pirate figures and boats is close to a display of pirate books. Nearby are two summary charts labelled "What We Think About Pirates" (among other things they are greedy, mean and spiteful) and "Facts about Pirates" (they attack other ships and have sword fights, for example). The back wall is decorated with a mural of pirates, drawn and coloured by the children, and including two female pirates. On the other side of the room, ample evidence of the children's active construction activities, as well as classroom equipment and useful gear overflow from a small storage area. Jan's loaded table is testament to the large amount of activity occurring in a busy classroom.

The children hurry into the classroom after the lunch break, moving straight to their places to begin the afternoon's activities. Many put on pirate hats they have made on an earlier occasion and work with those on their heads. No one mentions the hats, they are just part of the atmosphere. Soon, and with no fuss, those children who want to paint their boats are at work with lots of poster paint and brushes on a group of desks protected by newspaper. On the other cluster of desks, two boys who have made splendid boats out of balsa wood are painting with a turpentine-based paint. A mother of one of the boys hovers near, in case assistance is required, but she seems to be superfluous, so during the session she occasionally wanders around and is available to help other children.

Every child is fully occupied during this session. Each has his or her own boat to work on. There is no angry or impatient word from anyone. When Jan stops the class for a word or two about using scissors safely, there quickly is silence, then children resume their work. Every now and then, children stop and look around. Sometimes they compare notes with another, offer advice, or explain their own plans. Some disappear for long periods, but they are working elsewhere, choosing fabric from a large selection housed in boxes in the passage to an open inside area, for example. Four or five children whose work is finished are playing with Lego materials, making figures for their boats and constructively passing the time. The classroom hums with activity; it doesn't seem noisy because there are no raised voices.

Every one is cooperative, sharing, fetching, lending, holding things for each other. During the class, Jan remains seated at one of the desks, busy helping individual children with problems, but there is no long queue waiting for her, as for the most part, the children are very adept at helping themselves or getting help from their friends. The two Mums and a Dad in the class are also available to help. A lot of
cutting and measuring is going on, sometimes using trial and error, making adjustments until things fit. Then there is gluing and sticking, and comparing notes about adhesives to join things together.

I look carefully at the boats and talk to some children about their plans and designs. Many children designed their boat around boxes brought from home. Jan has a large supply of recycled and "junk" materials, so no child seems constrained by lack of resources. Most children amend their designs as they work to make use of materials they decided they like. It seems that girls are more likely to decorate their boats with bits and pieces of fabric, while the boys are more likely to paint theirs, but many girls are painting, too. Sasha is making a boat for lady pirates (she had drawn one of the lady pirates on the wall mural). She tells me it will have seats and a treasure chest with treasures and pictures of flowers on the wall. She has found some red lace material to help make her boat and is cutting it into shape. Kailie tiptoes past with her boat, holding her finger to her lips saying "SSshhh! My pirate's in bed!" Kailie explains to me the parts of her boat, which is dominated by a large bedroom in which her cardboard pirate, Polly, is in bed, covered with "blankets" which "she found in a cave". The other part of the boat has containers holding Polly's swords, and her rubies and treasure which she plundered after fights. The blue plastic circles (from bottle tops) attached to the outside of the boat, which I thought were portholes, represent the holes through which the cannons are fired, and Kailie has constructed a lever from a bent paper clip to fire them.

Michael's ship, made from balsa wood, is getting its hull painted black. The ship resembles a Spanish galleon, and his mother, who is one of the three classroom helpers today, confides to Jan that we, the visitors, probably won't believe that he made it himself. Michael tells me that his Dad helped tie on the sails, which are real canvas, with twine riggings. On the other side of this desk, Russell is carefully painting his balsa wood boat black and red, which he believes are the right colours for a pirate boat.

After a full hour, Jan calls the class to pack up. Tidying up is busy and active. The children know where to put things and they move fairly quickly, although some are reluctant to leave their work. It takes a good ten minutes, and Jan has to hurry along the stragglers to go to their next lesson. Finally, they are gone, the room is as tidy as it was before and the large amount of gear required has disappeared somewhere!

Development of the Pirate Theme

The pirate theme developed from work on the sea as part of social studies. Children showed an interest in ships, bringing models from home, and then pirates from Lego sets, and asked if they could make their own model pirate ships. The pirate theme continued for about two weeks and extended into every learning area. Early in the theme, children brainstormed what they knew about pirates, whether they were real or make-believe. Research using the available library books was used to help determine what was fact and what was fiction. The summary posters mentioned in the vignette were prepared and children wrote stories. Ben's story gives ideas which are typical of the children, while Prue's story is reminiscent of the grid work they did in maths related to treasure maps.
Pirates by Ben

Pirates are mean and smelly and they kill people. They attack other ships and they fight with swords. They fire cannonballs at other ships and they find treasure. They have lots of jewels and money.

Pirates by Prue

I know that pirates have to obey their orders. One spies at the top of the mast from the crow's nest. While the captain thinks "Where on the map is Mermaids Island?" He says "Pirate Scrubby, steer the ship west for ten minutes and then turn south. We should get to the island by dawn."

One child brought a newspaper cutting about pirates in Asia, and the children discussed pirate activities in Asian waters and the difference between today's pirates and those of long ago. Jan read them Bad Pirate Pete which led to a complex discussion of the moral issues about what pirates did and what they ought to do. The children decided that it was wrong for pirates to rob and keep their spoils. They considered it more acceptable if pirates robbed only the rich and gave to the poor, keeping only enough for their own needs. Children decided to write their own stories about Good Pirate Prue. At the instigation of the children, Jan took them all to see the movie The Muppets' Treasure Island after school one day, and they compared this story with the traditional story.

Assessment of the children's work was built into the normal class activities in an authentic way. Assessment in the technology task included both a written report of what children did and an oral presentation, during which they showed their model, told the class their plan, what they did, whether they succeeded and what they might do differently next time. Jan explains:

We have to go back [to the actual models] and look at what were the things they were expected to be able to do ... the design criteria they were given at the very beginning. ... I'll get them to evaluate each other. When I started to trial [peer assessment] last year, ... I couldn't believe it, how fair they were and how accurate. They usually use just a 0, 1 or 2, either they didn't meet it [the design criteria], they had a go and it was OK, or they met it really well. They're very, very fair with each other. And they actually evaluate their oral report as well.

Jan takes a child-centred, integrated approach to planning and implementing the curriculum in her class.

I usually have something planned at the beginning of the year and then just see how the children's interests go from there. Whichever direction that takes, we work with that and then develop a whole integrated program from it.

She was a very experienced, confident teacher, and this approach worked well for her class. One theme slipped into another: A health lesson about the problems pirates had with preserving food, and the associated cooking session on "weevilly" biscuits, led to the next theme on insects and small invertebrates, which the children decided to call "creepy crawlies". Jan ensures that the appropriate skills and content in the various subject areas were covered some time during the term, and she often has the children help out with this planning. "I just have a checklist of all the things I have to do, and we negotiate. We say, look, this is the stuff we have to do, we've got this much time to get this done."
Are the Curriculum and the Learning Environment Gender-Inclusive?

Hildebrand (1989, p. 10) claims that "when the goals and tasks, processes, timelines, products and assessment techniques are negotiated and clarified at the beginning of a topic, students appear to feel more motivated and involved in their own learning" [italics in original]. Negotiation of the curriculum makes sure that children's prior experiences and understandings are built upon, their interests and concerns are valued and included, and their preferred learning and assessment styles are taken into account. In Jan's classroom, the effects of the negotiated curriculum were clearly evident to Jan.

I can't believe what they're doing, they're surprising me every day. It's empowering them so much. As I've mentioned before, they're appraising me as well. If they think I'm not doing something that's the right shape or design, they'll let me know. And it's just such a totally different teaching style. They're like piranhas, they're just sort of draining me, they're just so motivated, and wanting to keep doing things.

The topic of pirates presents a challenge for a gender-inclusive approach, not only because pirates are stereotypically male, but because those pirates likely to be familiar to children are fictional characters belonging to a past, somewhat romanticised period. Captain Hook and the TV cartoon character Captain Pugwash are well-known examples, and each character had a look-alike drawn as part of the mural on the back wall. How can such a topic be relevant to children's current needs and life experiences? How can it build upon their prior knowledge, and how did the topic cater for preferred learning and assessment styles? Is the content of the curriculum challenged in a critical way? Or do pirates stay male and mean?

The most important consideration here is that the pirate topic is meaningful to the children because they thought of it themselves. It developed out of what they were doing in other subjects, and they negotiated the curriculum around their interests. In terms of the DMA task to build a pirate ship, children literally built on their prior knowledge and skills developed during previous construction work, but they pushed forward the boundaries of their skills as they learned new techniques. Encouraging children to bring their own designs to fruition, and using assessment techniques which compare children's outcomes against their own intentions, rather than some universal norm, caters for difference and diversity among the children.

In terms of the kinds of classrooms described as gender-inclusive, Jan's fits well. The physical environment is warm and supportive and children's work is displayed everywhere. Both boys and girls contributed to the "pirate table", which they set up themselves and they all seem comfortable in their classroom environment. Many authors suggest that in gender-inclusive classes boys and girls share equally in teacher interaction, asking and being asked questions, they work cooperatively and all are equally involved. In the lesson observed, all the children worked independently on their own model. Everyone was involved. There appeared to be no competition or envy over models of different quality. As the vignette shows, they were cooperating with each other. For example, one child was heard to tell another that masking tape would be better than glue for a particular task and went and got some.

Overall, the teaching, learning and assessment processes appear to be gender-inclusive. The content of the curriculum presents a more difficult challenge, one which it seems Jan has handled well. After drawing
out children' initial ideas about pirates in a brainstorming session, Jan allowed them to extend and challenge their ideas through research and discussion. Past and present pirates were compared, their activities subjected to critique, leading to an idea of what a more socially acceptable pirate might be like – Good Pirate Prue. Despite the prevailing masculine and aggressive image of pirates (a browse through the library books on display in class confirms typical pirates to be male and mean), children refused to believe they were male only. Two girls, Sasha and Samantha, drew pictures of "lady pirates" (displayed in the wall mural) and several of the girls, including Kailie and Sasha, were making boats for lady pirates. Samantha's story makes it clear that she is happy for there to be female pirates (note the exchange between third and first person as she involves herself in the story).

*Pirates by Samantha*

One day a pirate was sailing along and she heard a sound and it was a turtle having babies, so I helped it. Then I saw a big ship, it had male pirates in it. I feel scared. "Come on crew, we will fight!" Snip, snap, went the swords. "Now I've got you" said the girl pirate. Splash! "Yaha! We've got the treasure."

*Contradictions?*

Jan's class was busy, productive and self-motivated as children worked on their pirate ship models. The discussion suggests that the curriculum and the learning environment are approached in ways that might be described as gender-inclusive. However, the visible outcomes of the theme are not gender-free:

- Of nearly 30 pirate pictures on the wall, only two depict "lady pirates", both were drawn by girls.
- Only boys have used wood to make their pirate ship models.
- Only girls have extensive living quarters in their boat, and mainly girls use fabrics for decorating their model.
- Many (but not all) of the less-well-made boats are made by girls.
- The best-armed boats are made by boys (but Polly's boat had cannons and a mechanism for firing them).

Does it matter that the outcomes of this activity appear noticeably gendered? Do the differences in outcomes mean that the teaching and learning has not been gender-inclusive? Do the gender-stereotyped model boats create a problem for Jan or for the children? (or for you and me?) Is "pirates" an inherently gendered topic and hence one which should be avoided?

I want to answer no to all of these questions. My main reason for this is that I find it necessary to distinguish between the teaching-learning process and its outcomes. Allowing for differences and diversity in children's backgrounds, their needs and interests must allow for outcomes to be different as well. Negotiating tasks, making models according to their own designs and working in their own way, means that children's ideas are valued and incorporated into what happens in the classroom. Provided children have tried their best, the results of their efforts should be equally valued. It does not make sense to me to let children take control of their learning by valuing their input, but then to censure their chosen outcomes. The outcomes may be gendered if they are viewed as stereotypically representing children's interests, but there was no evidence that any boat was valued less by Jan (or even the other children) because of a lack of skill in making it. The
construction skills of girls may initially be less practiced, but they, as well as the boys progressed well over the year.

The last question, that topics like pirates should be avoided, requires a more qualified answer. A topic which is inherently gendered provides teachers with opportunities to challenge the structure of gender in ways which enable children to begin to understand how males and females are positioned in the prevailing discourse and how some groups are privileged over others. The content of a topic like pirates is, of course, quite different to the gendered structure of the knowledge base of science or mathematics, but even in this Year 2/3 class, the teacher was able to help children to develop different views of who pirates are, what they might do, and what a more socially just pirate existence might be like. Opportunities to challenge the way we think about things, even pirates, are taken too infrequently in our science and technology classrooms.

References


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Primary Investigations: An Evaluation by Teacher Education Students

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Abstract

The paper gives an evaluation of the Primary Investigations curriculum project. The source of data for the evaluation was 125 teacher education students at Edith Cowan. All students had completed two course units of primary science education. In each unit the students used the Primary Investigations material in work with children. The students also had other opportunities to become familiar with the project. Data was obtained by using a 40 item questionnaire. The students could also make detailed written comment and participated in class discussions on the project. The paper provides comment on several dimensions of the Primary Investigations material.

This study was made because there is very little data available on student teacher reactions to the use with children of the new Primary Investigations curriculum project. Most evaluations of the project made to date, (Fetherston, 1995; Wallace and Louden, 1995; Happs and Coulstock, 1995) deal only with the reactions of in-service teachers. Another study made by the author (Rowe, 1996) and based on anecdotal data indicates that few Australian universities require their students to give significant attention to Primary Investigations. When it was noticed that students at Edith Cowan were making evaluative comments about Primary Investigations it seemed to be an appropriate move to attempt to quantify and record some of the available information.

All teacher education students at Edith Cowan have considerable opportunity to use and evaluate the Primary Investigations curriculum material. This study is limited to the Mount Lawley campus because the staff at Churchlands were much more closely associated with the development of the project. The students do two one semester courses of science education.

The first of these courses deals mainly with teaching strategies. The students apply these strategies in several lessons given to small groups of children brought onto the campus. In the past these lessons have been based mainly on topics selected from Western Australian Education Department materials (1980). In 1995 it was decided to use Primary Investigations as a source for lessons, because the project showed promise of widespread adoption, and because it provides considerable assistance for beginning teachers. Students used the material but, because formal studies of curriculum materials is not part of the first course, made no formal evaluative studies of it. Some introductory description of the material was included in lectures, but little comparative or evaluative comment was made.

In the second course in science education, taught in 1996, the students visited schools in order to teach a complete science topic to a larger group of children. For most students the topics were chosen from Primary Investigations. Students were instructed to prepare the first three lessons from the Primary Investigations material. In the second half of the topic students were encouraged to use ideas from other curriculum projects as well as Primary Investigations. In previous years the students would have done much descriptive and comparative work on a variety of well known science curriculum projects. In 1996 this work was replaced by a workshop on mechanisms for evaluating curriculum projects, and self directed study on
student selected projects. Thus students received no formal evaluation of any science curriculum project directly from their lecturer.

Data Collection

After completing their science topic in the school, students were given a 40 item questionnaire requiring them to agree or disagree with statements made about Primary Investigations. The statements were mainly based on the informal comments about the project made by various students during the course. Space was provided for the subjects to describe the strengths and weaknesses of the project and to comment on other aspects of interest. The results of the questionnaire are shown in the Appendix. Of the 125 students who commenced the course some 111 completed the questionnaire.

Discussion of Results

Examination of the questionnaire results will show that in general terms the subjects showed a high level of satisfaction with Primary Investigations as an aid to presenting science topics to children. More specifically:-

1. General features of the project such as style, appearance, scope and sequence, and choice of topics were well accepted. (Questions 1-5)
2. The 5 E's was not favoured as an instructional model. This was probably because most students did not give it much attention with the absence of the normal inservice programme. (Questions 6-8)
3. The students were very satisfied with Primary Investigations as an aid to lesson planning and preparation. (Questions 9, 11, 19-25, and 31-33)
4. A majority of students were satisfied with the quality and variety of activities presented in the programme. A significant minority of students would have liked to see more choice and quality in the activities. (Questions 12-18)
5. The students were divided on the value of the assigned roles for group work. Again this was probably due to the lack of normal inservice. Some students were also concerned about the children's attitude and response to the lessons. It is suggested that they have inappropriate views about the role of curriculum materials on this issue and that they have insufficient awareness of the common difficulties of material centred lessons. (Questions 26-30)
6. The project was perceived to require supplementing in areas such as additional activities, integration with other subjects, and reference to other curriculum materials. (Questions 34-36, 38)
7. Some features such as readings, black line masters, and illustrations were very much appreciated. (Questions 37, 39, 40)

Anecdotal Comments

By far the most common reference was to the ease with which the Primary Investigations material could be prepared for presentation to children. Some 68 subjects were very positive about this. Perhaps this
says something about the priorities of teacher education students. It also indicates that the project developers have been very successful in this area.

Other areas given much favourable comment were:­
The quality of the activities. (15 subjects)
The conservative equipment requirements. (11 subjects)
The interesting nature of the project material. (10)
Small numbers of subjects commented favourably on the illustrations, the background information, the assigned roles, the outcome statements, evaluation, the blackline masters, the levels of difficulty, and the student books.

Negative comments were made about the following:­
Lessons that are not interesting. (24 subjects)
The activities. (21 subjects)
The lack of references related to integration and other curriculum areas. (14 subjects)
The lack of choice for lessons and topics. (11 subjects)
Smaller numbers of subjects commented unfavourably on the assigned roles, equipment requirements, evaluation, outcomes, and background information.

These comments indicate that for many attributes of the project there is considerable disagreement.

Conclusions

The study indicates that Primary Investigations is generally found to be a valued and useful project by the majority of teacher education students at the Mount Lawley campus of Edith Cowan. A few aspects of the project are regarded negatively, and for some there is a division of opinion. Some of the major criticisms of the project relate to areas that the developers did not attempt to deal with.

Appendix

PRIMARY INVESTIGATIONS EVALUATION QUESTIONNAIRE
For each of the following statements about the Primary Investigations curriculum project decide whether you

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
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1. The Teacher resource books are attractive and user friendly.
   47   62

2. The project has a good rationale. i.e. the basic approach is well justified.
   22   79

3. The project provides a good scope and sequence for primary science.
   24   73

4. The scope and sequence is hard to follow.
   7    80

5. There is a good choice of topics for each year.
   13   61
6. I used the 5 E's in planning my lessons.  

7. The 5 E's provide a good instructional model.  

8. The instructional model was a useful aid to planning lessons.  

9. The Primary Investigation outcomes helped me plan my lessons.  

10. I could not see what concepts the outcome statements were directed at.  

11. The outcome statements provided for a good blend of process and conceptual objectives.  

12. There were insufficient process oriented activities.  

13. The project has plenty of activities.  

14. I liked the activities I used.  

15. The children liked the activities I used.  

16. There were insufficient good material centred activities.  

17. Most of the activities provided an opportunity for sustained work with three dimensional materials.  

18. Too many of the activities were mainly paper and pencil exercises.  

19. The project gave plenty of information on how to present the lessons.  

20. It was easy to meet the equipment and material requirements of the lessons.  

21. I found the background information interesting.  

22. The background information met my needs.  

23. The lessons were easy to implement.  

24. The children found the lessons interesting.  

25. The work was intellectually challenging for the children.  

26. It was easy to keep the children on task.  

27. The programme did not give adequate attention to the development of children's attitudes.
28. I used the assigned roles.

29. The assigned roles were too much bother.

30. The use of assigned roles for the children made teaching the lessons easier.

31. The programme provided sufficient information on strategies for the lessons.

32. The strategies described were too complex and detailed to follow.

33. The suggestions for recording and evaluating children’s work were adequate.

34. I did not find the extension activities sufficiently challenging.

35. The Teacher resource book did not give adequate reference to a variety of other curriculum resources.

36. I found it necessary to use other curriculum materials for some lessons.

37. I found some of the readings to be valuable parts of my lessons.

38. The programme gave adequate attention to the integration of science with other subjects.

39. The blackline masters were very useful.

40. The illustrations in the text helped me to understand what the lessons were about.

References


‘I do feel a little more confident’: An Initiative in Primary Science Content

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Abstract

This paper reports an initiative funded by the Education Department to support primary school teachers to become more confident and effective in teaching science content. This initiative raises important issues related to (a) professional development (PD) of teachers and to (b) research in adult science learning. In relation to professional development, what are we asking of primary teachers when they teach science? Traditionally, science educators have focussed, in a variety of PD settings, on how content can be made ‘teachable’. However, we also need to ask how can we develop primary teachers’ pedagogical content knowledge if their content knowledge is limited? How can we expect primary teachers to make valid judgements about student learning in the conceptual strands of the Student Outcome Statements if these same teachers have limited understanding of related content? In relation to research, this initiative has raised an awareness of under-researched questions, including: What motivates adults to learn science concepts? What are major obstacles to their learning of science concepts?

The Role of Science Content Knowledge

A five day course was designed to provide a firmer basis for teachers in key areas of science knowledge, to increase their skills in translation of this into pedagogical content knowledge, and to develop skills in working with others as a presenter in science education. Support for this type of course can be found in many studies that define what teachers know and don't know about science, what forms of courses can have a successful impact, and they generally agree on the need for better levels of understanding on the part of teachers.

Smith and Neale (1989) investigated the subject matter knowledge and beliefs of ten primary teachers through interviews and videotapes of their teaching. They began their report in this way:

Science teaching in the primary grades has been a persistent problem ... Teachers in those grades are under pressure to focus on reading and mathematics ...; in addition they feel untrained and uncomfortable with science ... Science is not allocated much time in the school day ..., and when taught is usually in a recitation format that relies mainly on a textbook (p. 1).

There has been a shift in emphasis from process skills to content in primary science (Kruger and Summers, 1989). They reported a study of the views of nineteen primary teachers about changes in materials: changes in a burning candle, a boiling kettle and other everyday phenomena. They note that primary teachers will not be required to teach about such changes in molecular terms. Nevertheless, an understanding of such changes may be necessary, because they believe that:

it is difficult to see how children can be correctly led along an experiential path leading to understanding of changes in materials and the associated role of energy unless the teacher guiding them has some deeper understanding of the processes involved (p. 26).

The mismatch’ between primary teachers’ understanding of science concepts and the demands of the U. K. curriculum has prompted large scale programs in the UK (the Oxford University Primary School Proceedings of the 21st Annual Conference of the Western Australian Science Education Association, Perth, November, 1996.
Teachers and Science Project (PSTS) to address this problem (Kruger, Palacio and Summers, 1992). The Open University has produced a complete teacher’s professional development package in conjunction with the BBC, as a set of 6 workbooks with video support (see Tresman and Hodgkinson, 1993, and, Tresman and Fox, 1994). This was done in response to the National Curriculum and the evidence that teachers did not have sufficient science background to teach the key stages effectively. On this point, Summers and Kruger (1994) note that:

... in the past the science curriculum at the primary level has not taken account of the extent to which the teachers have knowledge and understanding of the concepts specified, or the ease with which these concepts can be acquired (p. 517).

Pedagogical Content Knowledge

The focus on pedagogical content knowledge has been stimulated by the proposition that unless teachers have the scientific models to contrast with student models, they are not likely to be able to foster their students’ conceptual change. To be an effective science teacher, you cannot just be one step ahead of your students. It would be like teaching year 5 maths if you only have a ‘personal best’ of Year 6 maths.

In the course, participants examined the potential for lack of knowledge to be a dangerous and potentially misleading barrier to supporting student learning. They also discussed issues such as: is the time to learn the content with the students, or before them?; do the advantages of co-learning outweigh the potential for mutual misleading and non-learning?; and if you don’t know why things float, will you be left with the option of sharing intuitive rules such as ‘light things float’?

The need for better levels of understanding on the part of teachers, in order to improve students learning in science is described by Geddis (1993) as beginning teachers’ simplistic views of teaching and learning, particularly the transmission view: ‘teaching is telling and learning is remembering’ (p 674). He then introduces ‘the intellectual heart of the teaching enterprise’: transforming the beginning teachers’ content knowledge into pedagogical content knowledge. This is a process of transforming subject matter knowledge into a form which makes it teachable to a particular group of children. There are a number of aspects of pedagogical content knowledge: knowledge of students’ concepts, strategies for teaching content, and shaping and elaborating the content. Smith and Neale (1989) concluded from their investigation that "staff development programs that focus on content-free skills and strategies, or even on particular curriculum packages [are] especially beneficial for teachers to focus on a particular content and the ways in which that content is translated in teaching." (p. 17).

These studies provided a strong basis for this course for primary school teachers and science leaders to ‘upgrade’ their science knowledge in response to the increasing importance of science lessons in the school curriculum. These courses cannot be just short term, as extending learning in many aspects of science as covered in primary science, requires long term commitment.

Effective Levels Of Science Knowledge

The majority of science educators agree on the need for more science content knowledge; however, the extent and depth of adequate levels of teachers science knowledge is under debate.
Symington and Mackay (1991) followed up the 1989 Discipline Review of Teacher Education in Mathematics and Science (Speedy et al., 1989) by surveying a sample of early childhood and primary teacher educators (19 in Victoria). The Report had recommended 'the equivalent of one unit of science discipline knowledge (including physical science) which is explicit and assessed'. The teacher educators who took part in the survey disagreed on this recommendation. Another study reports a study of 139 pre-science students' views about science teaching (Appleton, 1992). Several students 'felt a small amount of knowledge was sufficient for the teachers, provided they (approached) the teaching of it as co-learners with the children' (p. 17). For some courses, little change was evident: Gustafson and Rowell (1995) investigated the views of 27 primary teachers in a science education unit and reported few changes over 13 weeks of the views of learning, teaching and the nature of science.

Our experience with this course supports the view that extensive exposure of teachers to science content must be done in a way that links content to pedagogy, so the relevance and practical use of the content is paramount, in order to develop a positive view of participants to the material; and that such changes cannot be achieved in the short term, but require intensive and continuing education and support. The course described in this paper is a first attempt to meet these needs in pedagogical content, and to define effective levels of knowledge.

Course Outline

Participants met on three days, July 8, 9 and 10 in 1996. Fifteen of the eighteen teachers were also able to meet on days 4 and 5 of the course, on October 1 and 2. The five days of the professional development course to 'train the trainers' had as an important characteristic the emphasis on best practice in adult education. It involved an intensive introduction over three days. This was followed by a term's break, which provided a longer period of personal reflection and development with continuing contact with course presenters. The culmination phase, on Days 4 and 5, served to consolidate understandings and strengthen skills. This approach provided a model for trainers to use for their own courses.

The objectives of the course were to: 1. Increase participants' level of confidence in teaching science by increasing the level of participants' science understandings and skills; 2. Develop participants' skills as presenters of science content and in effective teaching by involving you in mini presentations; and 3. Through participants, to assist teachers in our schools to gain their own confidence in science content, and in turn, help their students to like science and to learn science effectively.

The course participants engaged in various activities to stimulate discussion of their existing concepts; evaluate their own, other participants and students' work in a cooperative mode; research aspects of their own interest; present mini sessions to other participants of how they would tutor concepts; refine their presentation skills, such as use of voice, eye contact, clarity, sequence, gestures and use of models. create models, develop analogies, draw diagrams and practice explanations; review effective questioning and response; interact with experts in the field eg Energy Research Institute, and experience environmental analysis work in a laboratory; develop an understanding of the links between Primary Investigations, the
Student Outcome Statements and their role in learning area statements and support documentation, and the developmental nature of science concepts and skills.

Materials were developed by the project leaders to support participants. The first three days of the course resulted in the production of a workbook of 66 pages, together with a set of 50 pages of supplementary readings. The second two days of the course resulted in the production of a workbook of 106 pages.

**Course Evaluation: Phase I**

At the end of the first three days participants were asked for feedback, to gauge the general strengths of the course format, to inform changes in format and design for the last two days, and to determine what content for the following two days was requested and should be included.

Responses indicated participants' awareness that one of the prime considerations of the course developers was to create an atmosphere where participants were free to recognise, confront and deal with their own misconceptions and level of knowledge. This characteristic of the group emphasis, the openness of the presentees to not being 'fonts of all knowledge' but being prepared to share their own science growth and the idea of science as a constant development of better and better theories, was mentioned as a key to the success of the course in days 1-3. Sample comments included:

- A great atmosphere - relaxed, informative and realistic.
- Ironically, perhaps it was my lack of understanding of such phenomenon as 'moon phases', 'the seasons' and 'floating and sinking' that proved to be most useful. Indeed there appeared to be very few who understood these concepts and this provided me with confidence to pursue an understanding of these concepts.
- In all the lessons I discovered that I know so little, so I enjoyed all of them. I still don't understand many of the concepts or even 'Why' but I do feel a little more confident in teaching these strands.

When asked about the relevance of sessions, and possible improvements, the majority of participants felt that all sessions were useful and relevant. Participants' comments supported that the period of five days was vital to allow participants to 'grow' into the mode of change, and to allow time for revisiting the concepts in different formats. This led to continuation of energy and chemistry strands in days 4 & 5, within realistic contexts such as water quality and weather patterns. The focus on presentation was given insufficient time in the first three days, but served to stimulate participants desire to learn more about it, which was given higher profile on days 4 and 5 with more extensive feedback and planning sessions. There is a clear need for a mechanism for trusted colleagues to give feedback to developing presenters - an impression supported by the final feedback when over half the participants indicated they would like to work with another course participate or a district science leader. Sample comments included:

- I felt all sessions were relevant - challenged old ideas and concepts.
- Initially I didn't want to hear any of the physics lessons as I didn't understand them, but they were presented in a simple format and paced at the right level so that I do feel a little better about them.
Requests for sessions focused on presentation skills, safety, links to local issues or habitats; the weather and the seasons; concepts of sound and forces; linking science concepts of chemistry and energy to our own bodies; and, understanding how these concepts are located in the Student Outcome Statements. 

Course evaluation: Phase II

Reports from participants at the end of the five day course indicated that most moved from continuous models of matter and energy change, into molecular and atomic explanations for the first time. Reports indicated that for some, the course had helped them create more robust models of events, and promoted more skill in explanations and linking diverse concepts into complex events taught in primary school curriculum. Others reported that although they had met these ideas in high school, they were forgotten, and the course refreshed and consolidated their understanding. For some, it made the content of high schools classes understandable and relevant, with this content losing its mystique, for the first time.

For all participants, the course was very successful in stimulating a growth in science understandings; a desire to continue their own personal learning; an interest in working with others to share this new attitude and understandings. For example:

Attending the course has in many ways undermined my confidence, which I have in sound measure in other areas of my work. However, I can now, on completion, see that this could become a strength to take on the challenge of re-education in this field and derive satisfaction and new confidence by doing so.

This five-day course contributed information on the desirable and achievable level of content knowledge for this type of intensive course. Feedback from participants indicated strongly that fewer days would not have supported such widespread change in thinking about the nature of science, personal conceptual change, and the growth of a positive attitude to personal change and construction of science knowledge. One participant noted:

This course has renewed my interest in science and has helped me see it in a new light. It has brought home to me the fact that we can learn anything with enough time and clear enough explanation. The course has encouraged me to endeavour to find adequate explanations, examples and analogies to do justice both to science and the students. Emphasised again the responsibilities we have as teachers.

Participants were asked to assess how well they thought the overall aims of the course were achieved. The responses of the fifteen participants are summarised in the tables below. The number of participants choosing each category of response is shown in each table.

Q1. To what extent has this course increased your level of confidence in teaching science by increasing the level of your science understandings and skills.

<table>
<thead>
<tr>
<th>Level of Confidence</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>a little</td>
<td>1</td>
</tr>
<tr>
<td>to a reasonable extent</td>
<td>3</td>
</tr>
<tr>
<td>a lot</td>
<td>7</td>
</tr>
<tr>
<td>to a great extent</td>
<td>4</td>
</tr>
</tbody>
</table>
Over 80% of the participants indicated that there had been a substantial increase in their understanding of science content, to the extent that their level of confidence has been increased. Sample comments were:

- I want to read more physics and chemistry books because now I feel I can understand some/most of it.
- There was a large gap to fill at the start of the course from my background content knowledge, to what I'd need to bring about confidence in this area of teaching. At first, I viewed this as a negative, but now fell that I have a sense of direction to follow, and that confidence can be achieved, though in the longer term.
- The course has refreshed my memory - I have a science background which I haven't used for many years. I've taught science, but it hasn't been a priority in my program and I haven't taught it well. I think it's always been a "poor relation" to other subjects, but I have more confidence and inspiration now, to change this attitude.
- To explore some of the 'main' science concepts in a way that individuals could participate without feeling threatened or stupid.
- The 'scary' things like chemistry are not so scary - in fact when you do 'hands on' they're really quite simple.

Q 2To what extent has this course developed your skills as a presenter of science content?

This proved to be one of the key achievements of the course (see Table 2), and over half of those completing the five days saw the course as contributing in a significant way to their personal development as a presenter. The group varied from those who had never presented at all, to those with more extensive training or experience. The links between increased confidence in the content and presentation skills were made clear.

Table 2

<table>
<thead>
<tr>
<th>Developed skills as a presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>a little</td>
</tr>
<tr>
<td>to a reasonable extent</td>
</tr>
<tr>
<td>a lot</td>
</tr>
<tr>
<td>to a great extent</td>
</tr>
</tbody>
</table>

Sample individual comments included the following.

- By demonstration modelling and more indirectly though discussion throughout the course. I feel the course presenters and other participants offered valuable strategies and information, tried and true ideas for presentation of science content.
- A greater understanding of science content has enabled me to present with confidence.
- I do feel motivated to develop and improve my skills as a presenter, however I am sceptical about how to get an audience.
- I had already attended a 10 day train the trainer course which made me aware of the skills needed to present - only the content of the presentation varies.

Q 3. To what extent will this course through you, assist teachers in our schools to gain their own confidence in science content, and in turn, help their students to like and learn science.
Participants showed a more limited sense of success for this aim, perhaps due to an awareness of the limited extent of their control over factors in the broader school context. However, over a quarter felt that they saw the course as contributing a lot to this aim, as shown in Table 3:

Table 3

Assist others to gain confidence in science content

<table>
<thead>
<tr>
<th>Level of Confidence</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>a little</td>
<td>2</td>
</tr>
<tr>
<td>to a reasonable extent</td>
<td>7</td>
</tr>
<tr>
<td>a lot</td>
<td>5</td>
</tr>
<tr>
<td>to a great extent</td>
<td>1</td>
</tr>
</tbody>
</table>

Sample individual comments included the following.

- Having been through the process of trying to "bridge the gap" in order to upgrade my science content knowledge, I now feel that I can relate that experience to the many teachers who remain apathetic to science teaching. Have genuine empathy as one who has so little science background, yet can see science as being important, yet fun. Definitely into demystifying science for those who feel it's beyond their scope.

- I've gone some way to making teachers in my school more aware of science content.

- I'm hoping my new found enthusiasm and knowledge of science content will assist teachers to develop their own levels of understanding of content.

- When teachers who know you see you presenting science in practical interesting ways - they tend to want to have a go and pass their new found knowledge on.

Rating Of Level Of Comfort

Participants were asked to rate topics they now feel more comfortable about helping others, using the three categories: Pretty confident (PC); OK with more research (OK); and Not confident (NC). The responses are summarised in Table 4. Participants indicated high levels of confidence for the two topics in Working Scientifically and Energy & Change, with increasing discomfort for the topics in Life and Living and Earth and Beyond. Both of these strands are traditionally seen as the province of primary science, so it is interesting that frequently taught concepts of plants, the moon and seasons are still proving conceptually challenging for the participants. This indicates the need to include these topics in future courses and to allow more time to come to terms with the concepts within these topics.

Table 4

Rating of comfort level

<table>
<thead>
<tr>
<th>Strand</th>
<th>Topic</th>
<th>PC</th>
<th>OK</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working scientifically</td>
<td>1. Fair testing</td>
<td>12</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2. Evolution of ideas</td>
<td>9</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>3. Energy transfers</td>
<td>9</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4. Floating &amp; sinking</td>
<td>6</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Energy &amp; Change</td>
<td>5. Matter</td>
<td>7</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6. Water analysis</td>
<td>7</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Natural &amp; Processed Mat.</td>
<td>7. The moon</td>
<td>3</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>8. The seasons</td>
<td>1</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Earth &amp; Beyond</td>
<td>9. Light &amp; photosynthesis</td>
<td>4</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Life &amp; Living</td>
<td>10. Inheritance &amp; DNA</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>
Participants were asked to indicate which topics they would prefer to tackle, and some were happy to work with a few topics they felt comfortable with, others felt able to tackle a much wider range. Others were more aware of the need to respond to the interests of the audience and choose to link to their needs.

**Extent of Change Of Knowledge**

Participants were asked to rate their change in knowledge from 0 (know or knew nothing) to 10 (know it all or knew it all), before the five day course and after the five day course. The average of participants' responses are given in Table 5. Results indicate a general improvement in all strands, with the highest average movement for water analysis, light and photosynthesis and fair testing. Individual movements were more varied, with little movement for topics of high familiarity (eg fair testing has been a focus of some individuals) and very dramatic movement for others (chemistry and matter topics). For many, apparently simple concepts were shown to be very complex to explain scientifically. In the words of one participant:

I was intrigued by the complexity and the number of science concepts involved in everyday occurrences. I was particularly intrigued with 'seasons' and 'phases of the moon'. The course greatly helped me to increase / fine tune my conceptual understanding, but more than this my approach to science, my perception of science and what science is about has been redefined.

**Table 5**

<table>
<thead>
<tr>
<th>Strand</th>
<th>Topic</th>
<th>Before (0-10)</th>
<th>After (0-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working scientifically</td>
<td>1. Fair testing</td>
<td>4.5</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>2. Evolution of ideas</td>
<td>3.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Energy &amp; Change</td>
<td>3. Energy transfers</td>
<td>3.1</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>4. Floating &amp; sinking</td>
<td>3.9</td>
<td>6.3</td>
</tr>
<tr>
<td>Natural &amp; Processed Materials</td>
<td>5. Matter</td>
<td>6.6</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>6. Water analysis</td>
<td>2.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Earth &amp; Beyond</td>
<td>7. The moon</td>
<td>3.8</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>8. The seasons</td>
<td>3.9</td>
<td>5.8</td>
</tr>
<tr>
<td>Life &amp; Living</td>
<td>9. Light &amp; photosynthesis</td>
<td>3.8</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>10. Inheritance &amp; DNA</td>
<td>3.3</td>
<td>6.3</td>
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</table>

**Discussion**

This course provides strong support for an increased focus on the content involved in primary science in teachers' professional development. Significant change was observed and reported by participants, perhaps because of the high motivation levels of the individuals (they had to apply and be accepted) and the intensive but shared group focus of the activities (the five days allowed effective interpersonal relationships to develop of mutual trust and support), and the high value their participation was awarded by the course organisers and presenters (participants were seen as high achievers and very talented individuals). Increases in confidence levels, in a more positive attitude to continuing self education, and a desire to promote science content as a way of improving student learning were the three most powerful outcomes of this course.
The title of this paper supports our belief that changers in adults' long held views and concepts is a
lengthy developmental process which brief 'one - off' PD sessions will not address.
Our experiences in working with this group of enthusiastic and dedicated professionals has raised important
theoretical and practical issues relating to the identification of the most effective ways to develop primary
teachers' content, and thus pedagogical knowledge in science, with the expectation it will assist them make
valid judgements about the level of achievement of their students.

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Delivering an Inclusive Curriculum in Science: An Impossible Dream?

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Curtin University of Technology

Inclusive curriculum as it relates to science has been described in the literature as using a variety of teaching and learning strategies including collaborative learning, teacher-student interaction at a personal level, examining integrated concepts within a relevant context, providing equal opportunities for all students to handle equipment, delivering a negotiated content, and using goal-based assessment practices. The suggested strategies for inclusivity in science bear a strong resemblance to those advocated for early adolescent students in their middle years of schooling. There is, as yet, little research evidence to confirm that these practices do include more students in the science curriculum in our schools.

In this paper, links are drawn between the literature for inclusive curriculum and for middle schooling, then data from case studies of lower secondary students in Western Australia are examined to determine whether the suggested features of the inclusive curriculum and middle schooling are used in their science classrooms. The students' own perceptions are presented to see whether they believe that the proposed strategies do or would contribute to more positive attitudes to science. In particular, some girls' experiences are described in order to illustrate the effect they had on their perceptions about science.

What is an Inclusive Curriculum?

The term inclusive curriculum in science education has been defined as one which incorporates and values the prior experiences and strengths of all students, and allows them to participate in the curriculum by using a variety of learning styles and assessment techniques in a supportive and relevant context (Hildebrand, 1989). In discussing a gender-inclusive science education, Hildebrand (1989) argues that it would be beneficial for all students. The problem, in her view, is not with the students (that is, the girls), but with the teaching of science. It should involve much more active learning by the students with activities, such as drama and creative writing, which stretch across the curriculum. Reiss (1993) agrees that "what is good science education for one particular segment of the school population is good science education for all" (p. 41). He recommends practical work involving open-ended investigations, problem-solving, attractive laboratories, and role play of personal, social and political issues.

While there appears general agreement as to the desired strategies to be employed, there is little research evidence to support those assertions. Hildebrand (1989) admits that the strategies which she suggests 'may not all be necessary, although specifically which ones are sufficient is as yet unknown' (p. 8). There are, however, many similarities between the recommended strategies for an inclusive curriculum, and the desirable educational practices which are advocated for young adolescents.
Middle Schooling

The educational needs of young adolescent students have been addressed in a large body of literature from the US, UK, Canada and Australia, and contains much common ground. Students in lower secondary school are undergoing great social, physical and intellectual changes in their lives. It is generally agreed that, to cater for their growth, schools need to become more responsive to the students’ needs (Anderman & Maehr, 1994; National Board of Employment, Education and Training [NBEET], 1992; NBEET, 1993). Hargreaves and Earl (1994) suggest that early adolescents have certain “rights of passage” which include

- rights to a rounded education,
- rights to learning that is relevant, imaginative and challenging,
- rights to wider opportunities for achievement and success,
- rights to routine review of their progress with someone who knows them well and
- rights to feel welcome and cared for in their school environment (p. 3).

Emphasising the capacity to think critically, to transfer knowledge and skills to other situations, and to take more responsibility for their own learning are vital in the middle years of schooling. These skills should be acquired in an environment which builds and maintains students’ self-confidence and self-esteem (NBEET, 1993). Strategies which have been suggested to achieve these aims include authentic student participation (as opposed to token involvement) in planning their own learning; interdisciplinary approaches to make the curriculum more relevant; smaller learning communities to enable closer student/teacher and peer relationships; and flexible teaching, learning and assessment strategies to meet the needs of individual students (Cumming, 1994; Eyers, 1992). There are strong links between inclusive strategies and those promoted for young adolescents.

Science in Secondary Schools

Practices in science teaching in lower secondary schools and their effectiveness in meeting the needs of students are beginning to come under more scrutiny, especially in Australia. The Australian Academy of Science is currently initiating research to examine and improve teaching strategies and student learning at the lower secondary level (“Study of Lower Secondary Science”, 1996). Some previous research examined the differences in attitude of students as they moved from primary to high school. In Victoria, Baird and Penna (1992) found that an overwhelming majority (93%) of students enjoyed science in primary school, but that they were disillusioned with science soon after beginning secondary school. They felt as if they just copied notes or watched demonstrations, and were not given any “real work”. The students expressed their disappointment at the lack of activities, the amount of notetaking, listening to lectures, and the irrelevant topics (Baird, 1994; Baird et al., 1990). Similar findings are reported by the Department of Employment, Education and Training (DEET, 1992) and the Department of Industry, Science and Technology (DIST, 1995). It is important to note that nearly all of the students felt that science could be more relevant and fun if more practical activities were included.
In South Australia, Cormack (1995) used the concept of 'alienation' to investigate students' estrangement and lack of engagement during the middle years of schooling. The students' relationship with the teachers was the common theme which was linked to issues such as relevant curriculum, school structures and teaching strategies, and had an impact on students' engagement with school. Cumming (1994) encapsulated the issues which need to be addressed by teachers and schools in the "middle school":

There is further evidence to suggest that for a significant number of adolescents the curriculum lacks relevance and cohesion; teaching practices are alienating or simply boring; and organisational structures and procedures are rigid and disempowering (p. 13).

Western Australian high school principals maintain that the tertiary selection requirements influence even the early years of secondary school, so that teaching "tends to be a headlong rush through the crowded curriculum with little time for higher order thinking skills" and "suffers from excessive content, bookishness, individualism, competitiveness, didacticism, force feeding, conformity and traditionalism" (Chadbourne, 1995, p. 4).

In the US, Baker and Leary (1995) interviewed girls who said that they disliked lectures and taking notes in science classes because they found such teaching strategies isolating. They preferred to interact with others, including the teacher, and made judgments about science based on their relational and affective needs. Baker (1995) found that girls had strong preferences for how science should be taught. They wanted problem-solving and hands-on activities, discussions, and more work to be done in small groups or with partners. "By eighth grade the teacher had assumed an important role in the science classroom. Attitudes toward science were often dependent on whether or not the teacher made the subject fun or boring. When science was perceived as boring or irrelevant the blame was often placed on the teacher" (Baker, 1995, p. 164).

**Method**

The case studies were compiled from data collected during a study in Western Australia which employed a longitudinal design and followed two groups of students from year 7, their final primary year, into secondary school. Data were collected at two levels: first, case studies of individual students using mainly qualitative data; and second, at a broader level, both qualitative and quantitative data were collected from the cohorts of the case study students. Semi-structured interviews were the main qualitative data source for the case study students. Field notes were taken during lesson observations, and were referred to in interviews with the students. The case study students were interviewed at the end of primary school, and during their first and second years of secondary school. In all, there were 16 case study students over the two stages of the study who were selected because of their enthusiasm for, and high achievement in, primary science. Four of these have been selected to illustrate the effect that inclusive strategies, or the lack of, had on the students' attitudes towards science.
Case Studies

Natalie

Natalie had been very keen on science for as long as she could remember. When she started attending the local government high school, Natalie did not show as much enthusiasm for science as she had expected. "It's just like a subject. I don't think of it as a good or a bad subject. It's just a subject that I have to do." Her teacher was friendly and conscientious, and most lessons involved an activity, but Natalie felt that her teacher did not "walk around and ask people questions and everything like that. He just stands out the front and does what he has to do". Later in the term, she considered that the special equipment and rooms for science were better than in primary school, but that the content and method of delivering it was not challenging for her. "I thought we'd be doing really interesting things, but we're not doing that interesting things, and it's not very different from primary school. ... I thought we'd be doing really interesting things like discovering new things, but we're not. ...I'd rather be given a question and asked to work it out for myself".

By the end of the first semester at the local government high school, Natalie ranked science as fourth on her list of favourite subjects, in the middle of the seven that she mentioned. She liked theatre best "because it's like really easy. ... [The teacher] is really nice. She's not like a teacher, more like a friend".

For Natalie, even though the class was often involved in practical activities in small groups, and the teacher was friendly, the science curriculum was boring, the tasks were not challenging, they allowed for no choice in methods, the result was already apparent, and the teacher did not relate to her personally. For these reasons, her attitude to science had become less positive.

Kym

For Kym, high school science was a great disappointment. She attended the local government school where her science teacher spent most of the lessons talking or writing notes on the board, and the class participated in very few practical activities. There was little to challenge her. "We haven't done anything really difficult where we've actually had to think much yet". By the end of the semester, the situation had not improved, with many students in the class complaining at the lack of activity work.

Science is still not very good at the moment because it's terribly boring. All the other groups say they've been doing lots of experiments.... So we asked him if we could do an experiment, but he said that because of our topic we couldn't really do that. But then the subject that we did last term, transition [science], a lot of the other students did experiments and we didn't. We looked at the microscopes once, and we've watched a few videos, but that's basically because he had nothing else to do.

Science had become Kym's least favourite subject. Her marks had been good (27 out of 30 for the most recent test). Her favourite subject was "Probably English because I've got Mr C - he's a cool teacher". Kym's negative perception of science was mainly the result of the science teacher's style of presenting the curriculum which she found boring and unstimulating. Her science class had participated in very few practical activities, and the content of the lessons had not been challenging.
Rochelle

Rochelle was enthusiastic about all aspects of science in primary school, and always did well in tests. She attended a private girls' secondary school where science was not as activity-oriented as she would have liked. By the end of the first semester, although she had not given up hope, her enthusiasm was waning. Her science teacher was not as friendly and approachable as some others. She had achieved a B grade in first semester. Each topic was approached in the same manner, and the assessment was always a written test at the end. Rochelle’s observations about the way science was presented illustrate her reasons for her reservations about her enjoyment.

They can be a bit tedious if it’s just going through work and doing assignments or just sheets....We’ve done a lot of topics, always following the same format. We always just go through the book, and we always have revision at the end, and I think we have a test after every so many...I think I might grow to enjoy different parts of it.

Rochelle felt that each science topic was presented in the same way, that is, by working through the book with a test at the end. This accounted for her decreasing enjoyment of science.

Elizabeth

Elizabeth was enthusiastic about primary school science, and wanted to be a nurse. After the first three weeks of high school, Elizabeth’s opinion was that “It’s good, but it’s all work. You don’t get any time to do any fun stuff”. Her favourite subject was science because “I like doing the experiments, and the teacher’s nice as well”. She felt that her science teacher, Mr Giles, was more relaxed than some of her other teachers, and he was friendly to everyone in the class. She felt that secondary science was different from her expectations of it.

I thought we would use much more of the book, but we haven’t used the book so far, so ... and I thought there would be a lot more like taking notes and writing and stuff, but we only have to write up our experiment, and that’s it.

Elizabeth’s initial positive reaction to science at high school was based on her perceptions of the friendliness and relaxed attitude of her science teacher, and the hands-on approach he used to teach science. She was surprised but pleased that they had not used the book, as she preferred experimenting to reading. At the end of term one, ten weeks into the school year, Elizabeth’s feelings about science had not altered. She had received an ‘A’ for the term’s work, and although the science “teacher tells us off sometimes because we’ve been talking too much”, usually he was “really relaxed about it [teaching science]”. Elizabeth was still impressed by the lack of text-book learning. “We do lots of experiments, and we take notes from that. Nearly every lesson we do some sort of activity.” She liked science a lot more than in primary school because “The teacher’s better. We do more of a range of stuff and we get to use more equipment. We didn’t have any equipment at primary school.” Science was still her favourite subject, along with Social Studies and Japanese, “because the teachers are nice and I just like the subjects.”

Elizabeth continued to achieve well throughout semester one, and science remained her favourite subject. She felt that she was learning a lot of new and varied things, always through a practical approach. Her science teacher made her feel relaxed, and that was why she felt that she was learning well.
We're always doing something different. We do the same topic, but we do different subheadings under that main topic, so I like doing that. We do quite a bit of experiments and practical work. ... He [the science teacher] is really nice, and he has a sense of humour. He keeps the class under control. And we were talking to him today, and we can say something to him, and he won't take that personally. Like if we say something to the other teachers, we just get busted. But he won't take it personally, and like we say stuff to him. We asked him how old he was, and he made a joke out of it.... there's no way that I would ask any of my other teachers how old they were!

So, for Elizabeth, her relationship with the teacher was a vital element in her enjoyment of a subject: “I have to like the work, but I also have to like the teacher to be able to enjoy the subject”. Her determination to be a nurse had not diminished.

Lesson Observations

As the researcher, I observed and took field notes during several lessons at the beginning of year 8 in Natalie's, Kym's and Elizabeth's science classrooms. Each of their teachers appeared to be friendly and conscientious about teaching science. However, only in Elizabeth's classroom did I observe any attempts to place any of the practical work in a relevant context. One example was when students were asked to observe the effects of acid on various types of rocks. Each class did this activity, but Mr Giles was the only teacher who began the lesson with a discussion about acid rain, its causes and effects. Elizabeth's science class was hardly ever silent, and individual conversations between Mr Giles and his students were commonplace. His class was also the only one which ventured outside for activities, and only his students were encouraged to use their own style of taking notes and revising work.

Mr Giles: What are you going to do to make yourself remember what the structure of the earth’s like?
Student 1: Um, read and take notes.
Mr Giles: That might be a way.
Student 2: Diagrams in colour.
Mr Giles: Diagrams are good, colours are good.
Student 3: Draw pictures.
Mr Giles: Pictures are good.

Discussion

Every teacher seemed to be under constraints of the timetable, having to rush through activities, and having little opportunity for discussion at the end. The common content and assessment tasks being presented in each classroom made it difficult to be innovative or to adapt to the needs of particular students. Notwithstanding these constraints, Mr Giles managed to work within them and present a more activity-oriented and contextual curriculum in which the students could make choices, while at the same time developing a close relationship with his students. Elizabeth's experiences illustrate the means by which girls may be encouraged to enjoy science and to pursue career paths related to science. Her enthusiasm for, and confidence in her ability in science was nurtured by a high school science teacher whose pedagogy
incorporated many of the strategies of an inclusive curriculum. Hands-on activities which had a real life context took place nearly every day in her science class. Student-led discussions on a wide variety of issues were commonplace. A relaxed attitude by the teacher, and the students’ obvious appreciation of the supportive, non-competitive environment were features of Elizabeth’s science classroom.

For Elizabeth, the close relationship which she developed with her science teacher, and the stimulating presentation of the curriculum were her main reasons for declaring science to be her favourite subject. This was in contrast to the experience of other students, such as Kym and Natalie, who felt isolated by the teaching strategies which were being used, and found their science teachers to be impersonal. The students whose teachers were using a less challenging approach and felt that their environment was less supportive in terms of their relationship with their teacher also provide evidence to endorse the suggestions by both the inclusivity and middle school literature.

References


Student Generated Kinematics Graphs

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Abstract

A computer mediated approach to learning basic kinematics concepts based on recent educational research has been trialed at Edith Cowan University. Students are able to graph their motion in real time as they move in front of a sonic ranger device linked to a computer. Concepts of position, distance, velocity and acceleration are explored through these graphs.

The effectiveness of this approach is being investigated using pre- and post-testing as well as observation and interviews. How students interact with the technology and the affect of these interactions on learning outcomes is also being investigated. Preliminary results are presented in this paper.

Introduction

This project arose out of a desire to make the laboratory program for students undertaking the one semester "Foundations of Physics" unit in the Department of Applied Science at Edith Cowan University more exciting, modern and relevant to their needs. The first author had also witnessed the generally poor understanding of key motion concepts held by students both before and after instruction and was convinced that it was time to try a new approach to teaching these concepts. It was therefore decided to include computer based laboratory activities into the program to address both of these concerns.

The science education literature of the 1980s and 1990s includes numerous studies which show that many students come to instruction with existing conceptions about natural phenomena (Driver, 1989; Gilbert, Osborne & Fensham, 1982) which are inconsistent with the scientific conceptions students are expected to learn. These alternative frameworks interact in complex ways with instruction and the resulting learning outcomes are often misconceptions (Osborne & Wittrock, 1983). Posner, Strike, Hewson and Gertzog (1982) argued that if students are to reconstruct their existing alternative frameworks the learner would need to become dissatisfied with their existing conception and the new conception would need to be intelligible, plausible and fruitful. Other writers have proposed instructional strategies that can facilitate this conceptual accommodation (e.g., Driver & Oldham, 1986; Osborne & Freyberg, 1985). These strategies include the provision of opportunities for the students to make their conceptions explicit, experiences with situations which cause cognitive conflict between the alternative framework and experimental data, and opportunities to discuss, compare and apply ideas. Others have argued that interactions with peers or the teacher can scaffold the student's thinking through the zone of proximal development, that is, the difference between the student's current thinking and the next level of thinking (Vygotsky, 1978).

Previous research by Trowbridge and McDermott (1980) revealed that American college students completing introductory physics courses had difficulty comparing the motion of real objects and identifying
when they had the same velocity. Many students associated "same speed" with "passing" or "same position" and did not have a concept of velocity involving a ratio of distance travelled and elapsed time. In a similar study of college students' understanding of acceleration Trowbridge and McDermott (1981) found that even after instruction fewer than half of the students demonstrated a sufficient qualitative understanding of acceleration as a ratio ($\Delta v/\Delta t$) to be able to apply the concept in a real situation. Students also experience difficulty in interpreting position-time graphs confusing the height of the line rather than the slope for velocity, and difficulty in sketching 'qualitative' graphs to represent the acceleration of objects (McDermott, Rosenquist & van Zee, 1987).

Thornton and Sokoloff (1990) reported much success in teaching these concepts in the laboratory using an ultrasonic motion sensor connected to a computer with fast graphing capabilities. Students walk in front of a motion sensor (which works like a radar, but using ultrasound) connected to a computer which can plot in real time the student’s distance (in front of the sensor), velocity and acceleration as functions of time. They were also asked to match pre-programmed motion graphs on the computer screen with their own motion and this was seen as a particularly useful tool. There was a significant improvement in students' understanding of motion graphs measured using identical pre- and post-tests.

This computer based laboratory activity has the potential to help make explicit students existing conceptions of velocity and acceleration and create cognitive conflict between those conceptions and the immediate feedback provided by the computer. It was decided therefore to study introductory physics students' interactions with this program and explore its potential for facilitating the accommodation of students alternative frameworks. More specifically the study addressed the following research questions:

- How do students interact with the technology and with each other and the laboratory demonstrator in this computer mediated learning environment?
- To what extent are students alternative frameworks made explicit, cognitive conflict created between conceptions and data, and conceptual accommodation occur?

**Method**

The participants were students in the SCP1122 Foundations of Physics unit at Edith Cowan University in second semester of 1996. This unit assumes no previous knowledge of TEE Physics. Motion concepts had been covered in the traditional way through lectures in the week preceding the laboratory classes. Students in three of the five laboratory classes participated in the computer assisted experiment using the ultrasonic motion sensor. Their main tasks were to:

- **Activity 1:** Produce and analyse distance-time and velocity-time graphs of their motion.
- **Activity 2a:** Match a pre-programmed distance-time graph with their motion (zero acceleration)
- **Activity 2b:** Match a pre-programmed velocity-time graph with their motion (zero acceleration)
- **Activity 3:** Predict a distance-time and velocity-time graph for a described motion
- **Activity 4:** Produce and analyse velocity-time and acceleration-time graphs of their motion
- **Activity 5:** Match two pre-programmed velocity-time graphs (uniform acceleration)
Students in the other two laboratory classes conducted a more traditional experiment using ticker timers.

All students were given pencil and paper pre- and post-tests with an emphasis on the interpretation of velocity graphs. The pre- and post-tests were identical and students were allocated up to 15 minutes to complete the tests leaving approximately 90 minutes for experimental work.

Students were given written instructions for the experiment immediately following their completion of the pre-test. Several minutes were allocated to demonstrate the motion sensor and computer software before students were split into groups of three. One group was videotaped from each of the three laboratory classes doing this experiment. The first group (group C - all male) selected themselves by choosing the equipment being videotaped, the second group (group B - all female) was selected to provide some gender balance and the third group (group A - all male) were selected as they were identified by their demonstrator as being a vocal group (we perceived our previous two groups to be very quiet). About 20 minutes from the end of the laboratory session these videotaped groups were debriefed with a standard set of questions before completing the post-test with all the other students.

Preliminary Results and Discussion

The results from the pencil and paper pre- and post-tests for the nine students who were videotaped are summarised in Table 1.

Table 1. *Mean pre- and post-test scores, and percentage change for the students who were videotaped while working on the computer based motion activity (n=9)*

<table>
<thead>
<tr>
<th>Question</th>
<th>Maximum possible score</th>
<th>Mean pre-test score</th>
<th>Mean post-test score</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation of motion from a velocity graph (free response)</td>
<td>8</td>
<td>5.0</td>
<td>5.8</td>
<td>+16</td>
</tr>
<tr>
<td>Sketch of acceleration graph from a velocity graph</td>
<td>5</td>
<td>1.1</td>
<td>2.3</td>
<td>+110</td>
</tr>
<tr>
<td>Concept of velocity (free response)</td>
<td>2</td>
<td>1.1</td>
<td>1.6</td>
<td>+40</td>
</tr>
<tr>
<td>Concept of acceleration (free response)</td>
<td>3</td>
<td>1.1</td>
<td>1.8</td>
<td>+60</td>
</tr>
<tr>
<td>Interpretation of velocity graphs (multiple choice) from Thornton &amp; Sokoloff (1990)</td>
<td>5</td>
<td>3.2</td>
<td>4.3</td>
<td>+34</td>
</tr>
<tr>
<td>TOTAL</td>
<td>23</td>
<td>11.6</td>
<td>15.8</td>
<td>+37</td>
</tr>
</tbody>
</table>

On all questions, the mean student score improved after conducting this experiment. The most dramatic improvement appears to be in the two questions involving acceleration; possible reasons for this and other trends are still the subject of investigation.

This paper is mainly concerned with students' interpretation of (constant) velocity graphs and in particular how two groups are learning the relevant concepts through activity 2b: where students match a pre-programmed velocity vs time graph for the first time. The graph being matched and a typical student attempt (as seen in both groups) is shown in Figure 1. Students had previously successfully matched a distance time
graph which necessitated moving both away and towards the motion sensor. The positive direction is away from the motion sensor.

Figure 1. A typical student attempt (triangles) at matching the pre-programmed velocity vs time graph (dashed line) in activity 2b.

Group A had five attempts at matching this graph. Each attempt resulted in a greater understanding. One student was particularly vocal and undertook a leading role throughout this activity and will be referred to in this paper as the “leading student”. In the first attempt, the student moved towards the motion sensor instead of away from the sensor for the positive velocity. There was discussion amongst the students about whether to move away or towards, forwards or back (students are always facing the motion sensor). The terms positive and negative direction were never used. After this attempt the students wanted to try again.

Leading student: let's do that one again.
Other student: move backwards?
Leading student: Yeah, when it goes up that means you're moving away from it (sic: motion sensor)

In the second attempt, the students misinterpreted the vertical and horizontal lines on the velocity graph to produce a graph similar to that shown in Figure 1. The vertical lines were interpreted as meaning “move” and the horizontal lines are interpreted as meaning “stay still”. In addition, upward vertical lines (at 4 and 18 seconds) are interpreted as meaning “move away” and the downward vertical lines (at 8 and 12 seconds) are interpreted as “move towards”. At the 4 second mark which corresponds to the first vertical line, the subject is encouraged by his peers to go backwards and then stay still.

Leading student: Backwards...yeah.....stay, no you've got to stay still.
But the subject is staying still and his velocity stays at zero rather than 0.5m/s.

A similar situation arose when he was supposed to move towards the sensor at 0.5m/s. He moved at the 12 second mark and then stopped and his corresponding motion was seen to move from -0.5m/s to zero, leading to the following conversation:

Exasperated student: How do you get it along there? (pointing towards horizontal line at -0.5m/s)
Leading student: I'll show you.

Pause

Exasperated student: How do you get it to stay there?

In the third attempt, the leading student demonstrates an understanding that the horizontal line at 0.5m/s means that he must move backwards at constant velocity. The exasperated student is able to work this out as he watches this motion and the corresponding graph.

Exasperated student: See, how do you keep it like that.........Oh, you keep at constant velocity moving back!

In the fourth attempt, the group discovered another problem.

Student: The problem is you've got to move forward all the time and you run out of space.
Leading student: I ran out of space.

The group realise that for the fifth and final attempt they must start further back.

In summary, the matching graph activity created a mismatch between the graph to be matched and their conception of how they should move to match the graph. The students in group A needed to relate the observed motion and corresponding graph with their existing knowledge structures, reflect critically and accommodate. One student in this group was able to do this and scaffold the activity for the other group members so that they could understand the operational meaning of the horizontal and vertical lines on the velocity graph.

Group B had many attempts at matching this graph. Like group A, the activity created cognitive conflict for all students, but unlike group A, this group was not able to resolve the conflict without intervention from the demonstrator.

The region between 4 and 8 seconds on the graph was interpreted by one group member as

Student: Go really fast, then stop, and go really quick back!

The corresponding first attempt mirrors these instructions leading to a graph similar to that shown in Figure 1. The students were somewhat bewildered:

Student 1 So what's going on there?
Student 2 Oh...no way!

They showed in their next attempt that they could not interpret this graph yet they were happy to move on to the next activity until the demonstrator intervened:

Demonstrator: How are you going?
Student: Done that one
Demonstrator: Done that one?
Student: Yes
Demonstrator: Oh...I don't know? (laughter)

The group had another six attempts and the demonstrator returned when it was obvious that were not going to be able to solve the problem without help. With prompting, the students could read the velocity on the provided graph as 0.5m/s at different times between 4 and 8 seconds and they decided that the velocity was constant in this region, but they still did not grasp what it meant to move at constant velocity:

Demonstrator: Can you see what you do.....to do that motion?
Student: You just have to step back half a metre and stop there.......would that do it?
Demonstrator: Or....half a metre every second. Every second you have to move half a second, backwards
Demonstrator: What happens if you stop?
Student: Going to go back to zero, there (pointing to horizontal time axis)
Demonstrator: And if you’re up there (pointing to 0.5m/s horizontal line between 4s and 8s)?
Student: You’ve got to stay constant
Student: You’ve just got to get at constant speed on those.
Demonstrator: Yes basically....that’s exactly right

In the following, and final attempt, the group demonstrated that they understood that they needed to move at constant speed for the horizontal lines. In summary, the matching graph activity created a cognitive conflict which the students were not able to resolve by themselves. The demonstrator was required to scaffold the task for students in group B in order to facilitate learning.

Conclusions

The preliminary analysis of data presented in this paper confirms the potential of this type of laboratory activity reported by Thornton and Sokoloff (1990), for helping students accommodate their alternative conceptions of velocity and acceleration. Students’ attempts to move in front of the motion sensor and match the graph on the computer does create cognitive conflict which in turn stimulates important interactions between the group members. For one group reported here these interactions led to resolution of the conflict, whereas in the other group, intervention by the demonstrator was necessary to scaffold the thinking of the students leading to resolution of the problem. Further analysis of the data regarding the nature of the interactions between the students and the computer will be necessary to explain the improved responses to the post-test questions regarding acceleration.

References


The Development of a Successful Industry-Education Partnership

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Abstract

This paper describes the development of the RGC Wetlands Education Centre in the South-west of Western Australia by RGC Mineral Sands in conjunction with the Science Teachers' Association of Western Australia. The purpose of the Centre is to facilitate an educational program for primary and secondary school students.

The three key components of the project are the development of a resource package specially designed to assist students and their teachers learn about the Wetlands, a school visits program, and a professional development program for teachers. The project offers students the opportunity to study and monitor the wetlands, thus creating an awareness of conservation and land management issues.

To date, more than 1000 students have benefited from the project and the material developed has been successfully trialed. The three components of the project are described and suggestions made for how key facets of the project may be transferred for use with students in other educational settings and wetlands areas.

The Site

The RGC Wetlands Centre is situated at Capel, 200 km south of Perth, Western Australia. It is composed of a chain of 15 lakes created from mining pits left after the extraction of mineral sands. The lakes cover approximately 50 ha of a total of 350 ha and are around two metres deep. Presently, the lakes are fed by treated water from the processing plant and some are interconnected.

Before to mining, the area was a pine plantation and a banksia woodland. Mining took place between 1976 and 1981. From 1981 to 1986, the pasture around the lakes was grazed by cattle while the planning of the new wetlands was undertaken.

In 1985, a committee was convened to oversee the development of the site. The RGC Wetlands Centre Management Committee drew representatives from RGC, the Royal Australasian Ornithologists Union (RAOU), UWA, Murdoch University, Curtin University of Technology, the department of Conservation and Land Management and, in 1993, the Science Teachers' Association of WA. The Education Manager and STAWA's Executive Officer attend all Wetlands Centre Management Committee meetings.

Since then, a development program has been in place. This incorporates the creation of a wide range of habitats to encourage numerous species of animals and the installation of facilities for visitors such as paths, hides and educational support materials including an Eco-centre classroom. Development has been planned so that each lake retains much of its own character and landscape. Tree and species selection, island and spit construction, and hay and branch additions are techniques that have been used to attract waterbirds and make each lake a unique environment.

The objectives of the RGC Wetlands Centre are:

1. To develop a self sustaining wetland ecosystem for the conservation of waterbirds, on lakes created by mining at Capel;
2. To facilitate research into wetlands ecosystems, including their development and management;
3. To develop facilities for public education and recreation at the Capel wetlands; and
4. To develop and demonstrate rehabilitation technology for wetlands created by human activities.

The Educational Program

The third objective above addresses the role the RGC Wetlands Centre has in providing the community with the opportunity to study and learn about wetlands environments. In 1992, RGC Mineral Sands expressed an interest in developing the educational potential of its Wetlands Centre. In 1993, STAWA was invited to take on the role of educational consultant and manager of the wetlands educational program. A part-time Education Manager was appointed. Since this appointment, an educational resource package has been produced, teachers have undertaken professional development at the Wetlands Centre and school groups now visit the Centre on a regular basis.

The initial STAWA management plan for the educational aspect of the RGC Wetlands project included the following aims:

1. To give the Wetlands management considered advice about the effects of physical development on the Wetlands' educational potential;
2. To develop suitable quality teaching resource materials for relevant primary and secondary school syllabuses;
3. To make all WA teachers aware of the educational potential of the RGC Wetlands;
4. To develop suitable quality educational material aimed at the general public; and
5. To store and distribute the educational materials developed by this program.

STAWA has its own committee that monitors the educational aspects of the RGC Wetlands Centre project. The Capel Wetlands Education Advisory Group (CWEAG) comprises a selection of teachers interested in the educational program being developed at the Wetlands. CWEAG members provide recommendations on curriculum and infrastructure development and generally support the program.

The purpose of this paper is to describe fully the educative function and practice of the Wetlands Centre. The following issues are addressed:

1. The development of a resource package—titled *From Sand to Ducks*—specially designed to assist students and their teachers learn about the Wetlands;
2. A school visits program involving students from both the primary and secondary levels of schooling; and
3. A professional development program for teachers.

The Resource Package

To gain maximum advantage from school visits to the Wetlands Centre, it is important that students have access to relevant learning materials of a high quality. The purpose of these materials is to guide teachers' decision-making processes and to facilitate student learning. The materials can be used also to provide pre-learning in preparation for a site visit, to structure on-site activities, and direct follow-up
activities in which students apply new knowledge gained from a field trip to new and interesting situations. It is possible also, that materials developed to support one geographic location may be used by teachers and students at other locations. This generalisability aspect, while an added advantage in this instance, was not a priority influencing the design of these materials.

The material which now comprises the package From Sand to Ducks targets primary and lower secondary students. It contains a wide variety of site-related practical activities which promote environmental awareness. It is a loose leafed file comprising photocopyable worksheets and background information for both teachers and students.

Collection of data to be used in this package started in 1993. It was necessary to acquire a knowledge of the area and the flora and fauna before any writing could commence. The package was written with the assistance of on-site staff from the RGC Wetlands Centre and consulting scientists who formed part of the RGC Wetlands Centre Management Committee.

The resource package, comprising over 150 pages, contains the following sections: (1) General Information, (2) Introductory Activities, (3) Plants, (4) Aquatics, (5) Frogs, (6) Reptiles, (7) Birds and (8) Post-visit Ideas and References.

Teachers choose the appropriate activities and then photocopy the material for their students. The activities have been trialed at the site with school groups and the overall aim of the package was for it to be practical and simple to understand. A summary at the front of the file indicates the year levels for which each activity is suitable. A brief description of the components of the package is provided below. A more detailed description of the package’s contents can be found elsewhere (Thiele & Donnelly, 1996).

The General Information chapter provides information for teachers about the history of the RGC Wetlands Centre, information about how to arrange a school visit to the Wetlands Centre, and it provides samples of programs for full- and part-day visits to the wetlands. The chapter also includes a pro-forma Visit Permission Note and an Educational Activities Booking Form. The educational activities available at the wetlands are briefly described in this chapter.

The Introductory Activities chapter aims to make students more aware of their surroundings and the living things in them. It encourages them to use all their senses to make useful observations. The chapter includes several practical activities including Where Have You Been?, Biologists for a Day, and Looking at a Lake.

The Plants chapter is the largest in the package due to the extensive plant identification keys provided in the package. The diversity of flora and habitats make it possible for students to participate in a variety of plant-related activities. The chapter contains three activities that engage small groups of students in locating, observing and naming plants. There are also activities introducing students to the concept of rehabilitation and encouraging them to develop their senses of sight and touch with an emphasis on flora.

The Aquatics chapter is the first of four that relate to animal life in the wetlands. The activities involve students in the use of dip nets to capture and observe aquatic animals, to use simple microscopy to observe water and mud samples from various sites around the wetlands, and in measuring pH and applying this knowledge to water samples.
The *Frogs* chapter is one of the more significant of the animals sections. *Finding Out About Frogs* is a pre-visit activity in which students use their own knowledge plus other resource materials to complete an excursion chart about frogs. *Catching and Identifying Frogs* involves the use of a specially designed dichotomous key and students make observations about frog habitats in *Frog Hollows*. The final activity in this chapter is *Trapping Frogs*. The activity introduces students to pitfall traps and the history and theory of pitfall use is described.

An activity about *Reptiles* is provided in the small chapter of that name. In doing *Reptile Report*, students learn about pitfall traps and making scientific observations. From this they learn the characteristics that all reptiles possess.

The *Birds* chapter, which is the last thematic section in *From Sand to Ducks*, contains a useful amount of teacher background information about bird species found at the Wetlands. The chapter’s first activity, *Bird Watching at McCarley’s Swamp*, involves the use of binoculars and telescopes to view and identify birds. The *Bird Hide* makes use of a large on-site bird hide that can accommodate a whole class simultaneously. Older students appreciate the chance to engage in *Mist-netting for Bush Birds*, an activity that usually takes place early in the morning.

The final chapter of the package includes *Post-visit Ideas* and *References*. Here, the activities listed are linked to other wetlands sites and a bibliography of literature and technical reports about the RGC (and other) Wetlands Centres is listed.

A supplementary set of activities, designed principally for secondary biology studies, is presently being edited. This will be added to the file by teachers of secondary students. A Teachers’ Writing Weekend was held in 1995 where four Biology teachers helped create some of the activities in the supplementary package. The completion of these secondary materials will mark the culmination of four years’ work in drafting, trialing, editing and publishing the package which has become integral to the activities of both school visits and the teacher professional development workshops that are discussed in detail below.

**School Visits**

School groups started visiting the RGC Wetlands Centre in 1994. Since then, more than 30 groups per year have visited the RGC Wetlands Centre to participate in educational activities.

While the first visits were used to trial the material which was produced for *From Sand to Ducks*, it was necessary for certain infrastructure to be on-site to support these visits. Hence, a number of educational facilities have been built by RGC since 1993. These include walk trails, board walks, a large bird hide, a classroom and storage area, and a toilet block. The area where many of the school activities are found is around Paperbark Lake; this is where most of the facilities are located. The other parts of the Wetlands are used to a lesser extent and this use is dependent on the aims and interests of the visiting school groups.

It was first thought that the worksheets in *From Sand to Ducks* may have been able to stand alone and not require additional input from a teacher employed on site. However, teachers’ knowledge bases often do not extend to the biological aspects of the Wetlands. Subsequently, the teachers were not prepared to visit unless they had support in the form of experienced personnel. It was a decision of the management of the
Centre to provide substantive and in-kind support for the Project Manager, Tour Guide and Education Manager to assist school groups visit the Wetlands Centre.

While at the Wetlands Centre, students engage in activities from the resource package described above. Activities popular with students include netting for birds, comparison of water birds and habitats, dip-netting, microscopy, frog, reptile and plant identification, water chemistry measurement, art activities, and food chains and web activities.

Visitation records indicate that the most frequent visitors to the Wetlands Centre are primary schools that are located less than 50 km from the site. It could be argued that travel costs and the inflexibility of high school timetables act to inhibit greater visitation to the Wetlands.

The timing of students’ visits to the Wetlands Centre depends upon several key factors. The climate of the South-west of WA is hot and dry in summer. Therefore, these months are not popular for school visits. In addition, it takes time for teachers to organise their programs and to become sufficiently familiar with their students so that they feel comfortable taking them on a site visit. Therefore, more school visits occur in the latter part of the year.

More primary groups visit than secondary. It is far easier to take a primary group out of school because it does not usually cause disruption to the rest of the school or teachers. In primary schools, one teacher is responsible for most of the education program for a class. In contrast, if a secondary class or a teacher is absent for a day there is disruption to the other classes taught by that teacher and to the other lessons normally attended by the students.

More local schools visit than any other group. It takes about twenty minutes to travel to Capel from the large neighbouring towns of Busselton and Bunbury so the time factor and the cost of bus hire influence the groups that visit.

**Participation in activities**

Most local school groups visit once in a year although there are usually a few classes that attend more frequently. If a primary group is making only one visit they are given a sample of the Wetlands’ activities. The day’s program might include:

1. An introduction to, and short history of, the Wetlands;
2. Environmental awareness activities;
3. A plant activity such as using maps to find tagged plants and either making observations of these or identifying them depending on the skills of the students;
4. A visit to the bird hide; and
5. Dip netting and identification of aquatic animals.

Other popular activities include:

1. Mist netting, identification and banding of birds (usually reserved for small groups and Years 11 and 12 Biology students);
2. Frog studies (identification, frog hollows);
3. Walk trail; and
4. Tree planting/rehabilitation.
If a school group comes on a number of visits in a year then a different theme is usually chosen for each visit.

**Teacher Professional Development**

It is important that teachers are made fully aware of the Wetlands Centre and the educational opportunities available. To ensure that this happens, STAWA promotes teacher professional development at the Centre.

The teacher professional development courses that are offered assist teachers:

1. To become aware of the RGC Wetlands Centre as a resource for studying the rehabilitation/creation of a habitat;
2. To study the environmental factors, both living and non-living, of wetlands ecosystems;
3. To use plant and animal identification keys and information sheets which have been developed for this wetland ecosystem; and
4. To determine the suitability of different activities for particular student groups during a visit to this Wetlands Centre.

Eight teacher professional development courses have been run since 1993 with a total of 69 teachers attending. Seven of these courses were held on weekends while one was a one-day course which proved popular with local teachers. Six enrolments is considered to be the minimum number for a viable course—any less and the course is usually cancelled. All courses are now offered to both primary and secondary teachers rather than separating the groups. This allows for more interaction and gives more of a chance of making up the required numbers.

The RAOU Project Manager and RGC’s Tour Guide run these courses with the Centre’s Education Manager. Weekend courses involve activities such as a mineral sands mine tour, mist netting, dip netting for aquatic animals, plant identification, rehabilitation and visiting the research sites. The groups also spend some time with a representative from the department of Conservation and Land Management (CALM) spotlighting for possums, observing birds on the nearby Wonnerup estuary and trying various trapping techniques.

The RGC component of the course takes place at the Wetlands Centre and the CALM component occurs in and around the Tuart Forest at Ludlow. This is an old mill site and residential area between Capel and Busselton where the CALM employees lived. Some still live there but it may be turned into a camp site for people wishing to explore the area in the future. A school room is available for visiting groups.

Teachers from local schools, other south-west towns, and from Perth have attended the courses. Some Perth teachers have brought their students back to camp and participate in activities at Ludlow and the Wetlands Centre and a few groups now visit annually.

Teachers’ awareness of the RGC Wetlands Centre and its role as an educational resource has been raised in a number of ways:

1. Each semester, the weekend teacher professional development courses are advertised to all WA schools through STAWA’s PD Booklet.
2. Flyers are sent to local schools advertising the weekend and one day courses.
3. Information about the Wetlands Centre is sent to local schools
4. In 1995 and 1996, displays were set up at the annual secondary science teachers' conference (CONSTAWA). The Education Manager attends these conferences to provide information for teachers and answer questions about the Wetlands.
5. Information was provided to attendees at the 1996 primary science teachers' conference (PRISSEM).
6. The Education Manager has many contacts in the local schools and uses these to promote the Wetlands.
7. “Word of mouth” - positive comments from teachers who have visited the Wetlands and attended professional development courses have encouraged other teachers to attend.
8. The production and launching of the resource package has given the Wetlands Centre a higher profile and educational standing.

Conclusion

The educational program offered to both teachers and students is fulfilling the original aims of the project. Some teachers are making a visit to the Wetlands Centre an annual event. Interest in the Centre is spreading as more people become aware of the variety of student-centred activities available. The presence of the educational support with school visits has contributed to the increasing use of, and interest in, this educational facility. Teachers who visit the Centre with their classes are very positive about the activities and support offered.

The number of groups visiting the centre is expected to maintain its current level and possibly increase as long as the support structure is present.

Note

Copies of the resource package (From Sand to Ducks) may be obtained from STAWA.

References

The Primary Science Teacher-Leader Project: What Have We Learned?

Grady Venville and John Wallace
Curtin University of Technology
William Louden
Edith Cowan University

Introduction

The Primary Science Teacher-Leader Project was conducted during 1995 and 1996 as part of the Education Department of Western Australia's Science Project - a four year initiative to improve the quality of science teaching and learning in Western Australian government schools. The overall goals of the Science Project are to:

- provide all schools with access to exemplary curriculum materials;
- establish an effective, whole school curriculum in primary schools;
- establish science teaching methodology in primary and secondary schools which is consistent with identified best practice;
- provide access for teachers to update their knowledge of science and its role in society; and
- establish networks of curriculum leaders to provide ongoing support for teachers.

The Primary Science Teacher-Leader Project - designed to address several of the overall goals - was conducted in two sections in 1996. These were the ongoing training of the 1995 primary teacher-leaders in 1996 and the training of the new primary teacher-leaders for 1996. Each district in the state was invited to fill one position in each section. Where the 1995 leader did not continue, the district was offered two positions for the 1996 Primary Teacher-Leader Project. At district level, teacher-leaders were asked to work with their district offices to plan and implement a science support program for local teachers. These local support programs were funded by the project, the level of financial support being between $12,000 and $16,000 per district. Selection of the personnel to attend the training program resulted in several teacher-leaders being based in district offices while others were school based. Five additional leaders were included in the 1996 project, each with specific expertise in one of the following areas: early childhood education; English as a second language; education support Aboriginal education and isolated and distant education. The 1995 teacher-leaders participated in a total of four days training. The 1996 teacher-leaders participated in a total of nine days training. This paper summarises the evaluation of the Primary Science Teacher-Leader Project in 1996 and focuses on the following issues:

- professional development of teacher-leaders with regard to primary science teaching methodology, theory, outcome based learning and leadership,
- networks established among 1995 and 1996 teacher-leaders and school coordinators,
- district level activity of teacher-leaders,
- school support provided by teacher-leaders and
- hurdles faced by teacher-leaders when implementing a program in their district.

The researchers undertook four data collection phases. In each of the phases a combination of data collection methods were used to triangulate at the data collection level in order to enhance the dependability of the findings (Guba & Lincoln, 1989; Patton, 1990). The first phase of the evaluation was a review of the training program. The researchers attended meetings of the Primary Science Teacher-Leader training program and data collection included observation of a range of course activities and semi-structured interviews (Hitchcock & Hughes, 1989) with five representative teacher-leaders from the 1995 group and five representative leaders from the 1996 group. The second phase consisted of a questionnaire conducted with 44 of the 65 teacher-leaders. The questionnaire was designed after consideration of the issues included in the evaluation brief and other issues which emerged from the interviews with the representative teacher-leaders in Phase 1. Respondents were asked to respond to items on a five point Likert scale (Wiersma, 1986). Several open-ended questions also were included on the questionnaire. Responses to the items on the questionnaire are presented in Table 1.

The third phase of the evaluation was conducted as case studies in five representative districts. The purpose of the case studies was to identify and describe the activity which was happening at the district level, in schools and the activity occurring in classrooms which could be attributed to the Primary Science Teacher-Leader Project. Data collection included observation of network meetings and professional development workshops, interviews with the district teacher-leaders, interviews with four or five other teachers from each district and at least one school visit. Case study 5 is presented in the findings section of this paper. The final phase of the evaluation was a validation phase, the purpose of which was to validate the results of the questionnaire and the case studies. The results of the questionnaire were presented to the 1996 group of teacher-leaders and the case studies were returned to the leaders of the districts in which they were conducted. The comments and suggestions from the leaders about the questionnaire results and from the case study district leaders were recorded and taken into consideration in the final report preparation phase.

Case Study Findings: Marble District

Background

Donna was the Science Coordinator for this metropolitan district in 1995 and has continued in this role in 1996. Donna is a classroom based teacher-leader and has been joined by Alex, another classroom based teacher-leader, this year. The district teacher-leaders have cooperated with two other districts as a cluster to organise many of the activities they planned for the Primary Science Project.

What's Happening at the District Level?

Science professional development conference at Rottnest Island  Donna and Alex, the district teacher-leaders, were very active in their role in 1996. There were a range of activities carried out through the year in order to support schools and teachers with regard to curriculum establishment, science teaching, and raising the awareness of science. The most visible of these activities was a science professional
Table 1
Results from questionnaire administered to Teacher-Leaders
Scale Scores
5 - strongly agree 4 - agree 3 - neutral 2 - disagree 1 - strongly disagree

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Mean (n=45)</th>
<th>St Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>The program has provided me with adequate theoretical background on</td>
<td>3.70</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>teaching science for my role as teacher leader.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>The program has improved my knowledge of teaching methodology in</td>
<td>4.16</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>science education.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>As a result of the program I am a more effective teacher of primary</td>
<td>4.14</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>I am part of an effective network of science teacher-leaders as a result</td>
<td>4.34</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>of the program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>The program has lead to a change in my understanding of outcome-based</td>
<td>4.30</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>learning in science.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>The program has complemented and supported the First Steps project.</td>
<td>3.43</td>
<td>0.85</td>
</tr>
<tr>
<td>12.</td>
<td>The program has improved my knowledge of how to be an effective</td>
<td>4.09</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>teacher-leader.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>My role as science teacher-leader is clear to me.</td>
<td>3.96</td>
<td>1.06</td>
</tr>
<tr>
<td>14.</td>
<td>The division of the teacher-leaders into 1995 and 1996 leaders was</td>
<td>4.00</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>appropriate for the training program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>The profile of science in my district has been raised this year?</td>
<td>4.22</td>
<td>0.97</td>
</tr>
<tr>
<td>16.</td>
<td>A successful support network for science coordinators has been</td>
<td>3.69</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>established in my district.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>I have provided support to primary schools in my district this year.</td>
<td>3.80</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>What are the three most effective ways you have been able to do this?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>The teacher-leaders in my district have worked effectively as a team</td>
<td>3.92</td>
<td>1.19</td>
</tr>
<tr>
<td></td>
<td>this year.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>The district office has been cooperative with me in my role as science</td>
<td>4.10</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>teacher-leader.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>The school administrators in the district have been cooperative with me.</td>
<td>3.67</td>
<td>0.80</td>
</tr>
<tr>
<td>21.</td>
<td>The school science coordinators have been supportive of the activities</td>
<td>4.10</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>which have been organised in my district.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>The school science coordinators in my district have effectively carried</td>
<td>3.59</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>out their role in their schools.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>The schools in my district have actively participated in activities</td>
<td>3.85</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>organised as part of the Science Project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>It has been beneficial to have more than one leader in my district.</td>
<td>4.08</td>
<td>1.06</td>
</tr>
<tr>
<td>25.</td>
<td>Communication with school coordinators has been a problem for me.</td>
<td>3.05</td>
<td>1.00</td>
</tr>
<tr>
<td>26.</td>
<td>More teachers are teaching science in my district as a result of the</td>
<td>3.61</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Science Project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>As a result of the Primary Science Teacher-Leader Project teachers are</td>
<td>3.50</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>teaching science more often in my district.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>As a result of the Primary Science Teacher-Leader Project the quality of</td>
<td>3.62</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>primary science teaching has improved in my district.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Primary school students in my district are participating in more science</td>
<td>3.85</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>as a result of the Science Project.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>I have had enough time to complete the tasks I planned to do as a</td>
<td>2.36</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>district teacher-leader.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>The new Education Department's professional development guidelines</td>
<td>1.84</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>have enabled the Science Project to operate effectively in my district.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>Funding has been adequate to allow for effective teacher professional</td>
<td>3.12</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>development.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.</td>
<td>I have had adequate funding to complete the tasks I planned as district</td>
<td>3.57</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>teacher-leader.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
development conference at Rottnest Island at which school coordinators from three districts in the cluster attended. The person from each school who attended the Rottnest conference was asked to share the knowledge, networking, skills, ideas and experience gained from the weekend with their staff on return to their schools. These same people were asked also to regularly attend district network meetings. Rottnest was chosen as a venue for the conference because the teacher-leaders felt it would be conducive to the development of collegiate support in a focused environment and it would focus the participants for the duration of the course. Donna and Alex felt the location would ensure a captive audience night and day and this would encourage more productive time on networking and professional development. They felt the trip away to Rottnest would reward the school coordinators for their commitment to science, recognise the coordinators as professionals and encourage long term commitment from them.

The conference was held on a Friday and Saturday in the middle of August and all travel to Rottnest Island, accommodation and meals were funded through the Science Project. Teacher relief was available for one person from each school for the Friday. The teacher-leaders felt this was a cost effective two days networking and professional development for one day teacher relief. The agenda at the Rottnest conference included an environmental walk, discussion of science tabloid days and science challenge activities, a science quiz night, and workshops on best practice and a range of ways to approach science, integrating technology and science and open ended investigations and links to student outcome statements. Time also was set aside for discussion of the district needs, how the coordinators can help their schools and how the coordinators can share their Rottnest conference experiences with their school. The Rottnest conference was generally felt to be an excellent forum for professional development by the teacher-leaders, and the school coordinators who attended. Not only was the professional development thought to be excellent, strong network bonds were established and the coordinators said they had a lot of fun too.

Network meetings. The coordinator's network meetings held on a once a term basis in this district have been a successful forum for the dissemination and sharing of information on science education and as a mode of feedback and communication between the school coordinators and Donna and Alex. For example it was established at the Rottnest conference that extension and enrichment of the activities in the Primary Investigations program was a high priority. This was subsequently included on the agenda for the network meeting held in early September. Other network meeting activities have included an overview of the Science Project, discussion of the district strategic plan, Rottnest conference feedback, newsletter discussion and workshops on science collaborative learning and Primary Investigations extension and enrichment. The network meetings also have included the display and presentation of a wide range of science resources.

Newsletter. The teacher-leaders are currently working to establish a science newsletter in the district as another form of communication other than the coordinators network meetings. At the network meeting in term three the coordinators agreed that a newsletter would be a good avenue for the school coordinators to share science information and extension activities with other schools and that all the school coordinators could submit articles to the teacher-leaders for the newsletter. It was decided that it would be useful to have a newsletter once a term, in-between coordinators network meetings.
Pre-Primary Science. A need for support for pre-primary teachers in the district trying to establish science in their classrooms was identified by Donna and Alex through feedback from the school coordinators. Primary Investigations does not include a pre-primary program and this means many pre-primary teachers feel excluded from the whole school programs being established. The district coordinator's network meeting in term three included a session on enrichment and extension of Primary Investigations and during the session the six pre-primary teachers present were grouped together so they could address their special needs. Since their successful meeting at the term three coordinators meeting some of the pre-primary teachers have established their own science network and are planning to develop more comprehensive pre-primary science teaching materials.

What's Happening at the School and Level and in the Classrooms?

Many of the schools in the district have introduced Primary Investigations or another whole school program. For example at Callistemon Primary School where Iris is the school coordinator Primary Investigations was introduced at the beginning of third term 1996. Many of the teachers at the school already had a science program for the class, however those who didn't have found Primary Investigations to be very useful. Those teachers who already had their own program have found Primary Investigations to be somewhat restrictive and prescriptive, however, Iris has been involved in helping those teachers to use Primary Investigations as a starting point and to use their own lessons to extend and integrate with other areas such as art and language. The school has yet to have any Primary Investigations training, however, Iris is currently organising this with the project leader.

Sophie is the science coordinator at Grevillia Primary School where Primary Investigations was initiated in 1995. All the 1995 teachers received Primary Investigations training and the program became part of school policy. The problems the school has faced in 1996 with Primary Investigations is that many of the new teachers who came to the school at the beginning of the year have not had Primary Investigations training and Sophie spends much time helping these teachers and encouraging them to use Primary Investigations or in some cases it has been diplomatic for her to let the new teachers use their own program. For Sophie, the idea of on-going professional development in this area is necessary for these reasons.

Martin is a middle primary school teacher and has been using Primary Investigations as part of his whole school science program since early in 1995. He says that the investigations are much easier for him to use this year because it's his second time around. This year he has been involved in adapting the investigations to the needs of his students and trying to make the investigations more open ended and increasing the amount of integration with other areas of the curriculum. For example, last year Martin used an activity from Primary Investigations that involved the students in testing different kinds of washing powder by washing pieces of material that had been stained with cooling oil. The students found that the stains were removed regardless of the kind of washing powder used. Even if the material was simply washed in cold water the stain still disappeared. This year, after having professional development on open investigations, Martin hopes to improve the activity by allowing the students to experiment with several alternative stains such as grease, tomato sauce, texta, and ink. He also plans to integrate the activity into social studies and look at consumer science and advertising.
Discussion

Teacher-leaders agreed that the training program provided them with adequate theoretical background on teaching science for their role as teacher-leader (Table A, item 6). In addition, they believed that the training program has improved their knowledge of science teaching methodologies (Table A, item 7). The balance between theory and practical activities was well received. Valuable networks have been established amongst 1996 leaders and between 1996 and 1995 teacher-leaders (Table A, item 9, 14 & 24). The network system is particularly cohesive between district office based teacher-leaders.

Teacher-leaders felt that as a result of the program, they have an improved and updated understanding of outcome based learning and assessment (Table A, item 10) and are able to apply these ideas to the classroom. Case studies show that the professional development at the district level has given some coordinators more confidence with outcome based learning. The leaders agreed that the program has prepared them effectively for their leadership role and that the leaders have been working effectively as teams in the district (Table A, items 12, 18). Leaders said and case studies showed that the presence of more than one leader in districts has been beneficial (Table A, item 24). A few school based leaders were not clear of their role and felt ineffective because of time limitations and a sense of domination by the district office leader.

Leaders agreed that networks of school coordinators had been established in their districts and that school coordinators had supported the activities organised by the Primary Science Project in their district (Table A, items 16 & 21). Case studies and leaders' comments suggest that coordinators who attended district network meetings and participated in professional development effectively carried out their role of support in their schools. Concerns were raised by the leaders about non-participating schools.

There was a clear message from the teacher-leaders that they agreed or strongly agreed that the profile of science had been raised in their districts in 1996 (Table A, item 15). Leaders generally agreed that they had provided support to primary schools in their district (Table A, item 17). The biggest successes of the programs being implemented in the science districts were the professional development days and science conferences which utilised the one day teacher relief available. Other areas of success mentioned by the leaders included science competitions, network meetings and Primary Investigations training.

Focus group leaders reported that they found it difficult to get started because they didn't have a set amount of allocated money and they didn't have a designated group of teachers or a district to work with. However, as the year progressed and with the help of the Science Project leaders, the focus group leaders overcame some of their initial problems and were able to provide some support in their focus areas.

The leaders disagreed that the new Education Department's professional development guidelines have enabled the Science Project to operate effectively in the districts (Table A, item 31). This issue in conjunction with other restrictions on spending was mentioned by leaders as being the biggest hurdle for them in implementing the program in their district. Other hurdles included lack of time, especially from school based leaders (Table A, item 30); geographical distance, especially from country based leaders;
communication with school coordinators (Table A, item 25); lack of interest from some schools and the late start to the 1996 program.

Case study data indicated that school based leaders were generally very active in their own schools. The ways that leaders supported science in their schools included encouraging teachers to get involved in science professional development, establishing a whole school program, encouraging teachers to exercise professional judgement in extending and altering programs to suit their students, making arrangements for science equipment, and organising and implementing science competitions for students.

Conclusions

The 1996 Primary Science Teacher-Leader Project has successfully conducted a professional development program for a highly motivated and dedicated team of primary science teacher-leaders in 1996. The evaluation provided sound evidence that the project made progress on all of its goals. The dedication of the Science Project team has maintained the momentum of the Science Project from 1995 to 1996. This has resulted in a year where teachers have had access to relevant professional development and schools and teachers have been encouraged and supported in their endeavours to improve the teaching of science at the primary level.

The project has extended the professional development and maintained successful networks among those teacher-leaders who started their training in 1995 and continued in 1996. The 1995 and 1996 teacher-leaders have, in most cases, worked effectively as teams in their districts to strengthen the commitment to primary science education and share the workload of the science teacher-leader role. The teacher-leaders have been committed and proactive in their districts providing relevant professional development for classroom teachers, raising the profile of science, and providing support to schools and teachers. Schools, generally, have been supportive and active in participating in activities organised by the teacher-leaders at the district level. The teacher-leaders have expressed concern about the schools in the state that have not become involved in the Science Project. Other areas of concern about the Science Project expressed by the teacher-leaders include the restrictions on the ways that the teacher-leaders have been able to spend their funding, particularly on teacher relief, time constraints for school based leaders, and distance restrictions in remote areas of Western Australia.

References


A Culturally Sensitive Learning Environment Instrument for Use in Science Classrooms: Development and Validation

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Science and Mathematics Education Centre
Curtin University of Technology

Abstract

Many students come from communities with widely differing cultural practices and thus, there is an increasing need for teachers to be sensitive to the important cultural milieu in which their teaching is placed. As schools are becoming increasingly diverse in their scope and clientele, any examination of the interaction of students' culturally sensitive learning environments with learning processes, assumes critical importance. The purpose of this exploratory study was to develop an instrument to assess these culturally sensitive learning environments, to provide initial validation information on the instrument and to examine associations between students' perceptions of their culturally sensitive learning environment and their attitudes towards science. A measure of science students' cultural factors that might affect learning, namely the Cultural Learning Environment Questionnaire (CLEQ), was developed from past learning environment instruments and was influenced by Hofstede's four dimensions of culture (Power Distance, Uncertainty Avoidance, Individualism and Masculinity/Femininity). The reliability and discriminant validity for each scale was obtained and associations between students' culturally sensitive learning environment and their attitudes were found. The homogeneity of perceived learning environments within classrooms was examined.

Introduction

While there are a number of research studies in science in existence concerning culture and education generally (Atwater, 1993, 1996; Cobern, in press; Maddock, 1981), comparatively little research examines the interaction that occurs between students' culturally sensitive learning environment and their learning processes. It is timely and relevant to examine how students' culturally sensitive learning environments enhance or inhibit their learning within a secondary school science classroom.

In this exploratory study, culture is defined as "the distinctive way of life of a group of people, their complete design for living" (Kluckhohn, 1951, p. 86). It is argued that at the macro-classroom level, there are distinctions that can be made between the preferred learning styles for different high school students. This article describes the development of a questionnaire to assess culturally sensitive learning environments and its application in investigating relationships between these culturally sensitive learning environments and students' preferred student-teacher interpersonal behaviour.

Assessing the Culturally Sensitive Learning Environment

In his research on human environment, Moos (1979) found that three general categories can be used in characterising diverse learning environments. This finding emerged from Moos' work in a variety of environments including hospital wards, school classrooms, prisons, military companies, university residences and work milieus. The three dimensions are: relationship dimensions which identify the nature and intensity of personal relationships within the environment and support and help each other; personal development dimensions which assess personal
growth and self-enhancement; and system maintenance and system change dimensions which involve the extent to which the environment is orderly, clear in expectations, maintains control, and is responsive to change.

In the past 25 years, Moos' work has influenced the development and use of instruments to assess the qualities of the classroom learning environment from the perspective of the student (Fraser, 1986, 1994; Fraser & Walberg, 1991). Examples of classroom environment instruments include: the Learning Environment Inventory (LEI) (Fraser, Anderson & Walberg, 1982) which measures student perceptions of 15 environment dimensions of secondary school classrooms; the Classroom Environment Scale (CES) (Moos & Trickett, 1987) which contains nine scales for use in secondary school classrooms; the My Class Inventory (McI) (Fraser, Anderson & Walberg, 1982) which is suitable for use with children in the 8-to-12 years age range; and the College and University Classroom Environment Inventory (CUCEI) (Fraser, Treagust & Dennis, 1986) which is suitable for use in tertiary education settings. Other more specialised instruments include: the Individualised Classroom Environment Questionnaire (ICEQ) (Fraser, 1990) which assesses those dimensions which distinguish individualised classrooms from conventional ones; the Science Laboratory Environment Inventory (SLEI) (McRobbie & Fraser, 1993) suitable for assessing the environment of science laboratory classes at the senior secondary or tertiary levels; and the Constructivist Learning Environment Survey (CLES) (Taylor, Dawson & Fraser, 1995) designed to assist researchers and teachers assess the degree to which a particular classroom's environment is consistent with a constructivist epistemology. As the scales of all of these instruments can be categorised into one of the dimensions of Moos's scheme for classifying human environments referred to above, there is some commonality in the conceptual frameworks underpinning the assessment of classroom environment. It was thus determined that any instrument used in this study would also be based on Moos' dimensions.

However, none of the instruments referred to above were designed specifically to be culturally sensitive to the student's learning environment and it was necessary to devise a new instrument. The new culturally sensitive learning environment instrument utilised in this study was based on previous learning environment scales that a review of research literature indicated could be culturally important. The selection of these scales was guided by the fields of anthropology, sociology, management theory and Hofstede's (1984) dimensions of culture. After collecting information with a detailed questionnaire from thousands of individuals working in multi-national corporations operating in 40 countries, Hofstede (1984) analysed the data and identified four dimensions of culture, namely, Power Distance, Uncertainty Avoidance, Individualism, and Masculinity/Femininity. Other studies, for example, Bochner & Hesketh (1994) and Stull & Von Till (1994) have used an instrument approach based on Hofstede's dimensions to study culture in education settings. Similarly, this study utilises an instrument containing scales whose construction were influenced these four dimensions.

An instrument, provisionally identified as the Cultural Learning Environment Questionnaire (CLEQ), was developed specifically for use in this study. The initial development of CLEQ was guided by the following criteria:
i. Consistency with previous learning environment research. All relevant scales contained in relevant existing instruments for learning were examined for guidance in identifying the scales.

ii. Consistency with the social psychology, organisation sociology and anthropological literature.

iii. Consistency with management theory literature. Important dimensions in the unique environment of multicultural, multinational organisations were identified through an extensive review of the literature (Hofstede, 1984).

iv. Coverage of Moos' general dimensions. Scales for the CLEQ were chosen to include at least one scale from each of Moos' three dimensions.

v. Salience to teachers and students. By interviewing teachers and students an attempt was made to ensure that the CLEQ's scales and individual items were considered salient by teachers and students.

vi. Economy. CLEQ was designed to have a relatively small number of reliable scales, each containing a small number of items.

The result was a questionnaire containing eight scales: Role Differentiation, Collaboration, Risk Involvement, Competition, Teacher Authority, Modelling, Congruence, and Communication. A description of each of these scales, together with a sample item from each is provided in Table 1.

Table 1
Descriptive information for each scale in the CLEQ instrument

<table>
<thead>
<tr>
<th>Scales</th>
<th>Description</th>
<th>Sample Item</th>
</tr>
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<tbody>
<tr>
<td>Role Differentiation</td>
<td>Measures the extent to which gender roles are perceived to be differentiated or overlapped by students.</td>
<td>I feel that comments in class by male and female students are equally important (+)</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Measures the extent to which students are part of a strong cohesive group.</td>
<td>I feel that it is important for the class to work together as a team (+)</td>
</tr>
<tr>
<td>Risk Involvement</td>
<td>Measures the extent to which students feel they can give their own opinion in class discussions.</td>
<td>I try to say what I think the teacher wants rather than give my own opinions (+)</td>
</tr>
<tr>
<td>Competition</td>
<td>Measures the extent to which the students that they are competitive with other students</td>
<td>I like to compete against the other students (+)</td>
</tr>
<tr>
<td>Teacher Authority</td>
<td>Measures the extent to which students feel they can challenge their teacher.</td>
<td>It is OK for me to disagree with teachers (+)</td>
</tr>
<tr>
<td>Modelling</td>
<td>Measures the extent to which the students prefer to learn by a process of modelling.</td>
<td>I like teachers to show me what to do (+)</td>
</tr>
<tr>
<td>Congruence</td>
<td>Measures the extent to which the students feel learning at school matches their learning at home.</td>
<td>What I learn in this class helps me at home (+)</td>
</tr>
<tr>
<td>Communication</td>
<td>Measures the extent to which students have more direct forms of communication with the person they are interacting with</td>
<td>I like to be able to see as well as hear what is happening in class (+)</td>
</tr>
</tbody>
</table>

Teacher-Student Interpersonal Behaviour

International research efforts involving the conceptualisation, assessment and investigation of perceptions of psychosocial aspects of the classroom environment have firmly established classroom environment as a thriving field of study (see reviews by Fraser, 1994; Fraser & Walberg, 1991). A team of
researchers in The Netherlands extended this research by focusing specifically on the interpersonal relationships between teachers and their students as assessed by the *Questionnaire on Teacher Interaction (QTI)* (Wubbels, Créton & Hooymayers, 1985). The Dutch researchers investigated teacher behaviour in classrooms from a systems perspective, adapting a theory on communication processes developed by Watzlawick, Beavin and Jackson (1967). Within the systems perspective on communication, it is assumed that the behaviours of participants influence each other mutually. The behaviour of the teacher is influenced by the behaviour of the students and in turn influences student behaviour. Circular communication processes develop which not only consist of behaviour, but determine behaviour as well.

With the systems perspective in mind, Wubbels, Créton and Hooymayers (1985) developed a model to map interpersonal teacher behaviour extrapolated from the work of Leary (1957). In the adaptation of the Leary model, teacher behaviour is mapped with a Proximity dimension (Cooperation, C - Opposition, O) and an Influence dimension (Dominance, D, - Submission, S) to form eight sectors, each describing different behaviour aspects: Leadership, Helping/Friendly, Understanding, Student Responsibility and Freedom, Uncertain, Dissatisfied, Admonishing and Strict behaviour. Figure 1 displays typical behaviours for each sector. The Questionnaire on Teacher Interaction (QTI) is based on this model.

Examples of items are "This teacher is friendly" (Helping/Friendly) and "This teacher gets angry unexpectedly" (Admonishing). The scores for each item within the same sector are added to obtain a total scale score. The higher the scale score, the more a teacher shows behaviours from that sector. Scale scores can be obtained for individual students, or can be combined to form the mean of all students in a class. An economical short 48-item version of the QTI was developed in Australia and containing six items for each sector of the model depicted in Figure 1.

The QTI has been shown to be a valid and reliable instrument (Wubbels & Levy, 1993). For example, the Australian version of the QTI was used with a sample of 792 grade 11 students and their 46 teachers, and the Cronbach alpha coefficients for QTI scales ranged from 0.80 to 0.95 for students and from 0.60 to 0.82 for teachers (Fisher, D., Henderson, D., & Fraser, B., 1995). This indicates that each QTI scale displays satisfactory internal consistency for scales containing only six items each. As with other classroom environment questionnaires, the QTI can be used in a preferred form where students respond in terms of what ideally they would prefer their class to be like rather than what it is actually like. The preferred or ideal form of the QTI was used in this study.
Figure 1. The model for interpersonal teacher behaviour

Methodology

The study reported here, is concerned with the culturally sensitive learning environments of secondary school students and how the cultural and contextual factors interact with what students would prefer the teacher-student interactions to be. The underlying premise of this research is that if we can identify the culturally sensitive learning environments of multicultural students in a given classroom then it follows that we have an opportunity to optimise the teaching strategies to be utilised with them. Specifically, the research seeks to determine students' culturally sensitive learning environments; students' preferred student-teacher interpersonal behaviours and then examine the relationship between students' culturally sensitive learning environments, and their preferred student-teacher interpersonal behaviours. Therefore, the two research tasks were to: develop the CLEQ and determine its reliability and validity; and investigate any differences between students' culturally sensitive learning environments, their attitudes and enquiry skills. This paper only reports the development and validation of the CLEQ.

The study involved a survey of 1834 science students in 95 classes in 34 secondary schools. The CLEQ contained 40 items which had been construct and content validated by teachers, students and fellow researchers. Each scale contained five items. Each item was responded to on a five-point scale with the extreme alternatives of Disagree - Agree. Table 1 clarified the meanings of each of the eight scales by providing a scale description and a sample item. Students were asked to indicate to what extent they preferred the stated description.
Table 2.

Factor loadings for items in 40-item version of personal form for the individual student as the unit of analysis

<table>
<thead>
<tr>
<th>Scale</th>
<th>Item No</th>
<th>Role Differentiation</th>
<th>Collaboration</th>
<th>Teacher Authority</th>
<th>Competition</th>
<th>Risk Involvement</th>
<th>Modelling</th>
<th>Congruence</th>
<th>Communication</th>
</tr>
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</tbody>
</table>

Factor Loadings smaller than 0.3 have been omitted.

Results

Factor Analyses

The first stage in the refinement and validation of the preferred form of the CLEQ involved a series of factor analyses the purpose of which was to examine the internal structure of the set of 40 items. Using
SPSS, principal components analysis with varimax rotation was used to generate orthogonal factors. Since the instrument was designed with eight scales, a eight-factor solution was considered.

Table 2 shows the factor loadings obtained for 1,834 school students in 95 classes in 34 schools. The results in Table 2 were obtained using the individual student as the unit of analysis. The percentage variance extracted and eigenvalue associated with each factor also are recorded at the bottom of each scale. The only factor loadings included in this table are those greater than or equal to the conventionally accepted value of 0.30. Factor analyses supported the 40-item 8-scale version of CLEQ.

Instrument Reliability

The first research question explored involved the reliability and validity of the CLEQ instrument. The CLEQ data were subjected to item analysis and the internal consistency/reliability (Cronbach alpha reliability coefficient) and discriminant validity (mean correlation with other scales) are shown in Table 3. The table shows that for the sample of students the alpha coefficients ranged from 0.67 to 0.85. The reliability data suggest that each CLEQ scale has acceptable reliability, especially for scales containing a relatively small number of items. The mean correlation of a scale with other scales was used as a convenient measure of the discriminant validity of the CLEQ. The mean correlations ranged from 0.08 to 0.22 indicating that the CLEQ measures distinct (although somewhat overlapping) aspects of the cultural learning environment. The conceptual distinctions among the scales are justified by the factor analysis and discriminant validity.

Table 3.
Mean, item mean, cronbach alpha reliability and discriminant validity (mean correlation with other scales) for each scale of the CLEQ.

<table>
<thead>
<tr>
<th>Scale</th>
<th>No of Items</th>
<th>Alpha Reliability</th>
<th>Mean Correlation with Other Scales</th>
<th>Scale Mean</th>
<th>Item</th>
<th>ANOVA Results</th>
<th>Eta²</th>
</tr>
</thead>
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<tr>
<td>Role Differentiation</td>
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<td>.81</td>
<td>.14</td>
<td>3.56</td>
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<td>.14</td>
<td>3.12</td>
<td>.08</td>
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<td>.08</td>
<td>2.00</td>
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<td>Teacher Authority</td>
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<td>.76</td>
<td>.17</td>
<td>2.00</td>
<td>.12</td>
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<td></td>
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<tr>
<td>Modelling</td>
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<td>.15</td>
<td>2.08</td>
<td>.09</td>
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<tr>
<td>Congruence</td>
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<td>.22</td>
<td>2.44</td>
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<tr>
<td>Communication</td>
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<td>.79</td>
<td>.22</td>
<td>2.72</td>
<td>.13</td>
<td></td>
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</tbody>
</table>

Although it was felt that detailed examination of the class as a unit of analysis was generally not meaningful, the possibility that the CLEQ was capable of differentiating between the perceptions of students in different classrooms was investigated. That is, does the mean within-class perceptions vary from classroom to classroom? This characteristic was explored for each scale with the 1,834 students in 95 secondary classrooms using one-way ANOVA, with class membership as the main effect and using the
individual student as the unit of analysis. The results of these analyses reported in Table 3 indicate that each scale differentiated significantly \((p<0.001)\) between classrooms. The \(\eta^2\) statistic, represents the amount of variance in the learning environment scores accounted for by class membership, ranged from 0.08 to 0.15.

**Outcomes**

Past environment research has often investigated associations between student outcomes and the nature of the classroom environment (Fraser, 1994). In order to permit examination of the predictive validity (i.e., the ability to predict student outcomes) of the perceived version of CLEQ, students completed a simple Likert-type questionnaire which assessed students' attitude towards science. Simple correlational analyses were used in examining the degree of association between students' perceptions of a culturally sensitive learning environment and attitudes. Overall, the dimensions of CLEQ were found to be related to students' attitudes. In particular, more favourable student attitudes were found with students who perceived less Role Differentiation \((p<0.01)\), Collaboration \((p<0.01)\), Teacher Authority \((p<0.05)\), Competition \((p<0.01)\), Risk Involvement \((p<0.01)\), Congruence \((p<0.01)\), and Communication \((p<0.01)\).

**Table 4**

*Student outcomes - simple and multiple correlation between attitudes and CLEQ scales*

<table>
<thead>
<tr>
<th>CLEQ Scale</th>
<th>Simple Correlation ((r))</th>
<th>Standardised Regression Weight ((\beta))</th>
</tr>
</thead>
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<td>Role Differentiation</td>
<td>0.26*</td>
<td>0.12*</td>
</tr>
<tr>
<td>Collaboration</td>
<td>0.10*</td>
<td>0.64</td>
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<tr>
<td>Teacher Authority</td>
<td>0.06**</td>
<td>0.69</td>
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<tr>
<td>Competition</td>
<td>0.18*</td>
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<td>Risk Involvement</td>
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<td>Modelling</td>
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<tr>
<td>Multiple Correlation</td>
<td></td>
<td>0.43*</td>
</tr>
</tbody>
</table>

* Sample Size = 1834

These associations were further investigated using multiple regression. The multiple regression results were obtained when the whole set of eight learning environment predictors was separately regressed on attitudes and enquiry skills. Beta weights and significance levels from \(t\) tests are reported. Table 4 also includes the simple correlation \((r)\) between the attitudinal outcome and the input variables and the standardised regression coefficient \((\beta)\) for each CLEQ scale. The magnitude and statistical significance of the regression coefficient provides a measure of the association between the outcomes and input variable when scores on the other input variables are held constant. It should be noted that there was a high degree of congruence between the results of simple correlation and multiple regression analyses.
Discussion

This article has described the development and validation of a questionnaire, (CLEQ) which assesses eight scales of the culturally sensitive learning environments of secondary school students. This exploratory study examined, in multicultural classrooms, relationships between secondary science students' perceptions of their attitudes towards science and their perceived culturally sensitive learning environments. Some might question how we can translate the results of such research into practical teaching strategies which are sensitive to the great diversity of preferred student culturally sensitive learning environments. However, the underlying premise of this research is that if we can identify the culturally sensitive learning environments of our secondary students in a given classroom then it follows that we have an opportunity to optimise the teaching strategies to be aligned with these cultural dimensions. It must not be assumed that we are arguing that only these preferred interactions must be utilized but rather teachers need to consider how different learning conditions are utilised given students' preferences for learning environments. This however poses a fundamental problem. What can the teacher do to utilise this important new information given the limited time available to teach a possibly already well defined syllabus?

First, the teacher can utilise this new information to better match the teaching strategies they select for that class with the preferred learning environments of their students. In practice, this would mean that the teacher, acting in the role of a secondary school-based curriculum developer, can select a balanced set of strategies and instructional approaches appropriate to the profile that has been determined by actual class measurement. It is assumed that these alternative approaches would be readily available to the teacher.

Second, in an era of democratic classroom decision-making, a number of important implications concerning student involvement in the learning process need to be noted:

- The students may be given more opportunity to choose the approach that best suits their individual interests and needs. That is, the teacher offers students alternative learning pathways in the form of a number of flexible learning approaches.
- The student is then able to choose the approach and format that meets their personal preference. Especially in those courses which have multiple groups, each group can utilise a learning approach that is more applicable to the many varied preferred learning styles of the subgroups. For example, one group may focus on a highly structured approach while another group may utilise constructivist approaches to learning.
- This approach that utilises a mix of different methods, not only negates some of the constraints that affect the selection of learning activities, but also provides the possibility of optimising the secondary school students' learning capabilities by the provision of a more culturally acceptable teaching approach.
- This information can provide the teacher about the appropriate mix of lecturing and tutorial methods that should be utilised throughout the course.
- In an era of multi-media and flexible approaches to learning, this may well be one way in which we can design more effective classroom environments for our students.

Finally,
Recognition of the existence of preferred learning styles leads to a notion of extending choice of learning method to the learner. The introduction of a modular approach to course organization opens up the possibility of extending choice of content to the learner (Hodson, 1993, p695).

Teachers can utilize this new information to better match the teaching strategies they select for that class with the cultural expectations of their students. In practice, this would mean that the teacher, acting in the role of a school-based manager of learning, can select a balanced set of strategies and instructional approaches appropriate to the profile that has been determined by the teacher.

References


