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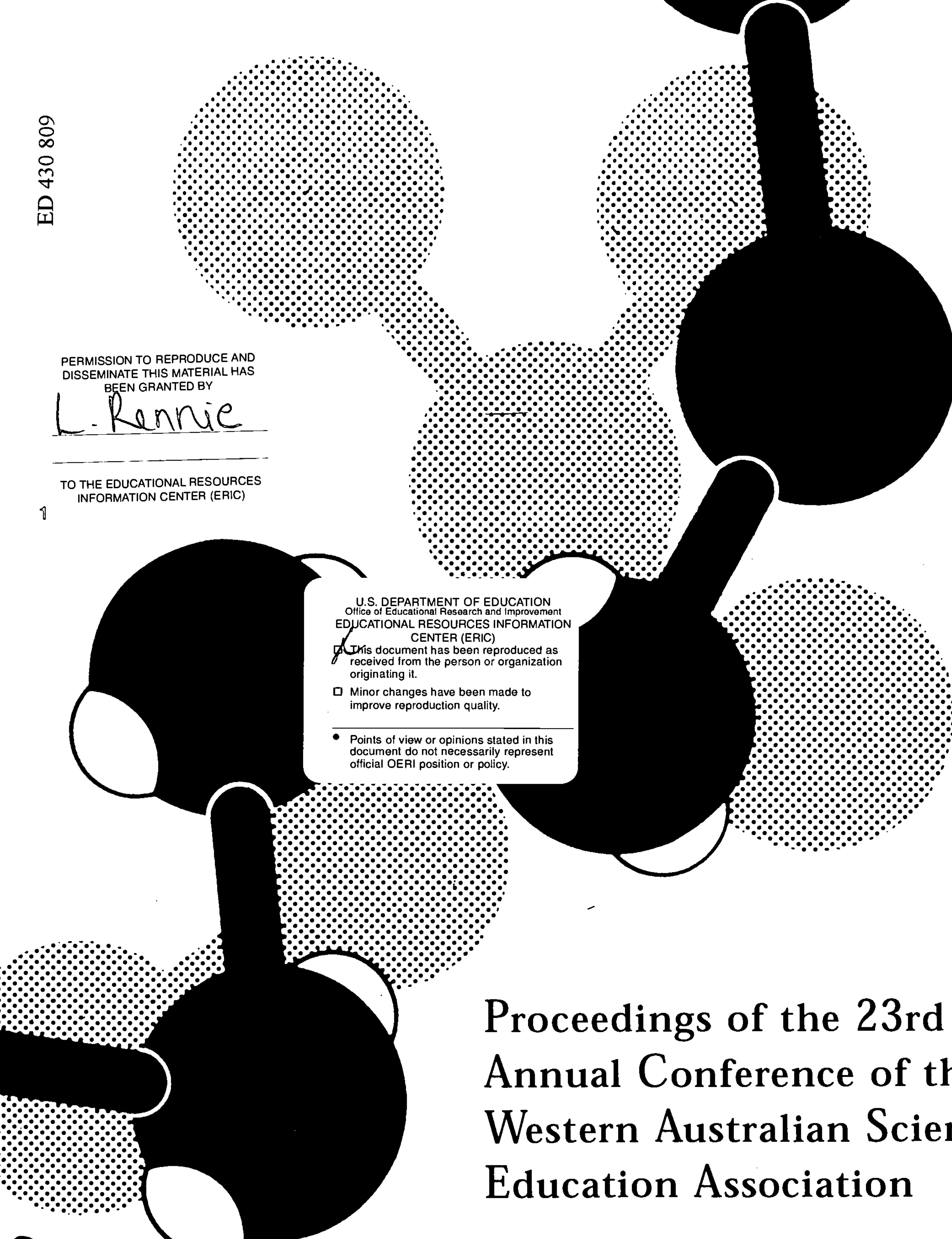
ABSTRACT

These proceedings contain reviewed and edited papers from the 23rd annual meeting of the Western Australian Science Education Association (WASEA). Papers include: (1) Using Quantitative and Qualitative Approaches to Validate a Questionnaire to Describe Science Teacher Behavior in Taiwan and Australia (Darrell Fisher, David Henderson, and Hsiao-Ching She); (2) Symposium: Approaches for Teaching Large Science Classes in Developing Countries--(i) How Introductory Chemistry is Taught at College Level in the Philippines (Marilou Gallos), (ii) Science Teaching Approach in Indonesia (Bambang Irianto), (iii) Saturday Science Classes in South Africa (L. Thapelo Mamiala); (3) New Challenges for Teaching Primary Science Curriculum Units to Undergraduate Students (Barbara Groombridge); (4) Making Judgments about Students' Science Work--Teacher's Concepts and How They Help and Hinder (Ruth Hickey); (5) Postgraduate Courses on the WWW: Teaching the Teachers and Educating the Lecturers (Stephen Kessell); (6) A Constructivist Multimedia Learning Environment: Learning Opportunities for Teachers (Dorit Maor); (7) Hierarchical Integration Cognitive and Affective Objectives in the Instructional Sequence of an Interactive Exhibit (Terence P. McClafferty); (8) An Investigation of Teacher-Student Interactions in Science Classrooms: Using Qualitative and Quantitative Methods (Tony Rickards and Darrell Fisher); (9) How Do We Encourage Higher Level Thinking in Students? (Renato Schibeci, Ruth Hickey, and Wendy Speering); (10) Learning Science through Design and Technology: A Case Study of an Interdisciplinary Approach (Grady Venville, John Wallace, Leonie Rennie, and John Malone); and (11) Learning with Freebody (Registered Trademark): Importance of Student Collaboration (Shelly Yeo, Robert Loss, Marjan Zadnik, and David Treagust). (WRM)



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Preface

The Western Australian Science Education Association (WASEA) is an informal group of science educators that meets annually for a conference at one of the Perth universities. The conference is organised by a committee of representatives from the universities and has contributed greatly to collegiality amongst the community of science educators in Perth.

The first meeting of WASEA was held at the Churchlands College of Advanced Education in 1975 and has been held each year except in 1979 and 1991 when the WASEA meeting was incorporated into the meeting of the Australian (now Australasian) Science Education Research Association.

These Proceedings comprise reviewed and edited papers from the 23rd meeting held in 1998*.

This collection of papers has been made available internationally through the Educational Resource Information Centre (ERIC). Enjoy them.

Léonie J. Rennie
Editor

* Pamala Leishnam is thanked for her assistance in organising the conference and coordinating the reviewing process, and Joan Gribble is thanked for her assistance in reviewing the final manuscript.

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Proceedings of the 23rd Annual Conference of the Western Australian Science Education Association

Using Quantitative and Qualitative Approaches to Validate a Questionnaire to Describe Science Teacher Behaviour in Taiwan and Australia

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Abstract

Teachers contribute enormously to a positive social climate in science classes, particularly through their communication with students. This presentation describes the development and validation of a questionnaire which assesses student perceptions of the following five important teacher behaviours: Challenging, Encouragement and Praise, Non-verbal Support, Understanding and Friendly, and Controlling. The questionnaire was administered to 1202 students from 30 classes in Taiwan and to 307 students from 13 classes in Australia. The reliability, factorial validity and discriminant validity of the questionnaire and its ability to differentiate between the perceptions of students in different classes were found to be satisfactory for both the Australian and Taiwan data. To further validate the questionnaire a qualitative approach was used where students were interviewed (two from each of five classes) in both Taiwan and Australia. The interview questions focused on these students' responses to selected questionnaire items, and the responses of students provided verification of the construct and content validity of the scales. Statistically significant correlations were found between students' perceptions of their teacher's behaviour and students' attitudes to their class for four of the five scales of the questionnaire, namely Challenging, Encouragement and Praise, Non-verbal Support, and Understanding and Friendly behaviours.

Introduction

This paper describes the development and validation of an instrument which assesses students' perceptions of their teacher's behaviour in the classroom environment. Both quantitative and qualitative methods have been used in the validation of the questionnaire. Data were gathered from a sample of Taiwanese and Australian students in science classrooms. In keeping with traditional approaches in classroom environment research, factor analyses, internal consistency, discriminant validity and the ability to differentiate between classes were used in a quantitative validation of the questionnaire. To further validate the questionnaire and explain the perceptions of students from the two countries, a qualitative approach was used involving the interviewing of students about their responses to the questionnaire.

Background

Past research has confirmed the important contribution made by teachers in creating a classroom environment or atmosphere conducive to science learning. Teachers

make a major contribution towards creating a positive learning environment in science classes, particularly through their interaction or communication with students (Wubbels & Levy, 1993). The way in which a teacher interacts with students is not only a predictor of student achievement, but also is related to such factors as teacher job satisfaction, teacher burnout. preventing discipline problems and fostering professional development (Wubbels & Levy, 1993).

Interactions occur rapidly in a classroom and teachers are usually not aware, or not able to describe or remember what happens in their interactions with students. For example, Good and Brophy (1974) interviewed teachers and confirmed that teachers usually were not aware how many questions they asked students and what kind of feedback they provided. Cuban (1984) found that the basic structure of classrooms (heavy reliance on teacher-student recitation) has remained unaltered for decades. Good and Brophy (1991) indicated that teachers in secondary schools may have interactions with 150 different students a day. Unless we can help teachers identify their own behaviours in teaching, and make them aware of what happens in class, it is difficult to promote positive science classroom environments.

Three common approaches to studying teachers and their classrooms involve systematic observation, descriptive case studies, and using student and teacher perceptions. Systematic observation and case studies have been used frequently in the past, however, perceptual measures now are used often, particularly when investigating a large sample of classes.

It is possible to ask teachers for their perceptions of their classrooms, however these usually differ in some respects from those of students (Cooper & Good, 1983; Fraser, 1998a; Wubbels & Levy, 1993). In this study, it was decided to focus on student perceptions. Therefore, the purpose of this study was to establish a questionnaire which would allow a study of student perceptions of teacher behaviour in a large number of science classes at the same time. In the longer term, it is hoped to develop a better understanding of teacher behaviour occurring in science classrooms in both Taiwan and Australia.

Until about 20 years ago, research involving science students' outcomes focussed primarily on educational objectives in the cognitive domain but, in more recent times, attention has been paid to outcomes in the affective domain; the study of student attitudes has formed a primary component of this research (Weinburgh, 1995). Shulman and Tamir (1972) suggested that affective outcomes of education are at least as important as cognitive outcomes and acknowledgement of the importance of affective outcomes is reflected in their increasing emphasis in curricula (Gardner & Gauld, 1990; Hough & Piper, 1982; Mathews, 1974).

Because of the importance of students' affective outcomes in education, and the fact that past studies frequently have reported statistically significant associations between students' perceptions of their learning environment and their affective learning outcomes (Fraser, 1998b), it was decided to examine associations between students' perceptions of their teachers' behaviour, and students' attitude to their class.

Development of the Questionnaire

Researchers in The Netherlands investigated teacher behaviour in a classroom from a systems perspective, where it is assumed that the behaviour of the teacher is influenced by the behaviour of the students and in turn influences the student behaviour. Based on this systems approach, the *Questionnaire on Teacher Interaction* (QTI) (Wubbels, Brekelmans & Hooymayers, 1991; Wubbels & Levy, 1993) was developed. Research with the QTI in The Netherlands, America and Australia clearly indicated that helpful, friendly and understanding teacher behaviour was associated with higher cognitive outcomes scores and positive student attitudes (Fisher, Henderson, & Fraser, 1995; Fisher, Fraser, & Rickards, 1997; Wubbels & Levy, 1993; Wubbels et al., 1991). Furthermore, it was demonstrated in these research studies that the teacher's strict or controlling behaviour was associated with student cognitive gains, although not with their attitudinal gains. It was thus decided to include in the questionnaire one scale to assess student perception of the teacher's understanding and friendly behaviour, and one to assess controlling behaviour.

Other research has shown that two teacher behaviours have had a considerable effect on students' achievement (e.g., Good & Brophy, 1974; Walberg, 1984). According to these research studies, questioning and the teachers' reactions to the students' answers are key factors in the interactions that occur between teachers and their students. Questions have been shown to be an important and integral part of learning, and questions asked by teachers can become indices of the quality of teaching (Carlsen, 1991; Smith, Blakeslee, & Anderson, 1993). Deal and Sterling (1997) suggested that effective classroom questions promote relevance, encourage ownership, help students interpret their observations, and link new learning to what students already know. Systematic classroom observation research in Taiwan involving the use of questioning, verbal reinforcement and non-verbal reinforcement in the teachers' behaviour towards students (She, 1997, 1998; She & Barrow, in press) supported the importance of these three teacher behaviours.

The development of this questionnaire was based on previous studies of teacher-student interactions in science classrooms. The initial version of the questionnaire contained a total of 60 items, with 12 items belonging to each of five scales. Each item is responded to on a five-point scale with the alternatives of almost never, seldom, sometimes, often, and very often. Table 1 contains a description of the meaning of each of the five scales and a sample item for each scale.

Table 1. Description of Scales and a Sample Item for Each Scale of the Questionnaire

Scale Name	Description of Scale	Sample Item
Challenging	Extent to which the teacher uses higher-order questions to challenge students in their learning	This teacher asks questions that require me to apply what I have learned in class in order to answer.
Encouragement and Praise	Extent to which the teacher praises and encourages students	This teacher praises me for asking a good question.
Non-Verbal Support	Extent to which the teacher uses non-verbal communication to interact positively with students.	This teacher smiles at me to show support while I am trying to solve a problem.
Understanding and Friendly	Extent to which the teacher is understanding and friendly towards the students	This teacher understands when I doubt something.
Controlling	Extent to which the teacher controls and manages student behaviour in the classroom.	This teacher requires us to be quiet in his/her class.

Items for the questionnaire were written originally in English and then translated into Chinese. A back translation of the Chinese version into English, by people not involved in the original translation, was then completed. This resulted in the modification of both the original English version and the Chinese translation.

Method

The Chinese version of each questionnaire was administered to 1202 students from 30 grades 7–9 science classes in Taiwan and 307 students from 13 grades 7 to 9 classes in Australia. This led to modifications to questionnaire items, and the extensive field testing and instrument validation procedures in both countries, outlined later, led to a final version consisting of 40 items altogether, with eight items in each of the five scales.

Having developed the five scales of the questionnaire, we wanted to determine their practical viability for use with students. We were interested in examining what perceptions students had of the scales and the items. How did they interpret each scale? What did they think an item meant? Were the students viewing the concepts behind each scale in a similar manner to that of the original developers?

In order to help answer these questions a number of students were interviewed. Students were selected according to their responses to the questionnaire. This was particularly important as the quantitative analyses of data suggested that in some classes a diverse range of students' views existed.

Ten students from each country were interviewed for a maximum of 15 minutes in a fully visible position where student confidentiality could be assured, for example, in an interview or counselling room, an open classroom, on school playground seating, or library annexe. After assuring them of the confidentiality of their responses, their approval for audio-recording was obtained. A semi-structured interview was used during which students were asked firstly to comment generally about the questionnaire. Secondly, the interview focused on the particular constructs assessed by the scales in the new questionnaire. Thirdly, it focused on their responses to individual items in those scales.

Students' attitudes to their class were assessed with a seven-item *Attitude to This Class* scale based on selected items from the *Test of Science-Related Attitudes* [TOSRA] (Fraser, 1981). This scale has been used in several previous studies involving students in science classes and has been shown to have satisfactory internal consistency (e.g., Fisher, Fraser, & Rickards, 1997; Henderson, Fisher, & Fraser, 1998).

Quantitative Analysis: Validation of the Questionnaire

Cross-national validation of the questionnaire involved a series of factor analyses to examine further the internal structure of the set of 60 items in the questionnaire. Principal components analysis with varimax rotation was used to generate orthogonal factors. These factor analyses, which were completed separately in each country, led to a decision to delete 20 items, either because they were loaded on more than one factor, or that their loading was lower than 0.31. The 40-item instrument, with 8 items in each of the 5 scales, was decided upon as the optimal structure for the final version of the questionnaire.

Estimates of the internal consistency of the five scales of the questionnaire, calculated using Cronbach's alpha coefficient and shown in Table 2, were found to be generally satisfactory for both the Australian and Taiwanese data. The alpha reliability coefficient for each scale, using the individual student as the unit of analysis, ranged between 0.86 and 0.93 in Australia and between 0.86 and 0.93 in Taiwan.

The mean correlation of a scale with other scales was used as a convenient measure of the discriminant validity of the questionnaire. The figures, reported in Table 2, show

that mean correlations ranged from 0.06 to 0.45 for the Australian sample, and from 0.16 to 0.50 for the Taiwanese sample. These figures indicate that the instrument measures distinct (although somewhat overlapping) aspects of teacher interpersonal behaviour.

Table 2. Internal Consistency (Cronbach Alpha Coefficient), Discriminant Validity (Mean Correlation with other Scales) and Ability to Differentiate Between Classrooms for the Questionnaire

Scale	Alpha Reliability		Mean Correlation with Other Scales		ANOVA Results (eta^2)	
	Aust	Taiwan	Aust	Taiwan	Aust	Taiwan
Challenging	0.86	0.88	0.37	0.40	0.15*	0.20*
Encouragement & Praise	0.87	0.90	0.45	0.50	0.17*	0.26*
Non-Verbal Support	0.91	0.93	0.44	0.50	0.22*	0.32*
Understanding & Friendly	0.93	0.91	0.40	0.46	0.15*	0.21*
Controlling	0.86	0.86	0.06	0.16	0.13*	0.65*

Taiwan, n= 1202; Australia, n=307.

The ability of a classroom environment instrument to differentiate between classes is important. Students within a class usually view the classroom learning environment similarly, but differently from students in other classes. The instrument's ability to differentiate in this way was measured using one-way analysis of variance (ANOVA) with class membership as the main effect. The results, depicted in Table 2, show that each of the scales did in fact significantly differentiate between classes ($p<0.001$). The amount of variance explained by class membership is reflected in the eta^2 scores which ranged from 0.13 to 0.22 in the Australian sample and from 0.21 to 0.65 in the Taiwanese sample.

Qualitative Analysis: Student Interviews

Ten students from each country were interviewed for a maximum of 15 minutes. Initially, students were asked whether they could tell us what the questionnaire was about. Among student comments were the following:

Yes they were about like the teacher's methods and how the teacher gets things through.

Well it's about the classroom teacher and how you feel in the class. Just trying to work out how the teacher teaches and stuff.

Yes, it was about the teacher and how she teaches.

From the above and other questions that were asked, it was clear to the researchers that the students were able to read the questionnaire and had some idea what it was about.

The questions then became more focused and we referred to student responses to various items to see if the scales were actually assessing what they were supposed to be assessing. We were also seeking questions about why students gave the responses they did. The following student comments from both countries supported the content and construct validity of the scales of the questionnaire.

Challenging

Could you see what this section was about?

About questions and how the teacher approaches us and asks us questions.

For most of the items you circled 5, but for number 7 you put 3. Why was that? (7. This teacher asks for my opinions during discussions.)

Because she asks everyone's opinion, not only me.

Again in relation to number 7 another student said

Yes, well we rarely have discussions during science it is just basically, correct answers.

Does your teacher ask questions very often?

Yes, the teacher asks a lot of questions.

What types of questions does your teacher ask?

The teacher asks questions that will make us think a while.

The teacher likes to ask us, "Why would it happen?", types of questions.

The teacher rarely asks us yes or no questions.

Why did you circle always or very often to these items?

Because the teacher always asks a lot of questions to all of us.

Encouragement and Praise

Um, those ones they were like encouraging you to answer questions.

Here's another one with 5 circled, question 14, this teacher praises my answers?

Yes, even though it (the answer) is wrong she just still says good attempt.

And here's a 5 here at number 12, the teacher does that a lot does she?

(This teacher praises me for asking a good question.)

Yes and it really boosts your confidence as well.

Yes, it's a good thing to do?

Yes. It is. And even if you don't get the answer right, they say yeah, like they know it's wrong but they like go on to correct it as well.

Does your teacher criticise you if you do not know the answer? (Asked to a student who circled never happens for this item)

The teacher will not criticise students if they do not know the answer, the teacher only asks them to sit down and asks other students to answer.

Non-verbal Support

Alright. This next group of questions here are about the teacher moving around the classroom and so on and moving closer to you when talking with you. This one here number 20, you said 2 for that one?

Sometimes she normally yes, if she is up the front if you ask a question she will just stay there and answer it most of the time but if she is near our desk yes she will just stay there.

Does your teacher use some other ways to help you answer questions?

The teacher usually will nod her head or smile to us.

(29. This teacher smiles at me to show support while I am trying to solve a problem.)

Why did you circle 5?

Always, while we have problems during the laboratory sessions or when we are trying to solve problems, the teacher always smiles to me to show her support.

Understanding and Friendly

The students had little difficulty understanding the nature of the Understanding and Friendly scale and made such comments as

Yes, because everything she says is clear and you can understand it.

Yes there is freedom to ask questions and stuff like and she is clear and explains things.

Yes, she is kind and friendly and not that strict.

Is your teacher friendly to you?

Yes, she is very friendly to us. She usually will not get angry unless we are too noisy.

(41. If I have something to say, this teacher will listen.)

Why did you circle 5?

For instance, we went to National Science Museum and the teacher listened to our talking while on the bus.

Controlling

You say she is not strict with you, how do you understand the word strict?

Like disciplined and very disciplined.

Do you understand what strict used here means?

Strict, isn't it saying, um, like we have to obey her every instruction?

The teacher does not always expect you to do everything she tells you to do. Is that what you are saying here.

Oh, sometimes if it is too hard she will let us not do it and she will explain it to us later. If she sets homework, its alright if we weren't able to do one if we really didn't understand it.

I see so that is a positive thing is it?

Yes.

Application of the Questionnaire

Once the questionnaire had been validated it was then used to examine associations between each of the five scales of the questionnaire and the students' attitudes to their science classes.

In order to investigate associations between students perceptions of learning environment and students' attitudinal outcomes, the data were analysed using simple correlation analyses. Table 4 reports the simple correlation (*r*), which describes the bivariate association between students' attitudinal outcomes and a scale.

Table 3. Associations Between Questionnaire Scales and Students' Attitudinal Outcomes in Terms of Simple Correlations ®

Scale	Strength of Environment-Outcome Association	
	Australia	Taiwan
Challenging	0.22**	0.38**
Encouragement & Praise	0.41**	0.37**
Non-Verbal Support	0.41**	0.38**
Understanding & Friendly	0.64**	0.48**
Controlling	-0.07	-0.06

$^{**}p < 0.001$ Taiwan, n=1202 ; Australia, n=307.

The simple correlation (r) figures reported in Table 3 indicate, for both Australian and Taiwanese data, that there were statistically significant ($p<0.001$) associations between students' attitude to class and four of the scales of the questionnaire, namely, Challenging, Encouragement and Praise, Non-Verbal Support, and Understanding and Friendly Behaviour. That is, students' attitude scores were higher where students perceived their teacher as using more challenging questions, as giving more encouragement and praise and more verbal support and as being more understanding and friendly.

Conclusions

One of this study's major contributions is the development and validation of a new instrument designed to measure science students' perceptions of their teacher's behaviour, although there is no reason why it could not be used in other subject areas. All five scales of the questionnaire were found to display satisfactory internal consistency reliability, discriminant validity, and factor validity. As well, further analyses supported the ability of the questionnaire to differentiate between the perceptions of students in different classrooms. In the validation process the researchers used a combination of quantitative and qualitative analyses. The quantitative data provided numerical descriptions of the reliability and validity of a new questionnaire while the qualitative data assisted in the content and construct validation of the instrument.

The interviews described above provided verification of the content and construct validity of the scales. It was important to examine students' perceptions of items in each scale even though statistical evidence suggests that the scale is valid. Students can interpret items or scales in ways that were not originally intended. Researchers need to examine the extent of this variation and to keep this in mind when describing the results of the questionnaire. Qualitative examination of the questionnaire can produce an 'authenticity' in the data that Guba and Lincoln (1989) state is essential for research results to become meaningful.

Four of the five aspects of science students' perceptions of their teacher's behaviour measured in this study, namely, Challenging, Encouragement and Praise, Non-Verbal Support, and Understanding and Friendly were found to be associated with students' attitudinal outcomes. In other words, in classes where students perceive that their teacher exhibits higher levels of each of these qualities, the students are likely to have more positive attitudes to their science class.

The instrument will continue to be utilised to study science classrooms in both Taiwan and Australia. In the future, the development of a teacher version and a student preferred version of the questionnaire will allow other comparisons to be made. For example, teachers will be able to use this information to promote an atmosphere of positive interaction in their science classrooms and improve student learning.

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Symposium: Approaches for Teaching Large Science Classes in Developing Countries

Abstract

The tendency towards the development or formation of large classes is a process often mitigated by financial constraints. It is a phenomenon that is now becoming apparent in both underdeveloped as well as developed countries. In the presentation we report on the techniques devised to teach science in large classes from the following developing countries:

- Philippines: How 'Introductory Chemistry' is taught at college level.
- Indonesia: Science teaching approach.
- South Africa: Saturday Science Classes (SSC).

In this presentation we indicate what seems to work when teaching large science classes as well as comment about some of the problems we have encountered.

How Introductory Chemistry is Taught at College Level in the Philippines

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Background Information

The Philippines' educational system requires a Filipino student to have six years in elementary school and four years in secondary school. Students who decide to continue in tertiary education, will be in college for 4 – 5 years. Normally, a first year college student is 17 years old. The first two years in college are spent doing courses preparatory to their chosen field of specialisation. Introductory Chemistry is one of the courses taken by all first year college students.

Every semester, the Chemistry Department of University of San Carlos, Cebu City Philippines, has approximately 1,600 or more student taking the Introductory Chemistry course. Each teacher in this Department is assigned to more or less 420 students split into 4 lecture classes of 55 – 60 students per class and 6 laboratory classes of 28 – 30 students per session.

This paper will focus on how large classes in Introductory Chemistry are conducted at the college level.

Teaching Approaches Used

The usual approach used by all the teachers is the lecture method. Some teachers combine this method with short demonstration activities, problem-solving exercises, showing videotapes, concept mapping and asking questions to initiate group discussions.

To engage students in collaborative learning, a 'starter experiment approach' (SEA) is used as an alternative approach. Table 1 shows the stages of SEA and the tasks assigned to teachers and students. A laboratory technician assists the teacher in the preparation of the apparatus and materials needed during the execution of their plan or performance of the designed experiment. Likewise, the BS Chemistry students conduct tutorials with students having difficulty in the course.

Table 1. The Phases of the Starter Experiment Approach

Phases	Teacher's Tasks	Students' Activities
A. Observation Phase	– Perform a five minute demonstration experiment. – Collects observation cards and group similar observations together. – Repeat the performance of the starter experiment.	– Observe carefully the set-up without talking to peers. – Write observations on a card. – Countercheck the displayed list of observations while the starter experiment is repeated.
B. Explanation Phase	– Request the students to give an explanation for each observation posted. – Collect explanations cards and group together similar explanations. – Divide the class into 10 groups with 6 students in each group.	– Explain each observation based from prior knowledge. – Write each explanation on a card. – Discuss further unclear explanations. – Discuss within the group and choose an explanation to work on.
C. Group Work Phase	– Monitor each group closely. – Provide suggestions on the materials and resources to be used. – Check the plan/design or experiment set-up. – See to it that all members are working.	– Brainstorm ideas from group members. – Come up with a plan, design or controlled experiment to prove the given explanation. – Execute the planning experiment or activity. – Observe and record data. – Interpret and annualise results. – Discuss among members the concepts developed from this experience.
D. Reporting Phase	– Discuss the mechanics for reporting or presentation. – Make comments for further improvements. – Assess and give feedback to each group.	– Demonstrate their designed activity or experiment in class. – Discuss results, interpretation and analysis. – Cite the chemistry concepts learned in the activity. – Report any good and weak points in their plan/design or experiment set-up. – Criticise other groups' work and make suggestions for improvement.

It should be noted that in the SEA, students are encouraged to teach each other, be responsible for learning the materials, and most of all, are involved in the group task to generate an answer that expresses the team's conceptual understanding in introductory chemistry. Dr. Ed van den Berg has stated:

> The most crucial elements in large group teaching are: (1) getting students to work and (2) organising a feedback system so that students can check for themselves they understand and what they don't understand.

Implementing these elements requires frequent interaction between teachers and students. The starter experiment approach has all the elements required and is one answer to creating collaborative learning even in a large class of introductory chemistry.

Science Teaching Approach in Indonesia

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Introduction

For almost two decades, the Ministry of Education and Culture (MOEC) of the Republic of Indonesia has implemented staff development programmes for secondary school science teachers. One popular in-service teacher training project is called Pemantapan Kerja Guru (PKG). Development of PKG began at the end of 1979. Since then, its development sometimes slowed by the lack of funds from the central government. Nevertheless, the project has contributed some changes to the science teaching approach in Indonesia. The project finished in March 1997.

Background about Indonesian Education

Indonesia, with its thousands of islands, has more than 202 million people. Under MOEC, there are 20,515 Junior High Schools or Sekolah Lanjutan Tingkat Pertama (SLTP). Of these, 9,841 are public schools, of which 7,463 have been equipped with science laboratory. There are 8,059 Senior High Schools or Sekolah Menengah Umum (SMU). Of these, 2,722 are public schools, of which 2,084 have been equipped with science laboratories (Dikmenum, 1998a, 1998b). The public SLTP's have 27,389 science teachers, while public SMU's have 19,576 science teachers (6,752 biology, 6,137 physics and 6,511 chemistry) (Statistic Dikmenum 1995/1996). These teachers teach approximately 30 - 45 teaching-periods a week without any assistance from a laboratory technician, unless the parents' association funds can provide for it.

The number of SLTP students is 4,262,453, grouped into 101,484 classes with 87,518 classrooms available; SMU students number 1,361,002, grouped into 34,509 classes, with 29,927 classrooms available (Dikmenum, 1996). It means that some schools operate a morning shift from 7.00 am to 12.30 pm and an afternoon shift from 12.30 to 6.00 pm. There are high numbers of students in each class (40-48).

Current Teaching Approach of Non-PKG Teachers

Current Science Teaching Approach of non-PKG Teachers

The non-PKG teachers implement a teaching approach which is more teacher-centred than student-centred. The approach focuses on teaching content because of teachers believe that their role is to deliver content. The most important objectives are to

achieve curriculum targets, have students pass the final national examination, and have as many students as possible pass the university entrance test. Most teachers do not know whether or not students understand what they are learning about science.

Based on the science teachers' beliefs, the way they teach could be described as follows.

a. Preparation stage.

In this stage a science teacher writes a semester plan allocating time for each topic which will be taught and lesson plan for each topic. At this stage teachers never analyse the depth of the subject content which will be taught. (This does not apply with the PKG teachers group.)

b. Teaching stage.

During this stage the teacher tells students about: the topic, definitions, formulas and other relevant information. After that, the teacher gives an example of how to solve a problem (if necessary), gives some problems for home work, and discusses students' work from previous classes (if time is available). Teachers seldom interact with students during the teaching and learning process. In fact, students are expected to sit quietly, listen to the teacher, take notes, and solve given problems. There is very little activity which involves student group discussion. Most teachers prefer it when students don't ask too many questions. Teachers seldom give an opportunity to students to provide their opinion or examine an argument in a class discussion. Students rarely explore or investigate information. One of the reasons is the time constraint placed on teachers.

c. Evaluation stage.

During this stage the teacher asks students to do a test at the end of each topic and at the end of semester as a summative evaluation. The questions in the test mostly measure students' content knowledge rather than skills. The test consists of more recall questions rather than analytical or evaluative questions. It is not known whether the questions used have suitable reliability and validity or not. In this evaluation stage, it has never been analysed which students need remedial teaching. Time constraints are a factor in this situation. PKG trainers realised from their first visit at every PKG participant school, that most science laboratories were not used effectively. This condition indicated that the science laboratory was not a popular teaching tool among science teachers.

The kind of teaching approach chosen by the non-PKG science teachers' group is for several reasons. They have certain beliefs about how science should be taught, they are constrained by high enrolments in their classes, and they face several different class groups each day. They have small budgets for experimental materials and limited laboratory

equipment. In the face of these difficulties, their salary is low when compared with other professions.

Current Science Teaching Approach of PKG Teachers

One of the PKG's objectives is to encourage teachers to become used to the experimental approach to teaching science (mixing lectures with laboratory experiments, switching from deductive methods to a blend of deductive and inductive approaches). Another PKG objective is to enable teachers to change their role in the classroom to allow students' active participation. Below is a sequence of laboratory work when students carry out an experiment. This activity is an example of some activities which are introduced by PKG.

a. Pre-laboratory discussion.
   In this part of the lesson the teacher asks some questions to determine what is in the students' knowledge about a particular topic. From the answers, the teacher encourages the students to further define the problem which could be solved by an experiment, guided by students' work sheets, or Lembar Kerja Siswa (LKS). In addition, the teacher introduces new material and equipment.
b. Carry out an experiment.
   Students set up the equipment according to the worksheet, collect data by measurement and/or observation, record data, interpret data, and draw conclusions. During this stage students work in groups.
c. Post laboratory discussion.
   In this stage the teacher leads the class discussions toward solving the problems experienced and distinguishes between pre-conceived ideas and new ideas derived from the experiment outcomes.

Irianto and Treagust (1989) realised that PKG participants are faced with several difficulties to implement the teaching approach introduced, such as the number of laboratories available for groups of 10 – 12 students. Therefore, PKG instructors found that some science teachers prefer to demonstrate an experiment rather than have students conduct the experiment.

The three stages in the science teaching approach introduced by PKG project mentioned above is the implementation of Ausubel's idea of meaningful verbal learning. Principally, the theory says that a concept acquires psychological (or 'real') meaning when it relates to an idea that is already present in the learner's mind. Moreover, the PKG objective to enable teachers to change their role in the classroom, to allow students' active participation, is parallel with the idea of student centred teaching (Combs, 1965; Irianto, 1989; Maslow, 1970; Roger, 1969) which is an instructional implication of humanistic

theory. These authors argue that teachers should be learning facilitators rather than didactic instructors (Lafrancois, 1988 in Irianto, 1989, p. 11).

The PKG advised a teaching approach from the lecture method to more student experimentation, or teacher demonstration, or discussion. The PKG approach of teaching is in tune with the idea of student-centred learning. These approaches are also parallel with Bruner's discovery learning. In principle, the theory says that learning takes place when students are not presented with subject matter in its final form but rather they are required to organise knowledge for themselves.

The three stages in the approach are also the implementation of theory of learning called 'constructivistic learning'. For example, the first stage is similar to the 'elicitation' stage (Driver & Scott, 1996, p. 99). In addition, Wittrock (1974 in Irianto, 1989, p. 12) points out that this view of learning considers students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Learning science therefore, involves students in not only adopting new ideas, but also in modifying or abandoning their pre-existing ones (Scott, Dyson, & Gater, 1987 in Irianto, 1989, p. 13).

During the second stage of the lesson, the students work co-operatively with their group members. This activity introduced by PKG is parallel to the idea of co-operative learning (Johnson & Johnson, 1975, in Irianto, 1989, p. 13). In addition, this part of the lesson corresponds with one of the stages of constructivistic learning theory Wittrock, 1974, as mentioned by Scott, Dyson, & Gater, 1987 in (Irianto, 1989, p. 13). This activity is also a medium for students either to practice or to implement one of the Indonesian National Values of Gotong Royong (or working co-operatively).

However, there is a question. How successful was the PKG project in changing science teaching approaches, and students' understanding? There were several evaluation studies. PKG has been able to establish an extensive network of trainers and has overcome the logistical obstacle associated with operating in a developing country that is geographically and culturally diverse (Thair, 1996). A formative evaluation of PKG indicates that the training has developed knowledge and teaching skills for most teachers involved in the in-service (Eggleston, 1984). A survey conducted by Irianto (1989) concluded that science trained teachers (more than 50%) experienced at least nine kinds of problems during implementation of teaching approaches introduced by PKG. An evaluation of PKG trainers with Master's degree qualifications showed that there were very positive attitudes among students and teachers concerning the PKG project and that teaching practice was a major factor in student achievement (Thair, 1996). Another study on the PKG Project concluded that the strength of this training is due to the in-service training being followed by on-service training at the participants' schools (Sujanto, 1996). On the other hand, a study involving PKG trainees indicated that the PKG training had

developed the knowledge and teaching skills of most trainees but had not improved students' outcomes (Hasan, 1995). These findings indicate that students learn science inadequately.

Conclusion

Basically, the objectives of the PKG project are parallel with the constructivist concept of teaching. Nevertheless, MOEC is still facing two basic problems in science teaching. First, how can the teaching approach of science teachers of the non-PKG group be changed? Second, why has there been no improvement in students' science understandings when they have been in classes conducted by science teachers of the PKG group?

If Indonesian teacher educators stand on the constructivist learning concept, there are two strong recommendations that are made. First, the teaching approach implemented by non-PKG teachers group must be changed. Second, the approach used in inservice teacher training must be analysed to find whether constructivist perspectives have been applied to science teacher education.

Since the background conditions can not easily be changed, science educators are expected to conduct some research to develop teaching approaches suitable for the particular context in Indonesia.

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Saturday Science Classes in South Africa

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Introduction

South Africa is implementing a new curriculum known as Curriculum 2005 with effect from 1998. According to the Discussion Document (Department of Education, 1997a, 1997b), outcomes based education (OBE) will be used as an approach for the implementation of this new curriculum.

Science and mathematics at a secondary level have a poor image among students and only a few students venture to choose them. Students perceive science and mathematics as 'killer subjects' as a result of high failure rate. Poor performance of students may be partly attributed to the lack of facilities and to overloaded teachers who are supposed to each other subjects as well as science.

With reference to the schools in historically disadvantaged communities, the class sizes at the lower standards, Year 8 – 9, where science is still compulsory, are high about 60 students per teacher. Students' composition is of mixed abilities and ages. This had been exacerbated by the previous system of education where students who performed poorly had to repeat the class or standard.

As a way to ease the situation and help as many students as possible to grasp the necessary basic concepts in science, most teachers and on voluntary basis, organised what is referred to as Saturday Science Classes (SSC).

I am reporting on one of the SSC projects that has been operating in Pretoria since 1993 to 1995 and in Port Elizabeth in 1996 to 1997.

The initial purpose of the SSC was for remedial work for Year 11 and 12, since they are about to write their final examinations. But as a result of its popularity and effectiveness, teachers decided to try it with lower classes where the class sizes were large. The approach was still to use the senior students as tutors.

Organisation and management of the project took off with minimal problems. Normally the teacher would request the assistance of the senior students to manage the lower classes. For instance, if she is meeting the juniors on Saturday, she will brief the seniors about the topic or concept that is to be discussed, so that they do not encounter problems when they are supposed to help the juniors the following day.

On a Saturday one teacher, with the help of the seniors, is in a position to manage a group of about 350 Year 8 or 9 students. The students are divided into groups of 50 and about five to eight seniors are assigned to each group. Whenever the juniors encounter any

problem in the given task, the seniors will be there to give them the individual attention. In the event that the senior is unable to help the junior, the teacher is then called.

Students, involvement and reaction was good. As a result of the project there has been a high degree of involvement of students in science. More seniors became motivated and confident in their understanding of the subject, this became evident in their performance in their quarterly tests. During the week more juniors were consulting the seniors about specific problems which were not clear during the SSC sessions.

There was a noticeable attitudinal change towards the subject at both senior and junior level. With the juniors there was more communication with the seniors rather than being dependent on the teacher. In the case of the seniors, the pressure of not wishing to be seen as being incapable of handling the 'junior stuff', resulted in them adopting a more responsible positive attitude in their preparations to meet the juniors. Their own subject knowledge also improved.

New Challenges for Teaching Primary Science Curriculum Units to Undergraduate Students

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Abstract

In the past decade, since the Hobart Declaration on Schooling identified science as one of eight key learning areas and the Curriculum Corporation produced a National Science Statement for science across the K-12 year levels, progress in primary science curriculum development has accelerated. In Western Australia, the Curriculum Framework Document, the Science Standards and Outcomes Framework and the Primary Investigations curriculum materials have filled a vacuum in the Primary Science Learning Area. These materials have provided primary teachers with the resources to help students to achieve the goal of science education in becoming 'scientifically literate'. In this paper two issues will be discussed. Firstly, how can science educators assist primary teacher trainees with the challenge of implementing these initiatives at a time of great change for teachers and schools? Secondly, lack of scientific knowledge is often a reason quoted for primary teachers feeling uncomfortable teaching science. How does an outcomes approach focussing on what is being learned rather than what is being taught, affect the notion of scientific knowledge at primary level? What is considered enough knowledge to enable a primary teacher to satisfy the outcomes of the four content strands associated with the Science Learning Area?

Introduction

Science is viewed by our society as a body of knowledge, resulting from centuries of investigations that have resulted in accepted facts, theories and a consensus of ideas about the universe (Fleer & Hardy, 1996). For primary school students, science certainly impacts on their lives in our culture and they need to be aware of the many facets of science which affect them on a daily basis.

> Attitudes to science begin to be formed at a very early age, and in the absence of positive primary science experiences, children could develop negative attitudes towards science. (Fleer & Hardy, 1996, p. 21)

Awareness raising is part of the notion of scientific literacy and it is here that the teaching of primary science can make a difference.

> Effective primary science will facilitate children changing their ideas so that they can make better sense of the way in which their world works. (Skamp, 1998, p. xv)

The notion of scientific literacy

Most people hold negative and contradictory views of science (Feasey, in Skamp, 1998), views which have been formed by their life experiences, their school experiences and the media. Television has made a great contribution to people's impressions of

science. The science programs show science as unique and intriguing, however, the scientists frequently are portrayed as destructive or insane! (Skamp, 1998, p. 31)

> The most pressing imperative is that somehow we reduce the gullibility among the population at large. That a large number of people accept without question, any old codswallop that someone cares to tell them is one of the greatest social problems of our time. (Haigh, quoted in Skamp, 1998, p. 30)

A scientifically literate person would have (according to Feasey & Gott, in Skamp, 1998): firstly, a factual background relating to the understanding of key facts and ideas in science and the ability to apply it to a range of concepts; and secondly, an understanding of evidence and the ability to challenge the reliability and validity of evidence. A good example of this would be the impact of various medical treatments, diets etc., useful for curing diseases that are alleged to be successful. Skamp (1998) suggests that a scientifically literate person would be able to make judgements based on evidence that would affect their life choices.

Constructivist teaching (Ollenrenshaw, et al., 1993) also requires teachers to be able to ask the right question. As Skamp points out, “A scientifically literate person needs to be an effective questioner, someone who can use his or her knowledge and understanding alongside the ability and confidence to ask the right question at the right time” (Skamp, 1998, p. 54). The ability to ask the right questions helps students make the conceptual changes necessary for progress in their learning. The teacher provides the model for children by allowing them to use language and by asking them effective questions. This is part of the process of thinking and working scientifically.

The Past

Many primary teachers, when faced with teaching science compared with any other subject in the primary school curriculum, would rather have opted out of it. They might have tried swapping their class with another teacher or would have found reasons to put the science lessons on the back burner. Primary science was often relegated to the natural history/environmental elements with some work being done in regard to a few popular topics such as magnetism, flight, the planets, keeping mini-beasts and growing seeds. These were the topics with which teachers felt safe! They had large library research components and were often turned into ‘projects’. The physical sciences received very little attention. Scientific inquiry method was not part of the science lesson unless the teacher was a science specialist. This emphasis on teaching topics favoured by the teachers led to a bias in teaching. Research has shown that students received only one hour or less of science teaching at the primary level per week (Fleer & Hardy, 1996).

There has been a change in thinking about the way in which primary students learn science. In the late 60’s, the Nuffield Foundation, a philanthropic organisation that supported educational endeavours in the United Kingdom, promoted the ‘discovery

method' of teaching science, where children 'discovered' science through their immediate environment and objects with which they were familiar. The Nuffield Science programme encouraged children to engage in real experimentation and real discovery. New concepts were developed by immersion in the activity which was organised by the teacher. The children were no longer passive recipients of science facts but were directly involved in the learning process. Unfortunately, in some science classrooms, the 'nature table' or 'science learning area' became a collection of unrelated 'odds and sods' brought in by the children.

Very quickly, however, science became a passive activity. Teacher demonstrations occurred when it became too difficult to allow the children to interact with materials. The science table often had a collection of teacher work-cards with science activities related to a theme or topic and children performed the activity as dictated by the card. This was not scientific inquiry as nothing new emerged. The children were expected to observe, hypothesise, record data and interpret results but the method, results and conclusions were very much prescribed, expected and confirmed. There was definitely an expected result that occurred every time the activity was performed.

Materials were developed and sponsored by many publishers and curriculum development organisations (Schools' Council 5-13 Project) and primary science did receive a lot of publicity as a relevant area of the primary school curriculum.

The Present

During the past decade the problems associated with the teaching of science in primary schools have been widely recognised and are now being addressed. The Hobart Declaration on Schooling (1989) identified science as one of eight key learning areas and closely linked it to technology and their roles in society. In 1994, the Curriculum Corporation produced a statement on science. It was not a syllabus but a guideline to the development of science from K-12. The States in Australia used this statement as a framework for curriculum development, and each interpreted the Statement in a slightly different way.

The *Curriculum Framework*, an initiative of the Western Australian Curriculum Council, identifies common learning outcomes across the eight Learning Areas. It describes itself as "neither a syllabus nor a curriculum but a framework provided so that schools and teachers can develop their own teaching programs according to the needs of their students" (Curriculum Framework, 1998, p. 6). The Curriculum Framework document encompasses all year levels from K-12 and is outcomes based. It is being implemented over the next five years and is mandated to be fully operational in all schools by the year 2004.

Five strands form the basis for the Science Learning Area in the Curriculum Framework. The four content strands are linked to the geology/astronomical sciences,

physics, biology and chemistry traditional divisions of science (respectively, Earth and Beyond, Energy and Change, Life and Living and Natural and Processed Materials). In addition, the "Working Scientifically" strand has five outcomes and all have been identified as relevant to the development of scientific literacy.

The Student Outcomes and Standards Framework is an initiative of the Education Department of Western Australia and sets appropriate levels of outcomes (1-8) which can be achieved by students in each of the Learning Areas. The Science Learning Area Student Outcomes and Standards Framework will provide supporting documentation to the Curriculum Framework.

Primary Investigations is a science learning program devised and promoted by the Australian Academy of Science. These materials were adapted from American curriculum materials and further developed and trialed in Australian primary schools in 1993/4. The materials provide a common primary syllabus for use across Australian schools. Unlike other Key Learning Areas, primary science has depended on the enthusiasm of individual and professional organisations such as Science Teachers' Association of Western Australia (STAWA), Australian Science Teachers Association and teacher training institutions for professional development. Unlike Britain and America, where a lot of research into primary science has been carried out over the past 25 years, funding has been given to provide and develop programs and teacher in-service professional development opportunities. Australian teachers did not have a core syllabus of materials to utilise until the development of Primary Investigations.

The curriculum initiatives have also taken an outcomes approach to learning which focuses on the learning that takes place and not the teaching approach. In other words "identifying what students should achieve and focusing on ensuring that they do achieve" (Curriculum Framework, p.14). This outcomes focus has also led to the development of profiles detailing the outcomes achievable across eight levels for each Learning Area. This is the next big challenge for teachers and schools: to relate the Curriculum Framework and Science Learning Outcomes to the pointers of achievement in the Outcomes and Standards Framework. This document has only just been released to schools after about three years of trialing. There is still much work to be done in the area of recording achievement and the assessment and evaluation process.

These recent initiatives have filled a vacuum in the Primary Science Learning Area. The challenges now are for these initiatives to inspire undergraduate teachers to become proficient in providing primary science activities to suit the needs of all students.

The Challenges of the Future

Two issues compound the problem associated with providing support to undergraduate teachers (Fleer & Hardy, 1996, p. xi). The first issue is concerned with the confidence of the students to teach science and the second is concerned with the variety of experiences offered by the teaching practicum. Some students will encounter schools where very little primary science is taught, and some will gain science teaching experience with schools that have implemented programs with teacher support and materials.

University Schools of Education should be at the forefront of exemplary practice and research. Teachers either in training or experienced, expect the institutions to provide them with support in collaboration with the other professional bodies associated with the development of science. The Schools of Education are in a good position as they can provide newly trained teachers with first impressions and role models of good primary school science teaching. If these impressions are ultimately to inspire teachers to provide effective science learning opportunities then there are many challenges ahead for the teacher educators.

Challenge 1, Actively contribute to the development of primary science.

Ensure that primary science educators are active contributors to the development of primary science at the K-7 level. This may also be extended to cover the middle years of schooling as there is a lot of development in this transition phase of education.

Participate in professional activities such as those organised by STAWA and Scitech. This is the means by which a network of science educators interacts and contributes by sharing ideas.

Challenge 2, Ensure teachers understand how children learn science.

Focus on what children are learning and not what is being taught is at the heart of the outcomes approach to education. The constructivist model of knowing and learning (Skamp, 1998, Fleer & Hardy, 1996, Bentley & Watts, 1994, Ollerenshaw & Ritchie, 1993, Tobin et al, 1993) where children's prior experiences provide conceptual change potential are at the heart of the 5 E's model (Explore, Engage, Explain, Elaborate, Evaluate) of teaching used in the Primary Investigations' materials. Teachers need to understand this learning process if they are to provide an effective range of teaching approaches and examples of science activities.

Challenge 3, Address the content issue. (see below)

Be aware of the range of resources available to assist teachers in improving their knowledge of scientific principles. The Understanding Concepts strands give a framework

for knowledge required and there are many ways in which teachers can acquire enough knowledge to facilitate learning in these areas.

Challenge 4, Ensure teachers are competent with the use of computer technology and the use of the Internet.

The pace of development of the Internet has opened up a large area for science activities. Sites such as Questacon, Scitech, Water Corporation and CALM offer many links to other areas. Professional organisations such as the ASTA's Home Page gives information on a wide range of science activities for schools and teachers including notices of science teachers' conferences.

Challenge 5, Be knowledgeable about the other learning areas and be able to link science across the curriculum.

Integrated science activities enable students to make associations and links based on previous knowledge and experiences. Some science concepts have already been entrenched in students; understanding before they get to school. These conceptions may be 'mis-conceptions' associated with the understanding or the language, ie the battery is 'flat" or "the moon just comes out at night as the sun sets", conjures up many ideas about what the child is thinking. Linking literacy and science is an essential part of planning meaningful primary science learning opportunities.

Challenge 6, Develop and maintain professional networks.

Maintain links with primary schools through the professional teaching practice experiences. Offer to give something back in the way of PD sessions for staff. Get to know which schools and teachers are doing exemplary work in the area of primary science education. Networking with teachers and school science co-ordinators also occurs through other PD opportunities such as postgraduate courses and in-service institutes for teachers that may be offered for credit or otherwise.

Challenge 7, Maintain links and associations with professional organisations world-wide

This helps to put primary science in perspective and is important for a geographically isolated place such as WA. The email network and professional listservs are excellent ways of keeping in touch with innovative work being done by colleagues. Colleagues are doing good things in the primary science areas within this State. Do we know about them? Personal networks are excellent ways of ensuring that one remains up to date with current practice.

Pre-service Teachers' Knowledge of Science Content - Where to Now?

Recently I have been teaching a second Year Curriculum science unit to pre-service primary teachers. The course evaluation completed by 37 students, signified that the

students were somewhat disappointed that the unit had focussed on the Curriculum Framework document, and the Primary Investigations materials and had not done enough content based workshops. I understood that content had been the focus of a science unit in the first year of their course. The students expressed lack of confidence and dissatisfaction with their ability to teach science at primary level at the beginning of this second year unit. This is consistent with Bentley and Watts' finding that "One of the major difficulties which teachers without a scientific background have experienced is the lack of confidence which comes from an insecure content base". (Bentley & Watts, 1994, p. 180)

However at the end of the unit, 62% of students felt *confident* to teach primary science and 35% of students felt *highly confident* to teach primary science. This confidence factor was not related to their previous scientific knowledge as although 67% of students had studied either Biology or Human Biology for the Tertiary Entrance Examination, only 16% had studied Chemistry, 11% had studied Physical Science and only 8% had studied Physics. In fact 22% of the students had not studied science at Year 12 level.

In the content strands of the Curriculum Framework science outcomes, only 3% of student teachers felt confident with their knowledge to teach the Natural and Processed Materials strand. To teach the Energy and Change area 24% of the students felt confident compared with 30% of students to teach the Earth and Beyond strand and 51% of students to teach the Life and Living strand. The percentages reflected the students' experiences of their own science education: (*I am most confident in all areas*) "due to my science TEE experience," (female student).

Fifty one percent of students thought they needed more knowledge in the Natural and Processed materials strand, 30% in the Energy and Change strand but only 8% and 11% felt they needed to improve their knowledge in the Life and Living and Earth and Beyond strand, respectively. Again these responses reflected their learning experiences as school students. The students in this small sample had become more confident through their course unit experience and thought they could address the content issue in the following ways:

The undergraduate/postgraduate experience:

- "the university will teach me"
- "science courses and other PD"

Teaching experience:

- "through research before a lesson"
- "observing science lessons"
- "teach science lessons that deal with areas that I am unsure of, then I'll gain practice, experience and confidence about these learning areas"

- "read up on areas I know I will be teaching in particular classes"
- "being provided with the opportunity to teach these subjects"
- " I don't feel I have a problem with what I teach, just how to teach it"

Own professional research:

- "research and resources that I will build up over many years"
- "through the internet"
- "excursions to places such as Scitech"
- "own research where needed"
- "reading books, magazines"
- "read books at least at children's level so that I know enough to teach them"
- "watch videos on topics"

Teacher knowledge, according to Bentley and Watts (1994, p.180) can be broken down into six areas: content knowledge, pedagogic knowledge, strategic knowledge, professional knowledge, situational knowledge and personal knowledge. Students expect their primary science curriculum sessions to provide them with additional hands-on experience throughout their courses to improve their science knowledge.

According to Hirst and Peters' philosophy of knowledge "the curriculum will only be constructed to deal with knowledge which is considered legitimate" (Smith & Lovat, 1990, p.67). The Curriculum Framework makes explicit eight key learning areas, one of which is science and therefore legitimises four content strands based on the traditional science disciplines of physics, chemistry, geology/astronomy, and biology. For a primary school teacher who might not have the background experience and knowledge then the ability to teach in these areas is certainly a challenge. It would appear that the pre-service teachers need additional support with the knowledge components associated with the Energy and Change and Natural and Processed materials strands.

Secondary science teachers usually have a positivist approach to teaching science (Schubert, 1986) whereby a body of knowledge is passed on from one generation to another. This knowledge quest has been described by Habermas as relating to one of technical control, wanting to know all the facts associated with the subject (Schubert, 1986). If a teacher's role is to "mediate the learning of students" (Tobin & Tippens, 1993, p. 9) then the focus should be on the learners, not the discipline. They believe teachers should not focus on content in the science classroom as the highest priority. Classroom research at secondary level (Tobin & Gallagher, in Tobin, 1993) has shown that students are not on task constantly in the science classroom and that teacher/student interaction is minimal. Primary science teaching has been more focussed on process and teachers have been encouraged to develop their own interactive teaching approach (Fleer & Hardy, 1996, p. xv).

One of the main problems associated with preservice teacher content knowledge in the primary science area is that of the lack of time in the four year course designated to primary science curriculum units. The onus is therefore on the individual teacher to acquire the content knowledge needed to satisfy the outcomes approach to education which requires that students demonstrate a level of understanding about what has been learnt rather than what has been taught. As part of effective classroom practice, it is important that teachers develop "a sound knowledge of the curriculum and monitoring and assessing children's progress" (Bentley & Watts, 1996, p. 186). The Roehampton Institute in the UK tried to get accreditation for a foundation science and mathematics course for pre-service teachers. However the course was not approved as being of degree level in-spite of positive evaluation from students (Bentley & Watts, 1996).

Pre-service teacher education has been without curriculum direction and suitable materials for the facilitation of learning in primary science. This is no longer the case. However student teachers start their courses with varying science experiences. Some mature age students have not been in a science classroom themselves for at least ten years. There is a pressing need for Schools of Education to support pre-service teachers in developing appropriate strategies to address the content issue. For example, at the Science and Mathematics Centre at Curtin University of Technology, science institutes have been offered as part of the postgraduate program for primary teachers. Over the next few years, other issues such as assessment profiles and how to address the content knowledge strands, will need to be addressed. Formal testing will probably become more significant and this will impact on the teaching and learning process. However the future looks much more exciting than it has done over the past 20 years.

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Making Judgements About Students' Science Work—Teachers' Concepts and How They Help and Hinder

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Abstract

This research examines the level of science content knowledge of practising primary and secondary science teachers and its impact on their ability to make accurate and effective judgments about students' conceptual development in science. When evaluating students' work, teachers responded in four different ways when their content knowledge influenced their ability to respond appropriately to students' work, and to support students' knowledge development. This research supports the view that teachers can be compromised when evaluating students' science work, in relation to their own level of science knowledge.

Introduction

Shulman's (1986) paper emphasised the link between knowing the content of science, and knowing about how to teach science, with discussion of pedagogical content knowledge. Since then, research in this area has shown continued interest in the influence of teachers' knowledge about science on their ability to support students' work.

The Department of Education, Employment and Training's (1989) *Discipline review of teacher education in mathematics and science* referred to the 'lack of confidence' of teachers in primary science, and suggested that part of this was due to low levels of science understanding. Similar work by McDiarmid, Ball, and Anderson (1989) indicated the need for teachers to have sound understandings of subject matter. Aubrey (1994) stated that educational research is now focused more on the conceptual understandings that teachers hold about specific subjects. Aubrey suggested a consequent impact of poor levels of teacher science education (at least for electricity), "there is some evidence to suggest that teacher's understanding of subjects they teach reveals gaps and misconceptions like those of their pupils". (Aubrey, 1994, p. 11)

Work by Carré and Ovens (1994, p. 39) suggested that a low level of teachers' science knowledge does hamper students' progress, particularly in "conceptual change teaching [which] involves helping children to articulate openly what they think and to challenge their own misconceptions by using a variety of teaching strategies" which is dependent on teachers' own conceptual level. They reported low levels of teacher knowledge, and that 11 years olds knew as much as their student teachers!

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In Australia, to support teachers' science understandings, the Primary Investigations curriculum (Academy of Science, 1994) included background information for teachers for the themes and lessons in the program.

This paper reports on research into the effects of primary teachers' science knowledge on the assessments they make of primary students' understandings, in a science context of a lighting a candle, observing it burning, and blowing it out. It identifies four types of problems when the teachers' evaluation of students' work was constrained by their pedagogical content knowledge in science.

Method

A selection of 20 teachers with at least five years in recent science teaching were selected to obtain representations of high or low levels of personal science knowledge, and experience as junior, or upper, primary teachers.

During an interview, each watched the process, then described striking a match, lighting a candle, then blowing the candle out. The interviewer prompted for more precise observations, clearer explanations, but did not provide any terminology or concepts not first introduced by the teacher, based on Tasker and Osborne's (1985, p. 11) 'interview-about-events' technique.

Next, each teacher was asked to evaluate a transcript of the responses from an unknown student, made during a similar interview about the candle with the researcher.

Analysis

Models for each teacher's understandings about the candle were developed from analysis of transcripts of interviews. This was based on work by work by Driver, Guesne, and Tiberghien (1985), and Tasker and Osborne (1985), who describe 'models' as distinctive and essential ideas about an event. The comments, evaluations, and descriptions teachers made while assessing and making judgements about what the student said and knows about the candle were analysed, and used to identify occasions when there was some form of mismatch, or inconsistency, between the student's response and that of the teacher. This analysis resulted in four types of problems being identified. These are discussed below, with an example for each.

Problem 1: Not recognising correct ideas

One of the potentially most limiting problems for teachers was that the level of their own understanding was not sufficient to recognise whether a student's ideas were correct, or on the way to being scientifically acceptable.

Some teachers described the match head using imprecise and generic terms, such as the term 'chemical', for example, *'the chemicals on the match head, the red part on the*

end of the match is a mixture of some sort of chemical type thing'. Some were able to hazard a guess: *'the match head is made out of, goodness, graphite or something. No, whatever it's made out of'*.

One student used the term 'sulfuric' for the head, but the teacher who analysed this student's work, used this only as a means to differentiate the student from primary students: *'an average primary student wouldn't use the term "sulfuric head" '*, and chose not to comment on the accuracy of the student's concept.

Most of the teachers were unable to provide students with a name for, or properties of, such chemicals, and in the case of students who used the name of appropriate chemicals, they were unsure if they were correct.

One teacher demonstrated how, when she was unable to determine if a student was correct, she may inadvertently cause confusion. She was confident about the student's language skills, for example: *'I'd say this child has done quite a few procedures [genre] before in class. "The first thing you do, the second thing you do" '*. She is aware *'he knows something about chemicals [that] there'd be a chemical reaction. It isn't just a match — it's— he's thinking further than that, um, but "you need heat". Maybe that concept is wrong. I don't know that heat is created [and later] Maybe he thinks here that we need heat from the candle because of the cold. I'm not sure why he says we need heat. Whether he means that heat is to make the match go?'* This teacher is unable to decide if the student's use of 'heat' is appropriate or accurate.

In the same transcript the student explains the match igniting by including *'molecules rub together which caused heat'* . But the teacher rejected this, saying *'he's getting mixed up with between heat and friction'*. When evaluating what the student says about kinetic energy, this same teacher states *'um I, I need to clarify in my mind again what "kinetic energy" is before I can — because I've forgotten'*.

Teachers held a variety of concepts about what the match head, and the striking plate, were made from, and how they interacted when making the match ignite. For some, their conception was of was a 'special surface' or 'chemical' on modern-day match boxes, because matches would not light up by just striking them on any surface — as was the case in the early cowboy movies. For others there were 'special chemicals' in the match head, that had to be scraped away before it would light. Very few were able to specify the relationship of friction, and ignition temperature for combustion, or to state what the chemicals were in the head.

Problem 2: Reinforcing student's misconceptions

When teachers hold alternative science conceptions, it is likely they will be unable to recognise if a student suggests incorrect reasons for events. Indeed, they are more likely

to respond positively to the idea if it is the same as their own, reinforcing the students' misconceptions.

Many teachers in the sample held the view that the wax on a candle was only there to slow down the rate of burning of the wick, and stated that the wax itself did not burn. For example: *'wax doesn't burn, the candle wick is meant to burn. The wax just changes from a solid to a liquid'.*

This was a common view of students as well. For one student, their view of what was keeping the flame alight was "O*il . I think or something flammable on the wick. And the wax is just stopping it from burning all the way through'*. The student later stated the wax was there *'to make sure that the, um, candle burns at a slow even rate, and that the wax doesn't burn it just melts, so the flame just sits on top'.*

Consequently, when assessing students work, teachers recognise this as an appropriate concept for the student to have, and find their own misconceptions repeated. They do not attempt to alter the view of the child, indirectly limiting the students' conceptual progress.

In the last example, the teacher commented on the student's statement with *'that's interesting'* and read aloud ' *"flammable oil on the wick." '*. When asked by the researcher what she thought of that, she answered *'um. [long pause] that's interesting'* and went on to provide evidence that the student was probably an adult because of the *'expression — words like "flammable" '.*

For one teacher, her own beliefs were that it was the wick that burned, and not the wax. So when assessing a student who had the same misconception, she described this student as *'he seems to have quite a bit of knowledge'* and *'he's got really good knowledge there'.*

Problem 3: Uncertainty misleads students

A teacher's own misconceptions, or uncertainties, can lead to inappropriate or misleading application to students' work, responses that may confuse, or mislead students, and hamper their further conceptual development.

This may be demonstrated by a non-committal approach to students' ideas, when the student could possibly benefit from more direct comment from the teacher. For example, few teachers demonstrated well-developed ideas about the role of gases in combustion. For one, the reason the candle went out was an inconclusive hedging involving oxygen deprivation, excess supply and then vacuum.

Teacher: Basically I provided too much oxygen at one time and it just smothered it, or removed it. Actually my blowing probably removed the oxygen from the direct contact .

Researcher: How would your blowing remove the oxygen?

Teacher: I'm not quite sure. I, well basically, it's altering the, the um, the amount of oxygen being burnt up around would suddenly disappear. I almost create a vacuum around it and just blows itself out.

When evaluating a student's work, although the child stated *'the fire goes out because I blew on it with my breath'* this teacher chose not make any comment. This is perhaps because he was unsure of his own conceptions, and was unwilling to provide any suggestions for fear of giving the wrong information. Based on this teacher's uncertainty about the link between blowing and the candle going out, he would find it very difficult to confidently assist this student to make the link.

Problem 4: Assess the terminology, not the concept

For some teachers, it was important that students used scientific terms. For example, one teacher seemed content to accept use of terminology as evidence of an acceptable conceptualisation by the student, as she did not search the transcript for accurate use of the concept: *'but again he's got the terminology. He's able to say it. He's obviously been quite comfortable with kinetic energy.'*

The use of 'science sounding' terminology was given more credence when evaluating a student's work than was evidence of the presence of appropriate concepts, which were 'masked' by less sophisticated science-specific terminology. For example, when describing the lighting of the match, one teacher used the term '*friction*' but was unable to provide any attempt at explanation of why '*rubbing something against something else*' made the match light, other than to create a '*spark*'. She did not mention the role of heat created by friction leading to the match head igniting.

When assessing a student's work, she noted that the child used the term '*sandpaper*' rather than friction, when describing the side of the matchbox. She stated that the student has '*got a basic understanding*', but failed to recognise the key elements that the student *did* understand, such a demonstrated a cause and effect relationship of heat in causing flame, for example, *'the chemicals and stuff in the red thing'* and *'the red thing on the end of the match heats up and then it catches fire'*.

For this teacher, the key idea was friction, not the presence of heat and ignition temperature, so she did not support this students' concepts, as they were not the same as her own, and were not 'high level' terminology.

The importance of teachers' recognition of higher levels of conceptual development is established in Western Australia curriculum materials (Curriculum Council of Western Australia, 1998). Teachers who do not recognise the presence of key concepts, irrespective of use of specific terminology as indicators of the concepts, may underestimate the level of the students' development, recommend work that will not foster conceptual development, and focus on the use of terms rather than of concepts.

Conclusion

The teachers in this study had mental models about the candle, burning, heating and melting, and why the candle could be blown out. These were applied when teachers made their assessment about students' work. A few teachers were able to use concepts and terms such as molecules, gas reactions, or heat energy transfers to make their judgements; but far more held misconceptions such as 'wax melts but does not burn', and operated on visual links of events and effects, such as candles smell 'because they go out' rather than concepts of gases and incomplete combustion.

For all teachers, there were identifiable effects of their mental models of the candle on the way they evaluated students' work. Examples from the teachers in the study support four dimensions of interference from a teacher's own personal level of science knowledge when making judgements about students' science work: not recognising scientifically correct views; reinforcing students' misconceptions; uncertainty providing inappropriate feedback for the student; and responding to the terminology, not the concept.

These four problems, relating to the everyday event of lighting a candle, support the views of Carré and Ovens' (1994) and others, that teachers' subject content knowledge can hamper children's progression in understanding. For each of the 20 teachers in the sample, to a greater or lesser extent, their ability to support the students was constrained by their pedagogical science knowledge.

However, there also were clear examples of teachers' knowledge being actively used to identify the stage of development of the student. For example, one teacher, clear himself on observable and molecular ideas about 'change' in the context of wax melting, was able to detect that a student: *'know[s] it heats up and it melts but they're not quite sure as to why, other than it's just wax'*. He was able to develop this perception into an argument that the student did not have an idea of why and how things changed, just that they did, for example, *'so my understanding is that they haven't had actually focused much in on wax and this change of structure, and yeah, and they know it becomes like eventually it will become soft and wax but they obviously they haven't been focused in on the how things can be changed, the structures of things can be changed'*.

Yet, few teachers explicitly stated that they would do research before planning further lessons for the students whose work they read, even though many referred directly to their own recognition of limitations in their knowledge: *'Well I'd like to find out why, I'd probably like to find out what actually is in the wick and I'd probably do research on what is in the match head — on what happens if you had different types of materials in the match head'*.

Limitations of the study (Simmons & Lunetta, 1993, p. 170) include the small sample size, the requirement for 'subjects to verbalize or use a think-aloud commentary',

the presence of the researcher (as described in Steier, 1995), and that teachers were responding to printed transcripts rather than more naturalistic, classroom situations. Nevertheless, the findings are important and should be tested in classroom situations.

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Postgraduate Courses on the WWW:
Teaching the Teachers and Educating the Lecturers

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Abstract

During 1998, I have initiated four new subjects that are taught exclusively via the World Wide Web. Students include a mix of SMEC postgraduate students and teachers enrolled for non-credit professional development. An interesting component of these courses is the provision of downloadable "teaching modules", which students (themselves teachers) can place on their own local area networks – Intranets – and use in their own classrooms. I have personally trialed several of these modules in six Perth secondary schools, and others have used them across Australia and in New Zealand, North America and South Africa. This paper concentrates on three issues: the creation of flexible, non-linear, multimedia courses for delivery to teachers via the WWW; the huge learning curve faced by lecturers implementing WWW courses; and preliminary formative and summative evaluation of these courses.

Introduction

Providing post-graduate courses and professional development opportunities to working teachers is never easy, and can be especially difficult if they reside away from urban campuses. There has been a great deal of hype about using communication and information technologies (CITs) and the WWW to deliver such materials (Cunningham, et al., 1998; Luke, 1996; West, 1998). At the same time, others decry the loss of face to face interaction between lecturer and student (Birkerts, 1994; Ryan, 1998) as well as the cost of preparing sound multimedia courses for WWW delivery (Ryan 1998; GAL 1997). This paper relates some personal experiences in developing and delivering four such courses during 1998.

Designing and Implementing a WWW Course

The four new WWW courses were:
Using Multimedia and the Internet in Secondary Science Education
Teaching Year 11 - 12 Computing, IT and Information Systems
Teaching Year 8 - 10 Computing and IT
Information Technology, Science and Society

The rationale behind developing them was to meet clear needs of secondary science and computing teachers either seeking university academic credit or simply studying for their own professional development. The "needs" arose from radical changes in the secondary computing/IT syllabi in Western Australia over the past two years (Curriculum

Council, 1998a, 1998b), the desire of many science teachers to utilise WWW sites and multimedia CD-ROMs more fully, and the motivation of a subset of both groups to create their own multimedia sites on their school's local area network.

Motivation for utilising electronically delivered multimedia, rather than traditional paper-based, distance education materials, included:

- the non-linear structure of WWW courses, such that different students may follow different "paths" through the material;
- provision of courses that students could study at times convenient to them and at their own pace;
- the ability to include graphics, animation and interactive demonstrations;
- the ease of updating; and
- the need to *demonstrate* multimedia by *using* multimedia.

A WWW course allows the author to cater for a much greater diversity of student needs, interests and backgrounds by providing both introductory and advanced links from a middle-of-the road path through the syllabus. (On the other hand, it is easy for students to become lost and/or overwhelmed when thousands of pages of linked materials are available.)

For example, in Using Multimedia and the Internet in Secondary Science Education, I was able to provide:

- additional readings appropriate to schools with different levels of CITs;
- basic, intermediate and advanced information searching strategies;
- links to hundreds of WWW science teaching sites that I had reviewed personally in terms of grade level, subject and quality;
- detailed reviews of three multimedia encyclopaedias and an additional 16 CD-ROM teaching packages;
- basic, intermediate and advanced advice on constructing your own multimedia site; and
- segregation of information appropriate to biology, chemistry, physics, earth science and general science teachers.

Similarly, in the two courses aimed at computing/IT teachers, a wide range – some would call it a "smorgasbord" of options – could be provided. The lack of personal contact between lecturer and students was compensated by regular use of a course Bulletin Board and email.

Perhaps the most useful feature of these courses was the provision of downloadable teaching modules on a range of topics, from "Design an Information System" and "Creating your own WWW Site" to "Using the *Exploring the Nardoo* Package" and "How to Write a Report". I have personally trialed these modules in six Perth secondary schools, and my students have trialed them in their own schools worldwide. As discussed below, many students found the availability of such teaching modules, which they could download

onto their own school systems, modify as required, and provide to their own students, to be the best feature of these courses.

I also provided a free "demonstration" WWW site, that includes some modules from each course and several downloads, to show interested (but perhaps reluctant) teachers what multimedia course delivery is all about. Anyone may create themselves a free account on this site by following the instructions provided at:

http://www.curtin.edu.au/curtin/dept/smec/ipd

The Learning Curve for WWW Course Developers

Despite the rapid improvement in html (hypertext mark-up language, the language of the WWW) editors and WWW course packaging programs, creating a new multimedia course is a huge amount of work. There are several reasons for this:

- there is a great deal to learn about generating html pages, inserting links, creating, editing and inserting graphics, sound, animations and video;
- it is extremely time consuming to locate and evaluate appropriate online material to which links should be provided; and
- most importantly, the whole notion of a *non-linear* multimedia course is very different from our traditional linear course structures.

When I designed the first course for delivery in first semester 1998, I assumed that a traditional linear, paper-based version would require about 100 hours to prepare, so I allowed 200 hours for writing a WWW course (I have a good background in computing). The actual time requirement was closer to 600 hours, and included perhaps 250 hours learning how to use all the multimedia authoring tools effectively. The course materials themselves include about 400 pages of primary text, 400 pages of optional text, several hundred graphics, and links to an additional 300 WWW sites. The other three courses, introduced in second semester 1998, required from 250 to 700 hours each to develop.

The issue is not merely becoming a "web authoring wizard". Creating a multimedia course for WWW delivery requires a very different thinking process. How do I accommodate both the novice and advanced student? Which of these hundreds of potential links should I include? How do I ensure that neither the students nor I get sidetracked or overwhelmed...? I would have spent nearly 400 hours simply finding, reading, testing and evaluating nearly two thousand WWW sites for the Multimedia in Science course before I selected about 400 to include; I would have spent another 200 hours reviewing and evaluating about 30 CD-ROMs. Even if one uses a commercial "WWW-course packaging program" (I used Web-CT) to provide the structure, Bulletin Board, chat room, internal email, etc., it still is a monumental first-time effort to put one of these courses together. The author of a multimedia course must also strike a balance between a slick course with lots of graphics, animations, and "bells and whistles" (which

may be very slow for students to download) and a "bare bones" delivery which is not very pleasing aesthetically. One slowly learns how to compromise, such as by using small "thumbnail" graphics which, when clicked, retrieve the full screen pictures.

There are, however, huge advantages to building a course using these media:

- updating and revision are extremely simple – there is no need to use last year's readers because they have been printed at some expense;
- when a student (or I) find a new link or source, everyone has it within hours;
- new teaching modules can be provided to all very easily – within four weeks of creating one new module, it had been tested in 12 schools in four countries and revised twice; and
- communication between lecturer and students, and amongst the students, is almost instantaneous.

In my experience, the *pros* greatly outweigh the *cons*, but I advise you to allow a lot of time to establish a new multimedia course on the WWW!

Another issue that must be addressed is intellectual property rights and copyright. If I wish to print an anthology for distribution to students, I can do so legally by paying each copyright owner a small fee; to date, this is NOT legal if the same material is being distributed *via* the WWW. (However, the federal attorney general announced, on 9 June 1998, proposed legislative changes that will [if passed] allow placing up to 10 percent of a copyright work on the Internet – but beware, it's not law yet!) On the other hand, the Australian Copyright Act of 1968 (as amended) does allow, under sections 40 and 41, a reasonable right to "fair dealing" of copyright material for the purpose of study, review and criticism (and suggests that the amount that may be used depends on the impact said review will have on the copyright owner – presumably a favourable review can use more material than an unfavourable one). It has been my experience that if one wishes to use more than 10 percent, it is not difficult to obtain copyright owners' consent if they are told you wish to write a review praising their product and urging others to purchase it! That aside, copyright issues are still a nagging problem.

Evaluation of the Four Courses

Both formative and summative evaluations were conducted for the single course offered in first semester 1998, and are being conducted for the four courses offer in second semester 1998.

Evaluation instruments and methods included:

- weekly feedback from students, both at (the optional) weekly tutorials and *via* the courses' on-line Bulletin Board and email;
- formal (on-line) end of course surveys;

- input from, and evaluation by, the Chair of the W.A. Curriculum Council Information Systems Syllabus Committee (for the two IT courses);
- measures of teachers' use of the on-line material in their own classrooms; and
- the lecturer regularly visiting the teachers' classrooms in six Perth secondary schools.

The weekly feedback centred mainly on: "How should I present this?"; "Can you provide more details/examples?"; "I don't understand this – where can I find help?"; "Can you add some material on such and such?"; and "Where can I find a site that…?".

The on-line end of course questionnaire was completed by 15 of the 30 students who studied in first semester, and (to date) by 15 of the 43 second semester students. Each questionnaire contained from 22 to 38 multiple choice and open-ended questions.

The questions addressed many issues, including:

- Had they studied *via* the WWW previously? Was it preferable to "paper"? Was it preferable to attending classes? Were the optional workshops useful?
- Questions about specific content, modules, examples, difficulty level, breadth, depth, workload, etc.
- Design/quality/inclusiveness of the WWW site and its links.
- Utility of on-line, downloadable teaching materials (which they could use in their own classrooms). Should some be removed? Should others be added?
- Should it be taught again? With what changes? Best features/worse features? Should other courses be offered in this format?

Only one student of the 30 who have responded to date had studied previously *via* the WWW, and that was only part of a course. All but one preferred a WWW course to attending weekly classes. Two of the 30 would have preferred a traditional paper-based course, five were not sure, and the rest preferred the WWW over paper.

Questions about the inclusion/emphasis/depth of specific modules produced an agreement rate which ranged between 82 and 100 percent, depending on the module. All students found the on-line hyperlinked reading and the "useful links page" to be useful.

All students stated that the courses should be taught again, in more or less their present form. Nearly half of the students in the multimedia science course requested a follow-on course next year. All but one thought more of SMEC's courses should be offered entirely over the WWW.

Several issues stood out in the "please write comments/suggestions" questions.

> Most teachers found the flexibility to study in their own time, plus the vast range of linked on-line material, to be a major benefit.
>
> Several noted that they did not have time to do justice to all the optional material. NB This led to my extending their access for an additional semester.

More on-line, downloadable teaching examples, exercises and modules were desired. One added: But that means we have to get **our** act together.
Individual comments included:

Great course -- thank you very much. (You also showed us just how much work is involved on setting up a quality course on the Internet)

I thoroughly enjoyed this unit. The material was interesting, the assignments flexible, the assignment turn around from Steve was excellent. If all the SMEC units are as well presented and carried out as this one I can see myself having a great time learning.

Thank you, Steve, for your efforts on behalf of computing teachers.

Thank to Steve K for his venture – it is only the beginning.

I enjoyed the course. I could see that Steve spent 100s of hours putting it together.

I did not see the lecturer at all but I liked his way in teaching very much. Simply, because I am very busy but his interesting stories about the teaching points attracted me to study all the topics of the subject. He must be a great teacher with a great sense of humour.

Tremendous planning and effort to get it right.

The flexibility of being able to "select" own topics for additional study.

Relating the material to the Yr 12 Information Systems course.

The course modules were very easy to read and absorb, and had good links to external resources.

Thank you from myself and my students for a heap of good teaching resources and ideas.

I found the course really worthwhile and realised how much work had gone into it when I tried a little Web based project on my own. Thanks very much!!

> I enjoyed doing the course. It was great to be directed to articles which were relevant to the work that I do. I appreciate the prompt replies to any questions I had. There is an enormous amount of material available, I wish I had more time to access it all. I hope it is available for some time as I would like to be able to revisit it and go over some of the modules in more detail. Actually studying a course via the Web was a great experience in relation to developing Web materials for my own students.
>
> The diversity of material presented and the practical way it was organised. I have already used many of the concepts and ideas, and have purchased two CDs. I really appreciate the sifting of sites as this has made preparation of a site for my own students much easier. It is an extremely time-consuming activity and your generous use of your time has saved us much both in terms of time and expense. Thanks.
>
> I have thoroughly enjoyed the course and have gained great benefit from it. While the formal side of things may soon be over, I believe that I will continue to refer to the site, use the techniques I have learned, and the sites I have explored, for many years to come.
>
> Thank you for your obvious prodigious efforts on our behalf. I've enjoyed it immensely as a learning experience, not just for academic credit.

In summary, features that students like most about the Internet format included:

- the ability to study at their own time and pace;
- not having to attend after-school classes on campus;
- the ability, when attending optional classes, to network and to compare notes with other teachers, rather than receive course content;
- the non-linear nature of an Internet course, where links to very basic material, advanced material, examples of applications, and numerous relevant sites are provided on-line;
- the almost instantaneous updating and revision of content; and
- the ability to download content for use in their own classrooms.

Features that students like least about the Internet format included:

- occasional difficulties in accessing the Internet;
- having to adopt different study patterns; and
- becoming overwhelmed and/or sidetracked by the vast amount of hyperlinked material available.

Conclusion and Outlook

I am not quite sure where all of this is going. Quite to my surprise, my use of the WWW for course delivery – a medium that some might see as isolating and reducing contact amongst lecturer and students – has done a great deal to promote collaborative curriculum development and delivery, especially with the rapid trial, evaluation and revision of new downloadable teaching modules.

While it is still "early days", I am now developing more and more on-line, downloadable modules as we go, encouraging the participating teachers to trial them, give me feedback, and share their own materials with the other participants. With a bit of luck, I think we can develop a fair range of useful materials, which will be available to all, over the next year or two.

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A Constructivist Multimedia Learning Environment: Learning Opportunities For Teachers

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Abstract

This paper describes a professional development program involving the use of a multimedia package to develop teachers' understanding of a constructivist epistemology in science education. The workshops were intended, firstly, to empower teachers to become comfortable in using computers in science classrooms, and secondly, to enable teachers to enhance their understanding of, and ability to use, personal and social constructivist approaches to teaching and learning in the computerised learning environment. Teachers' perceptions of the process of learning with the multimedia program and teachers' reactions were assessed using a new instrument, the Constructivist Multimedia Learning Environment Scale (CMLES).

The results of the study suggest that teachers who have participated as learners in the professional development program can understand the context, problems and issues faced by students in the classroom and therefore are able to better facilitate students' needs and enhance their understanding in this learning environment.

Introduction

The purpose of the study was to investigate the potential of using professional development workshops as a means of engaging teachers in epistemological transformation and subsequently influencing their use of constructivist approaches in their teaching practice. Teachers' epistemology refers to teachers' beliefs in pedagogy, the nature of knowledge and student learning. A constructivist teaching approach concentrates on learners constructing their own understandings, and on social interactions taking place in the classroom. This study focussed on teachers' difficulties in modifying their epistemologies to a more constructivist approach which will influence their classroom practice and, subsequently, help students develop higher-level learning. The literature (eg., Salomon, 1996) suggests that, to overcome these difficulties, teachers need to experience the novel learning environment as learners themselves. I believe that as teachers become proficient in the use of the multimedia they can enhance students' more effectively learning using this tool.

Changing Teachers' Epistemology

Lack of success in changing teachers' epistemologies to a more constructivist approach (Tobin, 1993) led to the design of the teachers' workshop. Salomon (1996) suggested that, in order for the teacher to be an autonomous, confident, widely knowledgeable professional, and a team player, there is a need for in-depth professional

training for teachers. Studies which have investigated constructivist approaches to teaching and learning have substantiated the importance of changing the role of the teacher in the learning process (Hand et al., 1991; Maor & Taylor, 1995; Treagust et al., 1996). Because a constructivist-oriented teaching pedagogy seems appropriate for realising the goals of inquiry-based curricula, the workshop included a focus on teachers' change in epistemology and provided opportunities for learners to reflect on their progress through a software program. This is important for the successful use of computers in promoting problem solving and thinking skills amongst the participant teachers.

The Role of a Constructivist Multimedia Package

The Interactive Multimedia program used in the professional development is Birds of Antarctica, was developed with the cooperation of students and teachers (Maor & Phillips, 1996). The developers were guided by a constructivist view of learning and an intention to create a 'rich' environment for students. Therefore the program was designed to:

- simulate authentic learning environments;
- provide multiple representations of data;
- engage students in a personal construction of 'reality';
- enable the students to generate their own questions and investigations; and
- promote social negotiations between students and provide them with opportunities to reflect upon real-life issues.

Teachers, I believe, need to facilitate the use of the program by building in time for reflection, debriefing sessions and whole-class sharing of ideas and experiences to promote higher-level learning. This aspect of the use of the program was emphasised in the professional development program.

Field of Classroom Environment Research

In the past three decades, much attention has been given to the development and use of instruments to assess the qualities of the classroom learning environment from the perspective of the student (Fraser, 1998), and one of the many promising applications of these instruments is in the evaluation of learning environments involving the use of computer-assisted learning (e.g., Maor & Fraser, 1996; Newby & Fisher, 1997; Teh & Fraser, 1994).

A classroom environment questionnaire, the *Constructivist Multimedia Learning Environment Survey* (CMLES), was designed for this study. The purpose of this instrument is to assess to what degree students and teachers think that the classroom environment is inquiry-oriented and follows constructivist approaches to learning and teaching. The first part of the CMLES measures students' perceptions of the process of learning with the multimedia program and contains three scales: *Student Negotiation,* derived from the

Constructivist Learning Environment Survey (Taylor, Fraser, & White, 1994) and *Inquiry Learning* and *Reflective Thinking,* derived from the Computer Classroom Environment Inventory (Maor & Fraser, 1996). The second part of the CMLES measures learners' reactions to the Interactive Multimedia program and contains two new scales, *Authenticity* and *Complexity.* There are 25 items in the CMLES, with five items in each scale of the instrument. A description of these scales, together with a sample item from each scale, is given in Table 1.

The CMLES exists in two versions, an 'actual' version, in which respondents are asked to rate their current learning environment, and a 'preferred' version, in which respondents rate their preferred learning environment.

The questionnaire was developed to provide a new, widely-applicable instrument for use in future studies of constructivist multimedia learning environments. In this study, it was designed to focus on the use of the computer in the science classroom. The questionnaire results also provide a skeleton on which to build further analysis of qualitative data. This analysis of the learning environment was drawn from teacher interviews during the workshop and consequently during the action research activities. This was done to monitor the extent to which teachers adopt and support constructivist and inquiry-based approaches in the science classroom when using the interactive multimedia program.

Table 1. Descriptive information and a sample item for each scale of the CMLES

Scale name	Description	Sample item
Student Negotiation	Extent to which students have opportunities to discuss their questions and their solutions to questions.	In this class, I get the chance to talk to other students.
Inquiry Learning	Extent to which students are encouraged to engage in inquiry learning.	In this class, I find out answers to question by investigation.
Reflective Thinking	Extent to which students have opportunities to reflect on their own learning and thinking.	In this class, I think about how I learn.
Authenticity	Extent to which the information in the program is authentic and representative of real life situations.	Working with this IMM program, I find that I am presented with realistic tasks.
Complexity	Extent to which the program is complex and represents data in a variety of ways.	Working with this IMM program, I find it easy to navigate.

Research Procedure

The Teachers' Workshop

A series of workshops was conducted with secondary school science teachers. The workshops were designed to guide teachers in the use of the computer program and to promote a constructivist approach to teaching and learning when using the program. Following the workshops, a classroom-based study investigated the development of students' higher-level thinking skills. Throughout the classroom-based study, workshop teachers were expected to use constructivist approaches to learning.

The aim of the workshop was to let participating teachers experience the interactive multimedia as learners. In the action research component, the teachers had to act as teacher-researchers. This distinction between teachers as learners and teachers as researchers also provided a framework to analyse data collected during the workshop.

During the workshop sessions the participants used the curriculum material to help them to navigate through the multimedia program. While the teachers were using the program they examined it for its usefulness and its applicability to their classroom teaching. Their interaction with the program also provided feedback for the developers for further improvement of the software. The workshop consisted of three separate, three-hour sessions conducted over a period of three weeks, with one session per week. Teachers came to the University computer laboratory after completing their normal school day. Ten teachers participated in the workshop. As a result of the workshop, two teachers implemented the program in their science classroom which enabled the research to be extended into their science classrooms.

In the study reported in this paper, the following specific research questions were investigated:

1. What are teachers' reactions to, and perceptions of, the new multimedia learning environment as experienced in the constructivist multimedia workshop?
2. To what extent did the workshop influence the teachers' role in their classrooms?

Four major data sources were used to answer the research questions:

- Teachers' responses to actual and preferred learning environment questionnaires;
- Audio recording of workshop discussions;
- An analysis of a video recording made during the 'hands on' sessions with the interactive multimedia; and
- Interviews with participant teachers.

Results

Teachers' Perceptions of the Constructivist Multimedia Learning Environment

To identify teachers' perceptions of the constructivist multimedia learning environment during the workshop, actual and preferred forms of the CMLES were administered to the ten teachers who participated in the workshop. Teachers were asked to respond to the questionnaires as learners in a new situation, namely, in a constructivist multimedia learning environment.

Following the administration of the questionnaires during the workshop, individual teacher scores were collated and displayed on an overhead projector for analysis and discussion by the teachers. The mean scores were calculated for each scale of both actual and preferred versions of the CMLES. Because teachers responded to items on a five-point scale, and there are five items in each scale, the maximum score for each scale is 25. To facilitate comparison between teachers' actual and preferred perceptions, the mean scores for each scale of both actual and preferred versions of the CMLES are presented graphically in Figure 1.

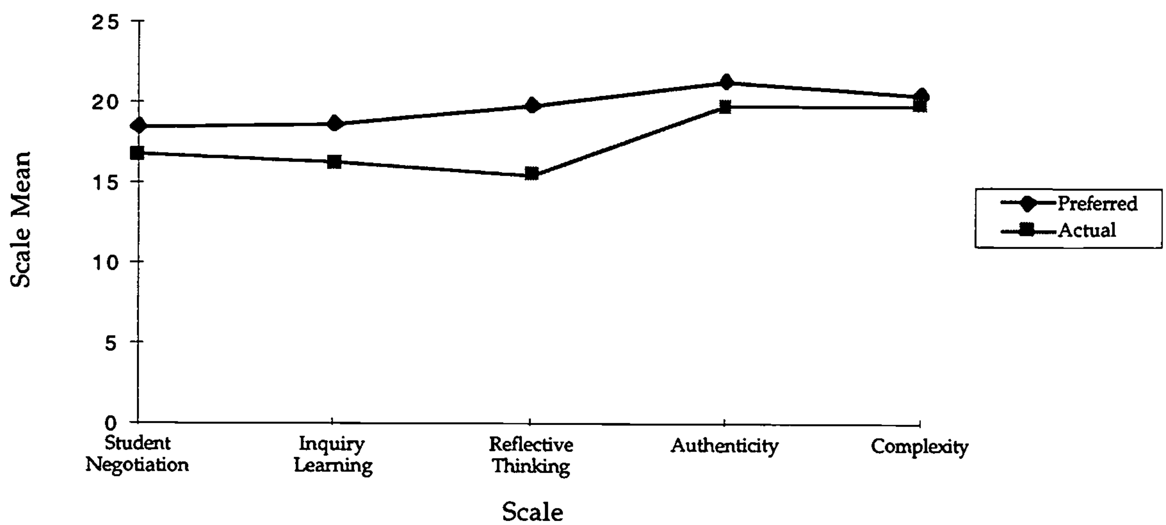

Figure 1. Scale Means for Actual and Preferred Versions of the CMLES

The data presented in Figure 1 indicate that, in comparison with the actual environment, teachers prefer an environment with higher levels of Negotiation, Inquiry Learning, Reflective Thinking, and to a less extent, Authenticity and Complexity.

The greatest discrepancy between teachers' actual and preferred perceptions is seen to exist in the Reflective Thinking scale, a measure of the extent to which the teachers as learners perceived opportunities to reflect on their own learning and thinking. Discussions

with the teachers indicated that the ability to reflect during the workshop was given different interpretations by individual teachers. Some teachers argued that although they had the opportunity, they were not engaged in reflective thinking as they were trying to learn how to use the program. Others suggested that they engaged in reflective thinking even at the level of learning how to use the program. From this, it was interesting to note that although teachers worked in pairs, there were, in some cases, obvious differences of opinion between teachers grouped together. Comments from teachers indicated that the concept of Reflective Thinking required more clarification:

> I think that the differences in the reflective learning are because teachers have different perceptions of what it really means. It's something that we have always done as teachers and probably students do it but it's hard to pinpoint... (Teacher workshop, May 97)

It was clear from the data that teachers preferred more opportunities for themselves as learners to discuss their questions during their interactions with the program and to engage in inquiry learning during this time. In relation to the Student Negotiation scale, the teachers' interpretations also varied according to the specific task they were asked to complete. Julie explained:

> I did get the chance to talk to other students, I answered it but I know if I wanted to or needed to I could... I knew the opportunity was there to do so even though I answered 5 (out of 25)

However, to a question regarding whether the program encouraged the user to discuss issues that emerged from the program the answer was:

> I think it's a different issue because I think there are other factors that cause you to talk and not to talk rather than just the program. There's another factor not being measured. Like being familiar or unfamiliar, some people like to talk more than others and some persons don't like to look to others. They like the opportunity to think (Julie, Teacher Workshop, May 1997).

It is interesting to note from the graph that most of the teachers agreed that the multimedia program should be Complex and Authentic. This reflects the design of the program which attempts to implement constructivist characteristics. Also, this reflects the constructivist nature of the environment which aims to promote students' negotiations, reflective thinking and inquiry learning.

The Multimedia Program: A Qualitative Perspective

Qualitative data obtained from workshop discussions, extracts from the teacher's journal, and interviews with teachers provided insights into the influence of the workshop on participating teachers. Specifically, the data were gathered from three individuals: Dan, Mark and Julie.

One of the first pedagogical issues that arose, which related to the complexity of the multimedia, was the type of the curriculum material that was used to help the user to navigate through the program. In the first meeting of the workshop the teachers used a Guided Tour which was open-ended and constructivist in nature (Maor & Cooper, 1997a). This style of tour provides little assistance to the user regarding navigation through the program and resulted in some criticism from teachers, as described in Mark's journal:

> My initial use of this program was under the direction of an open-ended guided tour. I found this very frustrating and quite frankly a waste of time....The lack of clear explanations as to where and what everything was, made progress very slow and laborious – it simply could not be done in this way with a classroom of average students. (Teacher's Journal, Dec. 97)

Mark further suggested this in his journal writing:

> A similar approach in a classroom would result in rejection of the program by students. Only highly motivated and academically talented students could hope to cope with this approach (Teacher's Journal, Dec. 97)

Julie also expressed this notion of frustration and uncertainty in the following way:

> I'd like a little bit of guidance to start off with, just to show what's available and not necessarily what to do with it, just what's in there.

A user-friendly program was a necessity according to the teachers. But as suggested by Julie, the program should still be complex to some extent and not too easy for the students.

As a result of the feedback from the teachers I changed the curriculum material to enable the teachers to quickly become familiar with the program and to be able to navigate successfully before being able to engage in higher-level tasks. Although I wanted to introduce the curriculum material in a constructivist way, I realised that I had to find the happy medium in which the user becomes familiar with the multimedia and not discouraged by their first experience.

Dan, in his analysis suggested that the use of the two guided tours, the instructivist and the constructivist, helped him to compare the merits of the two teaching approaches.

The Learning Process

The first data source came from Dan, who is a full time postgraduate student and participated in the workshop to obtain credits for his degree. As part of his assignment he analysed a video recording segment of himself and Mark while they were interacting with the multimedia program during the workshop. His analysis of the video and his self-reflection provided an excellent insight into the hands-on section of the workshop. In particular, he emphasised the benefit of the program to his own professional development.

I believe that the opportunity given to Dan to reflect on his own learning enriched the study and substantiated my interpretations.

Dan's critical self-reflection analysis included his thoughts about working with the program and about working with a partner. He suggested that the cooperation with Mark was a valuable experience enabling him to solve problems in consultation with his partner:

> Working cooperatively with a partner throughout the multimedia program Birds of Antarctica was very useful because we could share thoughts and explanations, and we complemented each other at times. Discussion helped us clarify certain things which we could not have done if we worked individually. It gave me a sense of relief, when I reached a dead end on something, Mark would offer a suggestion which led me to see the problem clearer and closer to a solution.

Nevertheless, Dan was also critical of the teamwork. He felt he had to give up some of his individual plans in order to follow the common goal. His self reflection included the following comments:

> However, there were times when I felt confined to doing only those things that were of common purpose between us. This meant that some of my insightful thoughts were not pursued further. (Dan, self reflection, Dec. 97)

This paragraph demonstrates Dan's role as a learner in the computerised learning environment. He enjoyed the cooperation but was also aware of the limitations of being in a group situation.

In order to answer Research Question Two, 'To what extent did the workshop influence the teacher's role in the classroom?', I studied two of the teachers who conducted research in their classrooms.

Mark was involved in the workshop and, consequently, conducted an action research project in his classroom. Mark used journal writing to document his reflections from the workshop as well as some impressions from his classroom-based research. His notes and the interview conducted with him were used to provide information regarding the extent to which the workshop influenced his classroom practice. Mark claimed that he was familiar with the principles of constructivism as presented in the workshop, but he found the concept of teacher as researcher very valuable. Mark used six critical questions, suggested in the workshop, to analyse the research conducted in his classroom.

> ...the use of 'real life' data and data analysis through inquiry learning as proposed by Birds of Antarctica package addresses the issues of relevance, motivation and scientific method. Through the use of such packages I hope I can further move my class towards student centred learning with my role continuing the change from teacher to guide. (Teacher's Journal Dec. 97).

Reflecting on the learning process in his class, Mark was pleased that students were asked to take ownership of their questions, and he suggested that they should do short presentations for the class.

> The group work was a great success and highlights the need for more regular use of this style of teaching (Teacher's Journal, Dec. 97).

The group work was greatly encouraged in the workshop, and therefore the project gave the teacher the opportunity:

> to take the class into a different style of learning ...it also initiated further discussion within the class room on the nature of learning. (Follow-up Interview)

In a conversation with the teacher he suggested that he would attempt a move towards a more constructivist, student centred approach to learning.

> I will also continue to develop an understanding as to the philosophy of learning with my students. (Follow-up Interview)

These excerpts illustrate that the workshop had significant impact on Mark's classroom practice. Although he was critical about the slowness of the program and its robustness, Mark suggested that:

> The use of the real data and open ended investigations does however appeal to me as a science teacher (Follow-up interview)

Julie, who participated in the workshop and enabled us to conduct research with her students, provided the third set of data. In Julie's class, a research assistant and I conducted the research and therefore the teacher had a passive role in her class. Although Julie actively engaged herself along with the students in the use of the program, the fact that we carried out our study disempowered her from making decisions or guiding her students. A follow up interview with her enabled me to examine the nature of the program and students' involvement in the process of learning with the multimedia. Julie was willing to participate in this research project because she wanted the science students to use this form of technology, and she wanted something useful "that did not have to end in assessment but which could be used for assessment if desired". She also suggested:

> I had been looking for some interactive technology program that was not looking at science content. The process of science could be utilised from the data (Follow-up interview, Dec. 97).

Therefore, the workshop encourages teachers to provide their students with a program which involves inquiry learning. Julie found that this type of learning and teaching process in the class had changed during the two weeks interaction with the program:

> students worked with minimal teacher's supervision, they became more motivated, they were able to ask questions or conduct investigations (Follow-up interview, Dec. 97).

During the use of the multimedia program students, as the teachers at the professional development, worked in pairs and enjoyed the opportunity to discuss and help each other to answer questions. This form of learning was not common to them in the science classroom and Julie acknowledged that the students had more opportunities for developing scientific investigation skills and creative thinking then before.

Summary and Conclusion

The potential of Information Technology to enable students to learn is grossly under utilised in schools. This study, which looked at teacher professional development in terms of developing an understanding of a constructivist epistemology, may be a step towards understanding the problems that are still unsolved in terms of utilising IT in schools. In this particular experiment teachers engaged in a constructivist multimedia learning environment in which they were exposed to the use of the multimedia and the constructivist theory of learning.

Based on the CMLES data gathered during the professional development workshop it is clear that the teachers preferred more opportunities for themselves as learners to negotiate their ideas during their interactions with the computer program and to engage in inquiry learning. They were also given more opportunities to reflect on their own learning and thinking. Teachers became aware of the need to promote critical reflection and discussion among students. This raises the important question as to whether teachers give their students enough opportunities to negotiate with other students, to engage in inquiry learning and to reflect on their own learning.

The teachers' perceived the program to be authentic and complex and this reflected the design of the program and the constructivist nature of the environment. Because of the complexity of the program, a guided tour was necessary to familiarise teachers with the program and help them to navigate through the program. Teachers preferred the instructivist guided tour rather than the constructivist one and the clear instructions enabled them to become familiar with the interface possibilities before they develop inquiry skills in subsequent use of the program.

The personal reflections of the three teachers who were part of a group involved in the workshop suggested that the professional development program was rewarding and useful.

During the professional development program, the teachers experienced as learners the constructivist multimedia learning environment. As a result they:

- became familiar with a constructivist multimedia learning environment;

- understood the context, problems and issues that students face in the classroom; and
- were better able to facilitate students' needs and to enhance their understanding in this learning environment.

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Hierarchial Integration Cognitive and Affective Objectives in the Instructional Sequence of an Interactive Exhibit

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Abstract

Let's Get Physical was an exhibit consisting of six activities designed to assess visitors' physical fitness and to encourage visitors to be active everyday. Visitors recorded their fitness results and later entered their scores into a computer that printed a graph as feedback. The graph allowed visitors to compare their performance to an average Australian of similar age and sex, provided brief information about their physical fitness and advice on improving their performance. The graph was a memento of the visit and was a strategy to encourage visitors to reflect on their physical fitness rating and motivate them to be active everyday. The subjects in this study were Years 10 and 11 students and their learning outcomes were investigated by visit, postvisit and delayed postvisit questionnaires, and observational notes about the tasks exercise activities. The questionnaires investigated the student's learning outcomes by determining their motivation for engaging with the exhibit, their attitude to physical fitness, their perception of their own physical fitness, and their physical exercise intentions and postvisit activity. Information-processing analysis was used to list the students' tasks on a flow-chart, following the instructional sequence. Next, the tasks were mapped with the students' outcomes according to Bloom's educational objectives and Gagne's learning outcomes. The study found that the students' intention for physical activities was a consequence of both their cognitive and affective objectives.

Introduction

SPORTS 2000 was an exhibition on the science of sport designed and built by Scitech Discovery Centre, Perth, Western Australia. The exhibition consisted of 18 sports exhibits and visitors were able to explore the physics, biology and physiology of sports. The exhibit, *Let's Get Physical,* was a mini-gym designed to measure visitors' muscular strength or power, muscular endurance, cardiovascular or aerobic endurance and flexibility. After completing the activities, visitors entered their scores for each activity in the *Let's Get Physical* computer and received feedback about their performance in the form of a graph that compared their performance in the six activities with the range of a person in the Australian population of similar age and sex. The specific objectives for *Let's Get Physical* were not described by the exhibit designers and the exhibit's goal was provided by the exhibition, *SPORTS 2000*, which aimed to encourage visitors to be active every day.

The purpose of the study was to identify the students' cognitive and affective learning outcomes, in the context of the exhibit's instructional sequence. The study used school students as subjects and was undertaken in two stages. Stage 1 identified the students' learning outcomes, and Stage 2 mapped the learning outcomes to the exhibit's instructional sequence. Stage 1 was guided by four research questions:

- Why were students using the exhibit?
- Do students consider themselves to be fit or unfit?
- How important is physical fitness for the students?
- What were the students' physical activity intentions undertaken after their exhibit experience?

Stage 2 was guided by two research questions:

- How do the students' learning outcomes map to the exhibit's instructional sequence?
- What is the relationship between the cognitive and affective learning outcomes and how do these effect the students' behavioural outcomes?

Description of Exhibit

Let's Get Physical consisted of six exercise activities that each tested a component of physical fitness. An orientation label advised the visitor to collect a *Let's Get Physical* Score Card to record their scores for each activity. The exhibit label and score card advised the visitor to begin at the Grip Strength activity and continue as listed on the score card. The activities and the physical fitness component are described below:

1 Grip Strength
This activity measured the muscular strength of the muscles used for grip in the visitor's arm.

2 Step Pulse
Visitors' cardiovascular endurance was measured whilst undergoing exercise. The exhibit label advised visitors to step up and down with a regular and steady rhythm and after 2 minutes to measure their pulse over a 30 s period.

3 Sit Ups
Muscular endurance of the abdominal muscles was measured by counting the number of sit ups.

4 Standing Jump
The power of the visitor's leg muscles was determined by completing a standing jump and measuring the distance jumped.

5 Sit and Reach
Flexibility of the visitor's hamstring muscles and the muscles of the lower back were measured through a movement routine.

6 Push Ups
Modified push ups were used to measure the muscular endurance of the biceps and pectoral muscles by counting the number of push ups completed in 30 seconds.

As each activity was completed, students recorded their results on a score card and when finished, entered these with their age and sex on the touch screen computer. The computer printed the *Let's Get Physical* bar graph, a figure that displayed the visitor's score and a shaded column indicating the distribution for the Australian population of similar age and sex. The graph provided a short explanation of how to interpret the information on the graph and by examining their performance on *Let's Get Physical* graph, a visitor was able to

determine their physical fitness rating for each activity. If their score was within the average Australian distribution for an activity they could consider themself as being fit, and if their score was below the distribution they could consider themself as being unfit.

Stage 1

Determining the Students' Learning Outcomes

Method

On arrival at the Scitech Discovery Centre Year 10 and 11 school students ($N = 63$), visiting the *SPORTS 2000* exhibition, were provided with a Student Visit Questionnaire. The questionnaire asked students to describe their attitude to undertaking physical fitness testing. Students were asked, "Why are you completing the activities in the *Let's Get Physical* exhibit?" In addition, observational notes were taken about the students' attention and engagement with the exhibit. The students' questionnaires were collected with their score cards after they had printed their graphs. For the printing of another copy of their graph for research purposes. The next day at school students answered the Postvisit Questionnaire that assessed their understanding of their fitness level using their *Let's Get Physical* graph. The results of their personal assessment were then compared to their actual fitness level obtained from the other copy of their graph.

Two weeks after their field trip students answered the Delayed Postvisit Questionnaire at school that investigated their cognitive and affective processing of the exhibit's graph, and if they had initiated any physical activities.

Results

Students' motivation to engage with the *Let's Get Physical* exhibit was investigated by the Student Visit Questionnaire. Some students stated that they were not interested in the exhibit and others failed to complete or omitted the Student Visit Questionnaire and avoided the exhibit. The students' responses for engaging with the exhibit were categorised as either:

- Compliant: Students who undertook the physical fitness assessment activities because of the teacher's directive.
- Motivated: Students who undertook the physical fitness assessment activities because they wanted to know their fitness rating and experience their own self-assessment.

From the Postvisit Questionnaire, students' were identified as either understanding the graph or not in terms of their physical fitness. The responses to the Delayed Postvisit Questionnaire identified those students who considered themselves as either being fit or unfit, and categorised students as those who either valued physical fitness or those who do not. Students' responses to other questions were used to categorise students as those who:

- Engaged in new physical activity to improve a poor fitness rating

- Engaged in new an activity to address a weakness exposed by the exhibit and maintained current activity
- Maintained current physical activity
- Ignored the results and undertook no activity.

Stage 2

Mapping the Learning Outcomes to the Instructional Sequence

Method

Two methods of task analysis were used to determine the learning outcomes of instruction of the *Let's Get Physical* exhibit. Information-processing analysis (Merrill, 1987) was used to identify the decisions and actions of the instructional sequence whilst interacting with the exhibit. Following the information-processing analysis, task classification (Gagné & Briggs, 1979) using the learning outcomes identified in Stage 1 was undertaken.

Information-processing analysis of students' interaction with the *Let's Get Physical* exhibit lists the students' decisions and actions whilst interacting with the exhibit. Using the analysis, each of the steps involved in the process of instruction and interaction with the exhibit were listed as tasks to form an instructional sequence. The analysis was undertaken by step by step analysis of what the students do before, during and after interacting with the exhibit. The data to undertake this analysis were obtained from the observational notes of the students' interactions with the exhibit, lesson notes taken whilst visiting the students in class before their field trip to the *SPORTS 2000* exhibition and students' responses to questions on the Student Visit Questionnaire.

Next the tasks were matched to the learning outcomes identified in Stage 1 using a process of Task Classification. The procedural steps identified from the information processing analysis were listed and the decisions, actions and processing for each of the tasks described. As a consequence of the type of action, decision or processing, each step was categorised into objectives of cognitive (Bloom, Engelhart, Furst, Hill & Krathwohl, 1956), affective (Krathwohl, Bloom & Masia, 1956) or psychomotor domain; or learning outcomes (Gagné & Briggs, 1979). Learning task classification provides a means to identify the prerequisites for each of the tasks to be learned and constructed the learning hierarchy (Gagné, 1971) for the exhibit. Though Gagné's and Bloom's classification methods are noticeably different, they have been used to describe the tasks and actions of the students. The difference is their focus. Bloom focuses on an objective, or what was intended, whilst Gagné focussed upon an outcome, or what will result.

Following task classification, each of the tasks listed on the flowchart by Information Processing Analysis were categorised as cognitive, affective or psychomotor outcomes.

Results

The information processing analysis of the students' interactions is described in Figure 1. as a sequence of seven steps. Classification of these identified tasks is shown on Table 1 for the educational objectives and learning outcomes. Here, the cognitive and affective objectives progress up the hierarchy as the student proceeded through the seven steps of the exhibit. For example, the first cognitive objective at Step 1 is 1.0 Knowledge, and progressed to Level 2.0 Comprehension and Level 4.0 Analysis at Steps 4 and 6. Similarly, affective objectives began with Level 2.0 Responding at Step 2, and progressed to Level 3 Valuing at Step 5 (Table 1). Next, the exhibit's instructional sequence was classified according to the educational domains and is shown as a flow chart on Figure 2. The students' objectives are listed on Table 2 and they show an alternating pattern between the cognitive and affective outcomes, effecting the behavioural outcome.

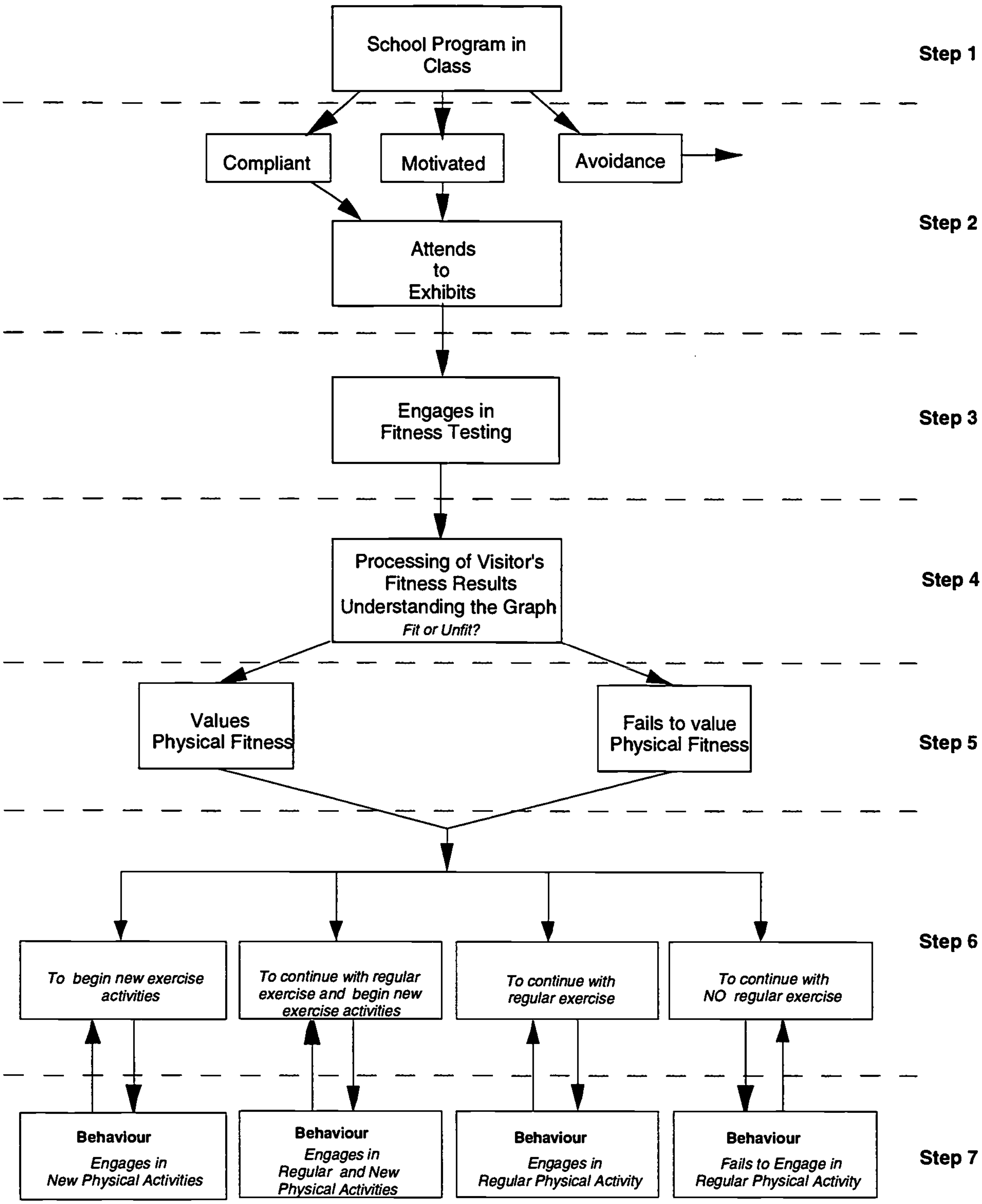

Figure 1. Information Processing Analysis of *Let's Get Physical*

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Table 1. Task Classification of *Let's Get Physical*into Educational Objective Domains and Learning Outcomes

Step	Decisions and Actions	Domain	Learning Outcomes
1	Students exposed to the message of physical fitness at school. The teacher has the students recalling knowledge and processes associated with physical fitness assessment before the field trip to use the exhibit.	Cognitive: 1.0 Knowledge	Outcome: • Intellectual Skills: *Internal and external conditions for learning*
2	After arrival at the centre, students are able to attend to the exhibit or avoid the exhibit. Attendance at the exhibit can be motivated either intrinsically, by the students wanting to determine their physical fitness, or extrinsically where the student complies with the teacher's instruction to engage with the exhibit. Some students who have previously developed negative attitudes to sport and fitness may avoid the exhibit and fail to attend.	Affective: Responding 2.1 Acquiescence to respond 2.2 Willingness to respond	Outcome: • Attitude *Acquired mental state influencing choice*
3	Physical interaction with the exhibit.	Psychomotor	Outcome: • Motor Skill *Executable movement in organised motor acts*
4	The student's cognitive processing of their physical fitness score has the students comprehending the message of the exhibit. After collecting the graph of their performance from the computer the students use knowledge to recall understandings of graphs, comprehension to make sense of the graph and analysis to recognise patterns in the results displayed on different graphs. Students begin to consider their fitness level and relate this to the level of physical activity in their every day life (fit or unfit?). This comprehension results in the students reviewing their level of physical activity. Students decide to engage in physical activities or maintain their current physical activities or avoid physical activities.	Cognitive: 1.0 Knowledge 2.0 Comprehension 4.0 Analysis	Outcome: • Intellectual skill • Cognitive strategies *Skills to manage learning, remembering and thinking* • Verbal information *Skills to comprehend results and graphs*
5	The student has to value and commit himself or herself to the behaviour of regular physical exercise. Here the student has to accept the need of physical activity in their everyday life and desire the physical activity.	Affective: Valuing 3.1 Acceptance of a value 3.2 Preference for a value	Outcome: • Attitude
6	Student develops intention and initiates action to deal with their physical fitness rating. This processing involves knowledge about the benefits of physical fitness, comprehension of physical activity upon oneself and analysis as the student determines what has to be done. The student has to organise their competing intentions and choose to engage or not engage in physical exercise.	Cognitive: 1.0 Knowledge 2.0 Comprehension 4.0 Analysis	Outcomes: • Intellectual skill • Cognitive strategies
7	Enactment of behaviour with student engaging in physical activities	Psychomotor	Outcome: • Motor Skill

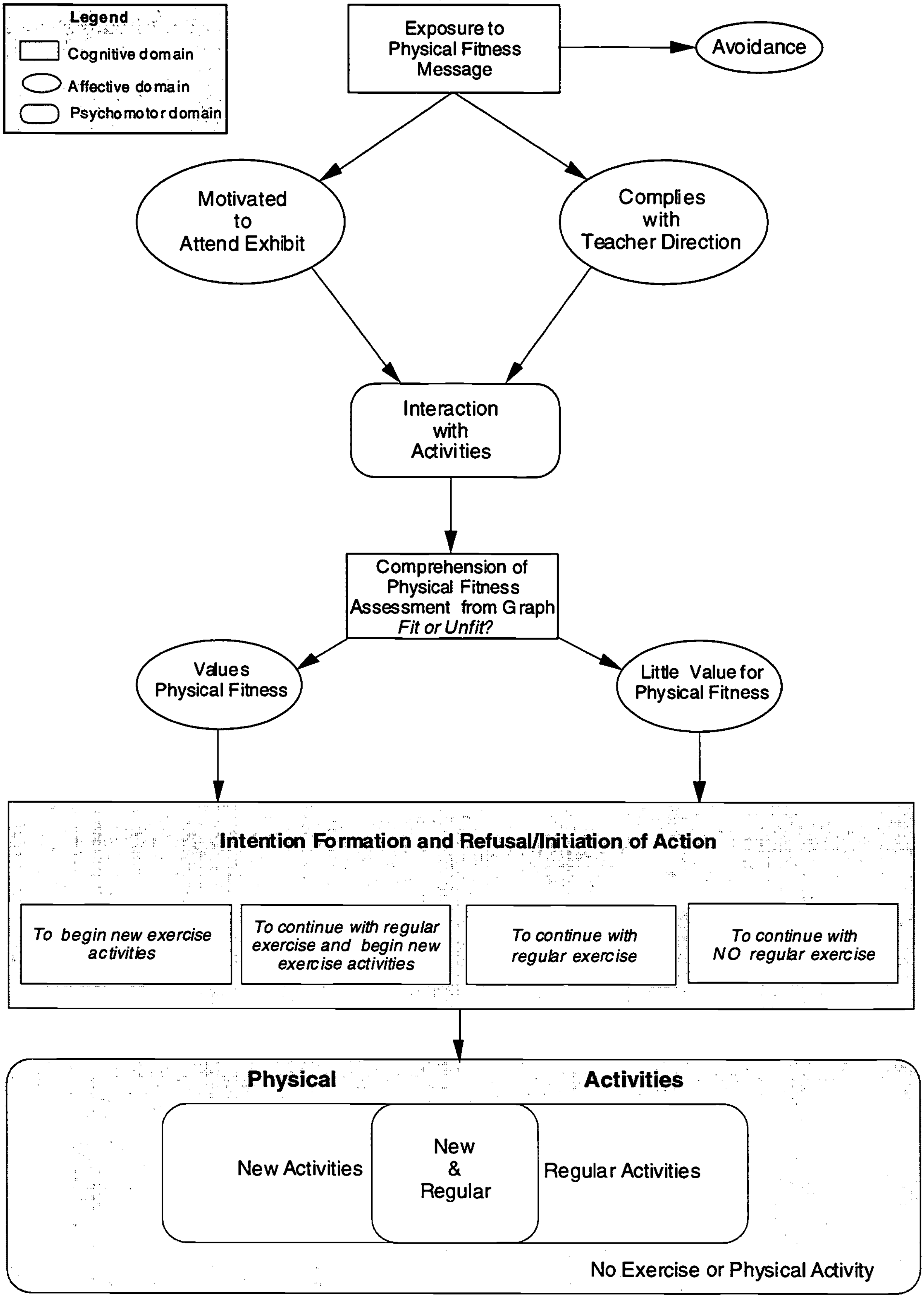

Figure 2. Educational Domains for the Instructional Sequence of *Let's Get Physical*

Table 2. Integrated Pattern of Outcomes for *Let's Get Physical* exhibit

Step	Domain	Outcome
		At School
1	Cognitive	Knowledge about physical fitness and the benefits of regular physical activities
		Exhibit
2	Affective	Interested in physical activities and assessment of physical fitness
3	Behavioural	Interaction with physical fitness exhibit
4	Cognitive	Comprehension of physical fitness rating from exhibit's graph
5	Affective	Valuing of physical fitness
6	Cognitive	Analysis of students' competing needs and the benefits of physical fitness
7	Behavioural	Enactment of regular physical activities

Discussion

The exhibit's strategy to persuade students to be active was based upon an integrated hierarchial pattern between the cognitive and affective domains (Martin & Briggs, 1986). In order to change the students' affective objectives, that is, their attitude to physical activity, the cognitive elements or their beliefs about their fitness rating have to be changed. It was the interaction of the students' attitude to physical fitness and their understanding of their fitness rating that was responsible for their intention or refusal to engage in physical activities following their visit.

The important issue here was the integrated pattern of the two outcomes. McManus (1993) argued that "a distinction between cognition and affect in the evaluation of museum communication is, in general, artificial and unhelpful" (p. 108). She believed this because a visitor's memory and or cognitive processing of any particular concept is "affected as much by the way that an individual values and feels about that particular concept as it is by his or her understanding of it" (1993, p. 108). McManus (1993) believed that the affective outcomes of pleasure, liking, valuing, commitment and integration are concerned with the matters upon which we cogitate.

This interaction between the cognitive and affective outcomes has been demonstrated in other research about children's fitness levels where their exists concern for the use of fitness testing to motivate children to engage in more physical fitness. A study by Douglas (1993) reported that current fitness testing in Australian primary schools does not promote positive affective and motivational outcomes for those children of below average ability. Other studies (Whitehead & Corbin, 1991a, 1991b) have found that if the cognitive feedback

from fitness tests reinforce to children that they are incompetent, there was a greater chance that the children's attitude to exercise will be negative and they will choose not to exercise.

Another researcher has investigated the benefit of positive cognitive feedback to children. Fox (1988) reported that motivation, perceived competence and self-esteem were higher when there was a focus on the achievement of personal goals, rather than on ego involved in comparisons between students or others. He suggested that a stronger cognitive approach should be pursued for the enhancement of students' attitude to physical fitness. Fox (1988) believed that school programs needed to include more cognitive elements and provide information about the what, why and how of physical activity. Instead of informing children about their normative scores, the fitness assessment should have health criterion standards, for example, an award that recognised six weeks of exercise involvement rather than high fitness scores.

The research findings of Whitehead and Corbin (1991a, 1991b), Fox (1988) and those of this study that identified an integrated relationship between the cognitive and affective outcomes, the strategy of *Let's Get Physical* providing normative feedback to visitors to persuade them to be active everyday should be reviewed. Visitors must be provided with information about the benefits of physical fitness and information that encourages their participation in regular physical activity. Any feedback that could result in negative advice, such as normative feedback, should be avoided.

Note: This paper is based on the author's doctoral study at the Science and Mathematics Education Centre, Curtin University of Technology.

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An Investigation of Teacher-Student Interactions in Science Classrooms: Using Qualitative and Quantitative Methods

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Abstract

This paper reports the results of a large-scale survey of science classes combining both quantitative and qualitative data collection. Perceptions of the classroom learning environment were gathered using the *Questionnaire on Teacher Interaction* (QTI) (Wubbels & Levy, 1993). Following statistical analyses of the responses of 3589 science students, in-depth interviews were conducted with students in order to seek to explain student perceptions more fully. The study also enhances our understanding of differences between boys and girls by examining the nature of the interactions between teachers and their students.

Teacher and Student Interaction in the Classroom

Watzlawick, Beavin, and Jackson (1967) described a systems perspective on communication. In this approach 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 this systems perspective in mind, Wubbels, Créton, and Hooymayers (1985) developed a model to map interpersonal teacher behaviour extrapolated from the work of Leary (1957). This model has been used in The Netherlands in the development of an instrument, the *Questionnaire on Teacher Interaction* (QTI), to gather student perceptions of interpersonal teacher behaviour (Wubbels & Levy, 1993). The model maps interpersonal behaviour with the aid of an *influence* dimension (Dominance, D – Submission, S) and a *proximity* dimension (Cooperation, C – Opposition, O). These dimensions are represented in a coordinate system divided into eight equal sectors and every instance of interactional teacher behaviour can be placed within this system. The scales of the QTI correspond to these eight sectors and are labelled as listed in Table 1. For example, leadership behaviour, characterised by a teacher who leads, organises, gives orders, determines procedure and structures the classroom situation is quite opposite to uncertain behaviour, characterised by a teacher who behaves in an uncertain manner and keeps a low profile.

Previous Use of the QTI

The QTI has been shown to be a valid and reliable instrument when used in The Netherlands (Wubbels & Levy, 1993). When the 64-item United States of America

version of the QTI was used with 1,606 students and 66 teachers in the USA, the cross-cultural validity and usefulness of the QTI were confirmed. Using the Cronbach alpha coefficient, Wubbels and Levy (1991) reported acceptable internal consistency reliabilities for the QTI scales ranging from .76 to .84 for student responses and from .74 to .84 for teacher responses.

Wubbels (1993) used the QTI with a sample of 792 students and 46 teachers in Western Australia and Tasmania. The results of this study were similar to previous Dutch and American research in that, generally, teachers did not reach their ideal and differed from the best teachers as perceived by students. Also the best teachers, according to students, were stronger leaders, more friendly and understanding, and less uncertain, dissatisfied and admonishing than teachers on average.

Another use of the QTI in The Netherlands involved investigation of relationships between perceptions on the QTI scales and student learning outcomes (Wubbels, Brekelmans, & Hooymayers, 1991). Regarding students' cognitive outcomes, the more that teachers demonstrated strict, leadership and helpful/friendly behaviour, the higher were cognitive outcomes scores. Conversely, student responsibility and freedom, uncertain and dissatisfied behaviours were related negatively to achievement. When teachers described their perceptions of their own behaviours, they tended to see it a little more favourably than did their students. On average, the teachers' perceptions were between the students' perceptions of actual behaviour and the teachers' ideal behaviour. An interpretation of this is that teachers think that they behave closer to their ideal than their students think that they do.

Variations in the students' attitudes toward the subject and the lessons have been characterised on the basis of the proximity dimension: the more cooperative the behaviour displayed, the higher the affective outcome scores (Wubbels, et al., 1991). That is, student responsibility and freedom, understanding, helping/friendly and leadership behaviours were related positively to student attitudes. Uncertain, dissatisfied, admonishing and strict behaviours were related negatively to student attitudes. Overall, previous studies have indicated that interpersonal teacher behaviour is an important aspect of the learning environment and that it is related strongly to student outcomes.

Levy, Wubbels, Brekelmans, and Morganfield (1997) investigated a sample of 550 high school students in 38 classes composed of three primary investigation groups, namely 117 Latinos, 111 Asians and 322 from the United States. The primary focus was the language and cultural factors in students' perceptions of teacher communication style. This study focused on identifying ways in which the students' culture relates to student perceptions of their teachers. The results from this study suggested that the students' cultural background is indeed significantly related to the perceptions that they had of their teachers' interaction behaviour. The study also concluded that teachers do not seem to be

aware of cultural differences in their interactions with students in their classes in the same way as their students were, despite altering their behaviour in classes with different cultural compositions.

The Australian version of the QTI containing 48 items was used in a pilot study involving upper secondary science classes in Western Australia and Tasmania (Fisher, Fraser, & Wubbels, 1993). This pilot study strongly supported the validity and potential usefulness of the QTI within the Australian context, and suggested the desirability of conducting further and more comprehensive research involving the QTI.

Methodology

The first aim of this study was to provide further validation information for the QTI (in terms of reliability and ability to differentiate between classrooms, etc.) when used with a large Australian sample. Secondly, differences between the perceptions of males and females were investigated. Thirdly, the study sought to investigate associations between the nature of these teacher-student interactions and attitudes of students to science.

The sample was composed of 173 science classes at the lower secondary levels in two Australian states, Tasmania and Western Australia. Only coeducational classes were used in order to permit an unconfounded test of sex difference. The total sample involved 3,589 students in classes spread approximately equally between grades 8, 9 and 10 in 35 different schools. Each student in the sample completed a survey which provided information on the students' sex, perceptions of student-teacher interactions and attitude to class. Attitude to class was assessed using a seven-item scale based on the *Test Of Science Related Attitudes* (TOSRA) (Fraser, 1981).

Following data preparation and preliminary analysis, 80 students in seven schools in both Tasmania and Western Australia were selected to be involved in individual interviews. This selection was based on getting a representative sample of students with even representation of differing attitudes to science and a sex balance and differing responses to the QTI. Typically, six or so representative students from each class were selected by the researchers. The student interviews took about 10 - 13 minutes each.

Results

Validation of the Questionnaire

This study resulted in the construction of a large database consisting of the responses to the QTI of 3,589 students in 173 classes thus providing validation data for the QTI with a large Australian sample.

Statistics are reported for two units of analysis, the student's individual score and the class mean score. As expected, reliabilities for class means were higher than those

where the individual student was used as the unit of analysis. Table 1 shows that the alpha reliability figures for different QTI scales ranged from .63 to .88 when the individual student was used as the unit of analysis, and from .78 to .96 when the class mean was used as the unit of analysis. These values presented in Table 2 for the present sample provide further information supporting the internal consistency of the QTI, with either the individual student or the class mean as the unit of analysis.

Table 1. Internal Consistency (Cronbach Alpha Coefficient) and Ability *to Differentiate Between Classrooms for the QTI*

Scale	Unit of Analysis	Alpha Reliability	ANOVA Results (eta^2)
Leadership	Individual	.82	.33*
	Class Mean	.93	
Helping/ Friendly	Individual	.88	.35*
	Class Mean	.96	
Understanding	Individual	.85	.32*
	Class Mean	.95	
Student Resp/ Freedom	Individual	.66	.26*
	Class Mean	.82	
Uncertain	Individual	.72	.22*
	Class Mean	.87	
Dissatisfied	Individual	.80	.23*
	Class Mean	.93	
Admonishing	Individual	.76	.31*
	Class Mean	.87	
Strict	Individual	.63	.23*
	Class Mean	.78	

*p<.001 n = 3589 students in 173 classes.

If an instrument like the QTI is to be effective it must be able to differentiate between the perceptions of students in different classrooms. That is, students within the same class should perceive it relatively similarly, while mean within-class perceptions should vary from class to class. This characteristic was explored for each scale of the QTI using a one-way ANOVA, with class membership as the main effect. It was found that each QTI scale differentiated significantly (p<.001) between classes and that the eta^2 statistic, representing the proportion of variance explained by class membership, ranged from .22 to .35 for different scales.

During the interviews, students were asked to comment on whether they agreed with the average student perception of the teacher-student interaction in their class. Students were informed that this was a representation of behaviour over time and not just for the last lesson that they had with this teacher. They were asked to comment on each of the eight scales in turn. When asked about the scales students were very cooperative and

listened with interest to the instructions on how to interpret the results. Their responses confirmed the data from the questionnaire and were very close to what the QTI was reporting in all cases. The following examples for the scale of Leadership typifies student responses from a classroom where the students rated their teacher highly on this scale. Pseudonyms are used for students' names.

> Jaqueline: Well compared to other teachers, she controls the students well and I can tell that because everyone is listening to her and if someone is doing something wrong she won't yell at them. She will just say it softly, but everyone does what she says.
>
> Emily: Um, she was able to keep everybody under control and she was like even if they were naughty she was still nice when she got them to work or showed them what to do. She just had a way with people. She was just great.
>
> David: Well, he sort of explains things to us. He is a good influence on us, like he will have fun and stuff but then he will show you that you have to get on with your work and things like that.

As a further example, when we interviewed students from Brian's class where there was a high scale mean score for Student Responsibility and Freedom, we found that the students perceived the teacher in a manner consistent with the data obtained from the questionnaire. Brian was concerned for the well-being of students and understood the need for some strictness, however, he balanced this with the students' need for freedom. One student commented:

> Well science is a pretty dangerous class so you can understand why people just can't run around mixing chemicals and all that kind of stuff so it is understandable why you have to have some restrictions. He allows us to go at our own pace, but he is not very lenient with us, he keeps us on track but that is science I suppose.

Similarly, when students reported in the questionnaire that another teacher allowed less student responsibility and freedom in their science classrooms then their comments supported this feeling.

> Yes, she doesn't seem to trust us. Like for instance we built something and a magnet went missing and we couldn't find it anywhere and she wouldn't let anyone out. We were all kept in the whole lunch hour and then she found it on her desk and she was blaming it on us. We got a big lecture about stealing and things like that. It didn't make me feel good about science that day but overall I like science, especially the experiments.

Student Donna's class rated their teacher low on the Student Responsibility and Freedom scale in their questionnaires. When asked about whether the students are given the opportunity for independent work in her class Donna said:

> She just got us to write down notes from the board and stuff like that. Weren't allowed to talk or anything if you had finished your work and you have to catch up on some other science work then she just won't let you go and finish that. You have to just put down your pens and just stop.

Generally, students expressed agreement with the quantitative results obtained from the use of the QTI. This was consistent whether for high or low levels of teacher behaviours and reinforced the notion that the QTI is, in fact, a reliable, valid and useful instrument that teachers can use to gather data upon which to reflect on their teacher-student interpersonal behaviour.

Student-Teacher Interaction and Sex Differences

Sex differences in student-teacher interactions were examined using a two-way MANOVA with the eight QTI scales as dependent variables. It should be noted that males and females were represented almost equally in the study. Table 2 presents the scale means and standard deviations for male and female students' scores on the eight scales of the QTI. Statistically significant sex differences were apparent in students' responses to seven of the eight scales of the QTI, with females perceiving greater leadership, helping/friendly and understanding behaviours in their teachers and males perceiving their teachers as being more uncertain, dissatisfied, admonishing and strict. Though the magnitude of these differences are not large, the differences generally indicated that females perceived their teachers in a more positive way than did males.

Table 2. Scale Means and Standard Deviations for Male and Female Science Students' Scores on the Eight Scales of the QTI

	Scale Mean		Difference	Standard Deviation		F-Value
Scale	Male	Female	(Female score - Male score)	Male	Female	
Leadership	2.75	2.80	.05	.76	.73	6.54 *
Helping/Friendly	2.78	2.94	.16	.94	.85	36.12 **
Understanding	2.79	2.92	.13	.85	.81	31.15 **
Student Resp/ Freedom	1.69	1.67	- .02	.65	.65	0.01
Uncertain	1.01	0.83	- .18	.75	.67	53.70 **
Dissatisfied	1.20	0.95	- .25	.84	.79	94.15 **
Admonishing	1.47	1.27	- .20	.86	.81	53.77 **
Strict	1.85	1.78	- .07	.67	.64	13.95 **

* $p<.05$ males n = 1844
**$p<.01$ females n = 1745

This was also supported by the interview data. To investigate sex differences during the interviews, students were asked questions about whether boys and girls were treated by the teacher in the same way in their class. The student responses seemed to go some way to explain the sex difference in the questionnaire data. When the comments from girls were examined, it was noted that girls tended to use the terms "interesting" and "keeps us interested" and that they preferred to be in classes with their friends. They suggested that they worked together more and did not like to be in different classes from their friends. Rachel made the point clearly when she said

> Oh, well I was split up from all my friends who are in another class now. I find it easier and more enjoyable in science when I am working with my friends because, I don't know because I get along really well with them and I had no one in this class really who I wanted to work on things with.

Several girls noted that their attitude was positive to science because they had a little more positive relationship with the teacher than the boys. Adrienne suggested that

> Boys and girls are treated the same in this class... but I think the girls, he trusts the girls a little more because the boys are more irresponsible. Like they are the ones that have always stuffed up the experiments and stuff so we can't do it any more and the teacher gives us less experiments to do 'cos of this. I prefer the teacher to be understanding and helping and friendly and with a good attitude. If they have a good attitude then you can usually work with them. I feel good about my science class this year. It is probably the best class that I have had so far.

In contrast William commented from the male perspective on the same issue when he said

> Everyone gets on well in this class but we chose this subject and we chose to be in this class, so we all sort of get on well. I don't really like the teacher because he is not very strict and he doesn't really respect us so we can do what we want really. I get on okay though 'cos I like science anyway even if he is not really happy with us. Well, um, if they are not a nice teacher and if they are sarcastic it makes you feel like I don't want to work either.

From the student responses provided by the interview data it is evident that there are sex differences in the perceptions of students in secondary science classes to the interpersonal behaviour exhibited by their teachers. The students validated what had been reported from the questionnaire data and gave a more holistic and rounded perspective to the conclusions that had been drawn initially from survey data alone.

Associations between Student-teacher Interaction and Attitude to Science

Associations between students' perceptions of student-teacher interaction and students' attitudinal outcomes are shown in Table 3. The data were analysed using both simple and multiple correlations. Whereas the simple correlation (*r*) describes the bivariate association between an outcome and a QTI scale, the standardised regression weight (β) characterises the association between an outcome and a particular QTI scale when all other QTI dimensions are controlled.

An examination of the simple correlation (*r*) figures in Table 3 indicates that all eight scales of the QTI reported a significant relationship ($p<.05$), between teacher-student interactions and student attitude. These associations were positive for the scales of Leadership, Helping/Friendly and Understanding and negative for the scales of Uncertain, Dissatisfied, Admonishing and Strict. An examination of the beta weights reveals 5 out of 8 significant relationships ($p<.05$), which is 12.5 times that expected by chance alone. This more conservative multiple regression analysis indicates that the greatest contribution to attitude occurred when teachers exhibited more leadership, helping/friendly and understanding behaviours in their classrooms and were less strict, dissatisfied and admonishing.

Table 3. Associations Between QTI Scales and Students Attitudinal Outcomes in Terms of Simple Correlations (r) and Standardised Regression Coefficients (ß)

	Attitude to Science	
Scale	*r*	β
Leadership	.54**	.19**
Helping/Friendly	.62**	.30**
Understanding	.57**	.04
Student Resp/ Freedom	.16**	.00
Uncertain	- .34**	- .01
Dissatisfied	- .51**	- .07**
Admonishing	- .48**	- .05*
Strict	- .41**	- .20**
Multiple *R* Correlation	.67*	

* $p<.05$ **$p<.01$ n = 3014

The student interviews produced some interesting data for this section of the questionnaire. One student, Doug, described his likes and dislikes in relation to teacher interaction behaviour quite well. He suggested that

> The way I feel about a teacher definitely affects how I feel about a subject. Well, you sort of walk into a class and think well she know what she is doing so I should know what I am doing and she's working so I should work where if she got up there and didn't really care you would just tend to have the same attitude. Where she sort of takes control and you think she can do it, so can I. I'm someone who likes a fair bit of freedom, as well as having the leadership that she's got I would sort of like to do things sometimes my own way or go at my own pace without having the pressure of doing everything the way she wants you to do it and I would like to try things my way or try different methods of doing things, like assignments and things like that. I'm quite happy this year though.

When Dominic was asked about whether his attitude to science was affected by the type of relationship he had with his teacher he said

> Yes, I suppose that would be correct because there was another teacher which I shouldn't name, and like nobody really gets along with and it shows by their marks and they aren't going to good and don't want to do science again next year. But Mrs E, we don't have a problem with her and we are all enjoying science this year. We know she has to be strict when necessary and understanding and confident at other times. When she speaks we listen as she is prepared to repeat herself when we don't understand and she is just somebody that you feel comfortable with when you have a problem so we don't have a hesitation in asking her a question.

Generally students related that the attitude to the science subjects that they were in was strongly related to how the teacher related to them as individuals. The comment was made by some students that even if they did not like their teacher they enjoyed the subject of science, especially during experiments. In a situation where their attitude to science was greatest, student preferences were for a teacher who frequently displayed those behaviours that had been shown in the quantitative data analysis to be related to higher student attitude.

Conclusions

The study has shown that the integration of quantitative and qualitative approaches has resulted in an increased understanding of the results. Students' comments in interviews supported the results that were collected by the questionnaires. This supported the construct validity of the QTI and enriched the preliminary conclusions that were drawn from the statistical data.

It seems clear from the results of this study that there are sex differences in the student perceptions of student-teacher interactions. Specifically, this study found that

females perceived their teachers in a more positive way than did males. This is encouraging in science and could contribute to the improved enjoyment and possibly achievement of girls in this subject.

Generally, the dimensions of the QTI were found to be significantly associated with student attitude scores. In particular, the study showed that there was a positive correlation between student attitude and the teachers' leadership, helping/friendly and understanding behaviours. Students commented that they had a more positive attitude to their class when their teacher exhibited more cooperative behaviours and less oppositional behaviours. If science teachers want to promote favourable student attitudes to their class, they should ensure the presence of cooperative friendly behaviours. Teachers could now use this information when examining their own learning environments with the QTI to determine whether they are in fact exhibiting those behaviours that have been identified as associated with a more positive student perception of the classroom learning environment.

Further research could involve a longitudinal study of teachers who are implementing the use of the QTI. This could provide a useful insight into the effectiveness of the QTI as a seed for change in the classroom and further enhance our knowledge about the stability of the teacher-student interpersonal behaviour patterns in science classes over time. What is important is that we now have a useful and reliable questionnaire with which to assess the interactions between science teachers and their students.

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How Do We Encourage Higher Level Thinking in Students?

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Abstract

As part of a Curtin University of Technology Staff Development grant, we developed a video package to encourage primary teacher education students to think carefully about the many dimensions of teaching and learning in school classrooms, such as questioning, sequencing activities and making judgements about children's understandings. Our evaluation of the first cohort of students to use the material was based on the range of responses to classroom situations, with levels ranging from superficial to deeper reflective thinking. With such varying levels of interaction possible with the material, we have had some success in our objective, but we found we needed to provide more support to develop students' skills in higher level thinking about teaching and learning processes. Considering ways to encourage higher level thinking in students led to modifications in the way the video was used for students in 1999.

Background

Our work with preservice student teachers and practising teachers through preservice and inservice science courses, has shown us that, given the stimulus of improving children's learning outcomes by developing their own personal knowledge levels, both groups become very keen to learn more science. This is usually not an appealing option if it appears to be solely theoretical and not woven into practical use.

Australia wide research supports our view that primary teachers are uncomfortable with science content, feel untrained, tend not to include it as a key subject, and often teach it from a textbook and not from hands-on practical activities (Smith & Neale, 1989). There is growing support that an effective way to address this problem is to look at the links between teachers' own substantive content knowledge and their pedagogical content knowledge. The focus on pedagogical content knowledge has been stimulated by the proposal 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. This process of transforming subject matter knowledge into a form which makes it teachable to a particular group of children (Geddis, 1993) is the key to our proposal. We are supported by a wide spread trend towards a focus on content in primary science (Kruger & Summers, 1989) as seen in a major project by the Oxford University Primary School Teachers and Science Project (PSTS). The choice of a video format in a higher education context is well supported (Davis, 1993; Laurillad; 1993; Slaughter, 1990).

A major project based at the Open University (Tresman and Fox, 1994) also tackled the lack of confidence of primary science teachers with a focus on distance

learning, using the BBC broadcast system. These materials do not translate well into the Australian context, and more importantly, do not include in their scope a strong linkage between content and process, to directly relate improvements in the quality of student-child interaction to improvements in the individual student teacher's science knowledge. We wish first to set up a powerful need and interest in extending personal science knowledge which is stimulated by practical realities. The workbooks with the UK material bear too strong a resemblance to high school science textbooks, which we wish to avoid with our presentation, as we have found high levels of resistance in our students to work with materials they associate with high school failure and disinterest.

The CUTSD Project

Why did the bulb light up? is an instructional, interactive video (90 mins) funded by CUTSD and designed to tackle a perceived problem with existing unit materials for external (off-campus) students in primary teacher education.

Targeted students for this project are in a preservice science teacher education unit, in their third year of the programme, or Diploma in Education students in a one year option. The videos are readily transferable to internal course students.

Current materials do not sufficiently support student development in two areas that are critical to their success as primary teachers: they do not actively promote development of their personal science content knowledge beyond its present level; and they do not provide focused and personalised feedback on the success of their interactions with children while discussing science activities.

Our approach to counter this problem was to provide video film of student teacher interactions with primary age children engaged in science activities, such as: floating and sinking, layers of liquids, and the chemical energy in batteries and circuits. These were presented as case studies in video format. Each case study was supported by a written commentary from a university tutor, or video of the student teachers talking about the science concepts and principles involved (the content), and the processes of the interactions. Off-campus students watched these case studies, and commented on what they saw. They were able to extend their content knowledge by reading linked information on the concepts and answering questions, then viewing the video again and commenting on how well the student teacher handled the content aspect of the interaction.

Tutor commentary included in the video guided students' reflections on the quality of the interaction from the point of view of questioning technique, appropriateness of response from the students, evidence of changes in the child's understanding, and making valid judgements about children's science concepts.

We have found that critically analysing the interactions of others in a guided fashion is a very powerful way for students to develop their own skills. Of course this

happens in the school experience component of their teacher eduction course, but frequently not with a science content expert, which significantly reduces the learning student teachers make about science specifically.

Students are generally loath to make comments that reveal problems they are having with the science content, or how this is reducing the effectiveness of their discussions and questioning of the child. If tutors can see the student-child interaction, they can give much more personalised comments specific to the interaction, link these precisely to instances in the video, and respond to strengths and problems that are often not included in existing written assignments.

To link the method of instruction to the method of assessment, in the examination for the unit, external students were asked to analyse a transcript of a small group lesson in science. They demonstrated their skills in content knowledge by commenting on the stage of the child's conceptual development, and also on student's interaction with a child, by commenting on the strengths of the teacher and suggesting alternatives to any less appropriate aspects of the interactions.

Evaluation

The draft package was evaluated formally by the target group of off-campus students in first semester 1998, through written surveys. Both the surveys, the assignment and examination responses to the transcript were analysed.

Analysis: Level Guide

In analysing students' responses to questions about specific video segments, four levels were identified. The are listed below, together with sample student responses.

1. Descriptive of teaching/learning strategies.

- It seemed to be like a waste of time as the students wouldn't learn the correct parts of the tongue.
- I think it would be better to encourage students to analyse and interpret their own results.

2. Simple analysis of conceptual development/outcomes.

- So in terms of learning outcomes, younger children are learning to investigate. ... Older children practise investigating a problem looking for evidence.
- I felt that one teacher was able to engage the students better. I think the learning was more beneficial for the first group than the second.

3. Critical analysis of issues in science education, eg. gender, pedagogy, epistemology.

- I believe these students fit into Piaget's concrete operational stage of development where they need to experience something in order to be able to explain it.
- You have to be careful about the concept of 'science' that you are portraying - the idea of some authority 'out there' that the students are inadvertently being compared against is disturbing

4. Constructs own views about science education from experience and evidence

- Children will also learn that by talking about the issues before carrying out the experiment they have a context set for their learning, a reason for doing the experiment, that investigating different ideas is a way to learn and construct new knowledge.

Results

External students were asked to comment on the interaction between student teachers and children, shown on the video. These were in two assignments, and also in the final examination. Internal students commented on one transcript during the examination. Table 1 summarises the analysis of the written responses of students.

Table 1. Levels of Students' Written Responses

	External students (n = 29)			Internal students (n = 47)
	Transcript 1	Transcript 2	Exam (Transcript 3)	Exam
Mean	1.64	1.76	2.30	2.24
Range	1 to 3	1 to 3	1 to 4	1 to 4

There was an overall improvement in the external students' responses in terms of the levels indicated, from 1.64 at Transcript 1, to 2.30 at the end of the course. The external students had a slightly higher mean score than the internal students in the exam transcript. The range of responses was increased, with more external students demonstrating Level 4 responses at the end of the course than at their first assignment. However, the average level is Level 2 for both internal and external students.

Comparison of internal and external students (see Table 2) was through analysis of the examination scripts (transcript 3). The number of responses at each level for the 27 external students (with corresponding numbers for the 47 internal students in parentheses): Level 1: 1 (7); Level 2: 18 (26); Level 3: 7 (10); and, Level 4: 1 (4). It would seem the video supported external students to move into Level 2, as the proportion of external students at Level 1 (3.4%) at the end of the course was lower than that of internal students (14.8%).

Table 2. Levels and Percentages of Students' Written Responses in the Examination

	External students (n = 29) Exam (Transcript 3)	%	Internal students (n = 47) Exam	%
Level 1	1	3.4	7	14.8
Level 2	18	62.0	26	55.3
Level 3	7	24.1	10	21.2
Level 4	1	3.4	4	8.4

Discussion

Most students in both groups demonstrated an awareness of teaching and learning of science with primary children at Level 2. The emphasis in the course on Student Outcome Statements seemed to influence the type of responses students gave. The internal students had more scores at the highest and lowest levels.

Conclusion

Generally students found the videos helpful, particularly as they showed them what was wanted from the course, and provided clear ideas on a starting point to develop their own lesson.

Analysis of how students commented on the transcript during assignments and the examination showed that most responses remained at early levels of development of reflective practice. Student teachers tended to focus on the surface features of the lessons, such as where the children sat, if there was enough equipment, and if the teacher was organised. Too few were able to comment on more sophisticated levels, such as the impact of the lesson on the learning of the children in science, the use of questions to draw out children's understandings, or the conceptual development of children as shown through their own questions.

Analysis supported the observation that the nature of the questions in each of the items, for the examination or the assignments, did not encourage higher level analysis of students' views about science in general and issues in science teaching in general. Therefore, it was the exceptional students who achieved the higher levels.

The Dilemma: How Do We Encourage Higher Level Thinking in Students?

The information gathered in the evaluation was being used to rework the written video commentary improving those aspects that did not appear to have sufficient effect. The reworked commentary includes more direct focus on these higher level skills, such as direct questions about the science understanding of children, the conceptual level of their responses, the understanding of the teacher of the scientific concepts involved.

Assignments for students to submit have also been restructured for these same aspects, and particularly in the area of teaching and learning, rather than just a focus on the teacher.

Clearly, the project has been successful in terms of encouraging greater student engagement with important teaching-learning concepts. However, we also need to do more to encourage higher level thinking. Reworking of the assignments for external students has led to an increase of question types that may prompt Level 3 responses. For example:

- How can this activity help children develop ideas about *Natural and Processed Materials?*
- What open ended, investigative questions could children pose to research for themselves?
- In the video, the teacher demonstrates how to pick up the liquid. Did you explain this in your lesson, or did you provide a challenge to students to try and work out how to do this for themselves?
- What do you think the child or children in your lesson learned? What is your evidence? Give specific examples, including quotes from their responses.
- Comment on this series of interactions in the video (shown at Point 3). Comment specifically on the (i) concepts discussed and (ii) the teacher's responses to student comments:

T: Is that all right? O.K., so what have you understood about circuits?
S3: *They need electricity to, to run.*
T: What about, how, how can you make a circuit, yes?
S2: *They have to be all joined together.*
T: That's right, it has to be joined together correctly, all right (?). And what about a battery, what
does a battery have, has?
S6: *Energy...*
T: Good. Good girl. It has stored energy sitting in there, ready to be used... all right... and what is your task Matthew?
S5: *To make the, um, bulb go, um...* (T: Great) *turn on...*
T: And what are you doing, you're experimenting to...?
S2: *To see if... some materials work..*
T: If they will conduct electricity?
S2: *Yes.*

Continued student monitoring of the project is a key feature, as we believe its success will lie in part in what our students tell us, so feedback by students about the support the video provides will be continued.

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Learning Science Through Design and Technology: A Case Study of an Interdisciplinary Approach

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Abstract

The work reported in this paper aimed to investigate students' learning and understanding of the concept of forces in the context of a Year 9 class studying an integrated technology unit called the Bridge Project. Data consisted of cases prepared from observational field notes and formal interviews with the teachers and five of the students in the class. The results of the case study indicated that all five interviewed students recognised passive forces involved in the equilibrium situation of the bridge and four of the five students appeared to accept a force as a feature of interaction between two objects. The results were surprising when compared with a vast body of literature that suggests that the majority of students of this age associate forces only with movement and as a property of a single object. Several aspects of the course that may have contributed to the students' understanding of forces are discussed.

Introduction

In Western Australia, the recently published Curriculum Framework (Curriculum Council, 1998) describes a new learning area that encompasses subjects such as manual arts, home economics and computing. The learning area of Technology and Enterprise, to be implemented in schools over the next four years with the Curriculum Framework, has a status equivalent with more traditional learning areas such as science, mathematics and English. The Technology and Enterprise learning area is directly linked with the Science learning area in the Curriculum Framework and curriculum integration is encouraged throughout the document.

Calls for the introduction of technology into the curriculum have not been isolated to Western Australia. Price and Cross (1995) suggest that in the United Kingdom this change has been fuelled by economic difficulties and high unemployment and that the aim of these developments has been to make science better understood. This may well be the case in Australia and other countries, but the question remains, what does curriculum integration look like in practice? What do students learn about science when taught in an integrated context? In an effort to address this question, this study investigated students' learning and understanding of forces in the context of a Year 9 integrated technology unit called the Bridge Project.

Integration

The debate over whether an integrated curriculum or a discipline based curriculum is more beneficial for young adolescent students is one that continues with fervent dialogue. Advocates of a disciplinary approach argue that robust understandings of important phenomena and concepts depend on the study of disciplines and the methods and approaches of those disciplines. Conversely, advocates of an integrated curriculum argue that disciplines are historical creations that fragment and compartmentalise knowledge and constrain teachers' ability to carry out learning activities that reflect or connect the way children perceive the world (Hatch, 1998).

A dearth of recent empirical research investigating student learning in integrated contexts has been noted by several educators (Berlin, 1989; Hargreaves et al., 1996). Of the many studies of integration, few have examined learning outcomes, and fewer still report that students in integrated programs do as well as, if not better than students in single subject curricular structures (Vars, 1991). By focusing on student learning of scientific concepts, we hope to begin to understand patterns of learning of traditionally discipline oriented concepts in an integrated environment.

Learning about Forces

The bridge project incorporated many aspects of science and mathematics, but this investigation focused on the students' learning of concepts related to forces. A recent summary of research about students' learning and understanding of forces (Driver, Squires, Rushworth, & Wood-Robinson, 1994) reported that high school students tend to associate forces only with movement, not recognising the passive forces involved in equilibrium situations. For example, a Norwegian study (Sjoberg & Lie, 1981) reported that more than 50% of a sample of 1000 upper high school students did not recognise passive forces. Erickson and Hobbs (1978) found only 9 of 28 (32%) 12 to 14-year-old students recognised forces acting in both directions when a weight is suspended by a fixed string and Minstrell (1982) found that only 12 of a group of 27 high school students (44%) thought that a table exerts an upward force on a book resting on the table. Driver et al. suggested that these results are a consequence of learners thinking of forces as a property of a single object rather than as a feature of interaction between two objects.

Clement (1987) used a series of "bridging analogies" with students to remediate their misconception that a table does not exert an upward force on a book resting on the table. By discussing a book resting on a spring and a book resting on a flexible table and then returning to the problem of the book on a normal table, he found that students were more likely to accept the idea that the table exerts an upward force on the book. A load on a bridge is similar to a book on a table in terms of the equal and opposite forces in action.

For this reason, Clement's (1987) bridging analogies were utilised during interviews with students in this study (see the method for more details).

This study brought together two important avenues of research, firstly an investigation of student learning in an interdisciplinary setting, and secondly, an investigation of students' understanding of forces. By doing this, we hoped to explore whether the contextualised nature of the bridge project was beneficial for students in terms of learning science concepts.

The Bridge Project

The design and technology teacher in this suburban high school, Ms O'Reilly (psuedonyms are used throughout the study), developed an engineering science course incorporating science and mathematics principles and practices within technology projects. The technology studies course is a Year 9 (13/14 year old) optional unit comprising two, one-hour lessons per week. The course attracts a wide range of students of different ability levels. Ms O'Reilly said that regardless of their ability levels, most of the students are "interested and motivated." The class involved in this study comprised 15 male students. The students were involved in several projects throughout the year, one of which was the bridge project.

The bridge project was a five-week course requiring groups of two or three students to role play a bridge construction company. The students were informed that another company had gone bankrupt, leaving one of their bridges unfinished and they were to use the information they discovered about structures to complete the job. Students were asked to produce a strong, aesthetically pleasing bridge, while minimising the cost. Design criteria included a span of 750mm with no support or legs and support capacity of two cartons of coke cans. The bridge was to have a maximum of 25mm vertical deflection under full load, constructed from the materials on the official supply list with tools available in the workshop and cost under $150.00 in 'bridge bucks' (play money supplied by the teacher).

In the first two weeks of the course, the students completed several investigations about structures, beams and bending, joints and jointing, and were introduced to types of forces, the history of bridges and bridge types, before planning their bridges. The students designed, manufactured and evaluated their own bridge before the class evaluation where prizes were awarded to the structure with the best strength to weight ratio, the most aesthetically pleasing bridge and the cheapest bridge that met all the design criteria. A prize also was awarded to the group who submitted the best written documentation of their project.

Method

Seven of the 10 lessons in the five-week course were observed. The first author used field notes to record the activity of the teacher, the students and students' responses to the teacher's questions about their bridges. Interviews with five students were conducted one week after the completion of the course. Students were selected in collaboration with the teacher, with the aim of interviewing a range of academic ability students from as many groups as practical. The semi-formal interviews consisted of a list of prescribed questions, however, the interviewer adjusted the scope of the interview according to individual student's responses. The first seven questions elicited the student's description of his bridge, his reasons for the design, opinions about what was learned during the project and the usefulness of science and mathematics knowledge for the construction of the bridge. The final three questions were specifically aimed at probing the students' understanding of the forces acting when a load is placed on a bridge. These questions were adapted from Clement's (1987) investigations of students' understanding of forces. Students were asked about the forces acting in three diagrams (Figure 1). Diagram A showed a load on a straight bridge, diagram B showed a load on a bridge that was flexed in a downward direction and diagram C showed a load on a spring.

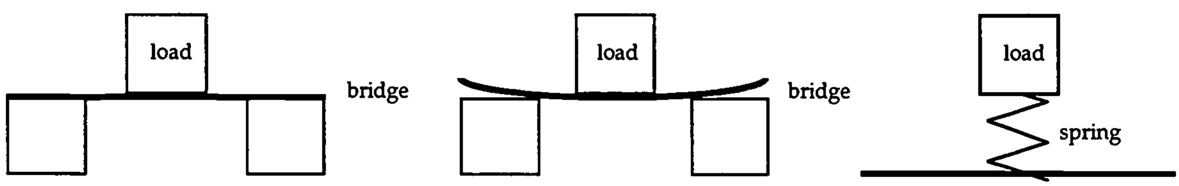

diagram A diagram B diagram C

Figure 1: The diagrams used during interviews with students (adapted from Clement, 1987)

The teacher was interviewed two weeks after the completion of the course with the aim of documenting her general reflections and opinions about integrating science, mathematics and technology through the bridge project. All interviews were audio-taped and transcribed. The students' ideas about the forces acting in diagrams A, B and C were summarised and tabulated (Table 1). The student and teacher interview transcripts and field notes were reviewed by the researchers so that a case story about each of the student's experiences during this course could be constructed. The five case stories, field notes and interview data were used to generate discussion about the aspects of the course that may have contributed to the students' understanding about forces.

Results

The results of the interview are summarised in Table 1 which shows the five students' ideas about the forces acting in diagrams A, B and C. This table is referred to in three case stories about Gavin, Adam, and Lawrence presented below.

Table 1: Student responses to diagrams A, B, and C during the interview.

Student	Response to Diagram A	Response to Diagram B	Response to Diagram C
Gavin	↓ ↑	*	*
James	↓ ?	↓ ?	↓ ↑
Adam	↓ ↑	↓ ↑	↓ ↑
Steven	↓ ↑	↓ ↑	↓ s
Lawrence	↓ *	↓ *	↓ X

Key for Table 1: ↓ – student said there is a force acting down on the load
↑ - student said there is a force acting up on the load
* - question not asked in interview
s – student said there is a small force acting up on the load
? - student said they don't know whether there are any forces acting in that direction
X - student said there is no force acting in that direction

Gavin

Gavin was described by Ms O'Reilly as creative and prepared to take a risk. She said that Gavin asks a lot of questions in class and will (light heartedly) challenge her if he thinks she has made a mistake. Gavin worked with Colby to make the bridge for this project and, like most of the other groups, they constructed a deck bridge from two pieces of plywood with "I" beams in-between. Gavin said they tested different beam structures with pop sticks at the beginning of the project and found that triangles and "I" beams were strong but the triangles were too expensive.

Gavin and Colby spent considerable time during one lesson debating whether to spend more money strengthening their bridge or to make it more aesthetically pleasing. They also said they were wondering whether to do this at all, because the bridge was already strong and they could get a prize for spending less money. They decided to add suspension "because it will add some strength and it doesn't cost very much." Gavin had to work out the cost of the string. He wanted 3000mm of string and he knew that the string cost $1.00 for every 300mm. He had difficulty doing the proportional problem to work out how much he had to pay. Ms O'Reilly helped him work out that the string would cost

$10.00 by doing the cross multiplication on the blackboard. When he saw the calculation he said they do those all the time in mathematics.

Gavin and Colby decorated their bridge with dowel rods and string, spray painted it and covered the ends so that the internal "I" beams were not visible. The students then covered the bottom of their bridge with corrugated cardboard "to make it look good." During testing, when two cartons of drink cans were placed on top of Gavin and Colby's bridge, it deflected slightly, but not more than the 25mm limit. This group won the "best looking bridge" competition and the teacher from the English department who did the judging said that the suspension presented pleasing curves, the bridge had slim, clean lines and the corrugated cardboard was interesting.

Gavin said that their biggest problem during construction was working out how to fix the top deck on their bridge. The glue from the hot glue gun dried too quickly, so they decided to use PVA glue even though this meant the bridge had to be clamped and left to set. They also had difficulty reinforcing some screws and they solved that problem by drilling them into the "I" beams. The students only spent one hundred of the one hundred and fifty bridge bucks they were allocated and Gavin said they could have spent less, but they decided to spend some on decoration. Gavin felt that learning about the "I" beams and triangles being strong structures was important and that his mathematics knowledge was useful for measuring. He also said that his scientific knowledge was useful for finding out a lot about using the "I" beams and the triangles.

When asked during the interview about the forces acting in Diagram A, Gavin said that they were "static" forces because "it's just holding up itself like by the strength of the wood or whatever the materials are". When asked if the forces had any direction. Gavin said that, "mainly it's just, well, the load is pushing down, but it won't go down unless it was going to snap" (Table 1). The interviewer asked Gavin why the load stays there and he answered, "because of the strength of the bridge." When asked if there is a force acting up on the load he said, "I suppose, the strength of the bridge would be pushing up...that would even out until there was a larger load here, then it would overcome this one, which is a set load I suppose, and it would push down and it would break" (Table 1).

Adam

According to the teacher, Adam is a very good practical student, an independent thinker and worker, he is logical and always produces the paperwork. Adam worked in a group of three with Daniel and JJ for this project and they produced a deck bridge that was the lightest bridge in the class that held the required weight without any deflection. The students had tested several structures in class and worked out the strongest. They then did simple calculations to estimate the costs of the various structures. As a result of their calculations, they also decided to use "I" beams, and only spent $88.00 in total. Adam,

Daniel and JJ decorated their bridge with string rails along the edges and they coloured the deck with charcoal. The students made a mistake when calculating the amount of string they needed to go down both sides of their bridge and then had to buy a second piece. The three students were very proud of their bridge because they thought it was strong and inexpensive. When tested, the bridge did not show any deflection under the weight of the cartons of drink.

Adam said that one of the problems they had to overcome was finding a cheap design and that's why they did the calculations to work out which structure would be inexpensive. Adam felt the important things he learnt were the different kinds of structures, beams and triangles, for example, that were alternatives to "just putting planks on planks." Adam found his mathematics knowledge useful for "totalling things up, working out measurements, strength and things like ratios." Adam didn't think his scientific knowledge was very useful for this project, but said it was useful for other technology studies projects like a Lego racing car project. Adam enjoyed the project because he liked "constructing things, problem solving, always doing research and things like that."

Adam said that the kind of forces acting in Diagram A are, "just static forces, hitting one place, just going down... also shear force here [the sides of the bridge], that's a force down and that's a force up like that." When asked to explain further Adam said, "that's [the bridge's] just holding it [the load] there, so there is an equal push down and up" (Table 1). For Diagram B Adam explained that it was the same as Diagram A except there was "a heavier load that had bent the bridge" and for Diagram C he said that "the load is pushing down and the spring's coil is pushing up" (Table 1).

Lawrence

Ms O'Reilly described Lawrence as "capable, a good on-the-spot problem solver, but not an academic kid. He doesn't like the paperwork, I still haven't got his paper work in." Lawrence corroborated the teacher's description when he said, "I enjoyed it [the project], I didn't like all the paper work because it was way too much and she [Ms O'Reilly] made a big deal out of it."

Lawrence worked with David and Cain and made a double layered deck bridge with the bottom layer consisting of "I" beams in-between two pieces of plywood and the top layer comprising a layer of Styrofoam with a third piece of plywood. The group found that the "I" beams were the strongest structure from the testing they did and Lawrence explained how they got their idea for the two-layered bridge.

It didn't take long to make, we "stole" the design from two people's bridges piled on top of each other. We saw them on the desk while people were putting away their stuff and that's where we got the idea.

The main problem for this group was that by the end of the project they had spent eight dollars more than they were allocated. Lawrence said they solved the problem by borrowing the extra money from Ms O'Reilly. Lawrence admitted that the group did not work out how much money their design would cost before they started constructing it. "We sort of made it up as we went along." The double-layer bridge was very strong and didn't deflect at all during testing, but the weight of the bridge was comparatively high, so this group didn't win any prizes.

During the construction of the bridge, Lawrence's group had difficulty adhering the "I" beams with PVA glue. Lawrence said that one important thing he learnt during the project was that "PVA glue doesn't work very well on the plywood for the "I" beams, the glue gun [hot glue] was good with the "I" beams." Lawrence didn't think his mathematics knowledge was useful during the project because the mathematics involved was "fairly simple." Creativity was the aspect of science that Lawrence said was useful for the project, "we sort of painted it, that's the only creativity we used."

When asked about the forces acting in diagram A, Lawrence said that he didn't think there were any forces acting on the load, but there was on the bridge. The interviewer asked him what forces were acting on the bridge and Lawrence replied, "the load." For diagram B, Lawrence thought that there were forces acting on the load, "yes, it's being pulled because this is going down" (Table 1). When asked whether he thought the spring in diagram C was pushing up on the load, Lawrence suggested that "the spring is just sitting there, and this [the load] is pushing down on it a bit. The load is pushing down on the spring, I don't think the spring is doing much at all" (Table 1). Lawrence clarified his explanation by adding, "if it was light, the spring would be real high and the load would fall off and that but, it's all the way down, I don't know how high it is." The extent to which the spring was pushed down was important information for Lawrence to decide whether or not the spring was exerting a force on the load.

Discussion

The results of this case study provide considerable information about students learning science in a technology-based, integrated environment. There is evidence to suggest that the practical, technological experience of the bridge building project precipitated important scientific understandings about forces for the majority of the students. For example, all interviewed students recognised that there were forces in action in diagrams A, B, and C, even though there is no suggested movement in any of these diagrams (Table 1). The results of this study contradict the findings from research discussed earlier that the majority of students of this age associate forces only with movement. Moreover, three of the five students, Gavin, Adam and Steven, clearly recognised that forces were acting in opposite directions in diagram A. Two of these

students, Gavin and Adam, identified some kind of balance between the forces resulting in the equilibrium situation of the load on the bridge. In Adam's words, "so there is an equal push down and up."

In contrast to the encouraging results discussed above, there were indications that some of the students held misconceptions. Lawrence's notion that the load was the force acting on the bridge suggested that he saw a force as a property of a single object (the load) rather than an interaction between two objects. Steven and Lawrence's pondering about the extent to which the spring was pushed down may indicate that they had an anthropomorphic view similar to that described by Viennot and Rozier (1994) where students saw a mass suspended from a spring "as a dynamic conflict between the two objects in which the strongest of them determines a global motion in the direction of its own effort" (p. 239). This brings into question Clement's (1987) and Brown and Clement's (1989) use of the spring as a bridging analogy for understanding the forces involved when a book sits on a table.

While it is difficult to directly attribute students' learning to the bridge project, there seems to be something about the project that switched the students on to a scientific understanding of forces. It may have been one specific classroom learning episode, however, it is more likely to have been a composite of several components of the learning environment that contributed to the success of this project. One aspect of the project that made it different from introductory physics courses was its hands on nature. The students had to physically construct the bridges and test the consequences of putting a load on the bridge. During the course of the project, the students were constantly handling the materials and testing them. James discussed the "tension in the wood" and this association with the materials may have been a contributing factor in the students' understanding of the forces in action.

Aside from the practical aspects of the bridge project, the students were involved in complex problem solving, for example, how to increase the strength of their bridge while keeping costs to a minimum. The problem solving process engaged the students in thinking about the materials available and their properties because they had to make decisions about their bridge based on this knowledge. The testing of beams and structures at the beginning of the course assisted the decision making process. The tests were often mentioned by students as they sought solutions to their problems. For example, Gavin and Colby found from their testing that "I" beams were strong, but the triangles were too expensive, so they used "I" beams for their bridge.

Students were encouraged to be creative and a prize was awarded for the most aesthetically pleasing bridge. This created an alternative dimension to the bridge building project that complicated the process of problem solving. The students had to find solutions for the problems they encountered within parameters for strength, cost and aesthetics. This

engaged the students in complex cost-benefit analysis. The social aspects of the bridge project were apparent. Students within groups worked together to test materials and conferred with each other to make decisions about their bridge. The social aspects of learning also were evident between the groups, for example, when Laurence's group's ideas came from observing two other groups' bridges and Steven consulted Adam about the materials his group had used. The structure of the project itself may have contributed to the students' understanding of forces. Students were introduced to ideas about static and dynamic forces early in the project and the practical and social aspects of the course were likely to have reinforced those ideas. Another important aspect of this project was the content knowledge of the teacher. Ms O'Reilly had a background as an architect with a keen interest in engineering science. Her content knowledge was outstanding and this in itself may have been an important factor.

Although some of the students interviewed from this classroom demonstrated surprisingly good understanding of some of the scientific principles associated with the bridge project, three of the five students did not think their scientific knowledge was useful during this project and one other student identified creativity as the only aspect of science that he used. For example, Steven discussed several ways in which he used his mathematics knowledge during the project but said, "I don't think we did as much science." Not only was there considerable science about forces implicit within this project, students were involved in investigating different structures in a scientific way to help them make decisions about the kind of bridge they would make. Gavin was the only student who said that science was useful for helping him with the investigations. Adam recognised that he was doing "research" when he did the investigations and he said that he liked doing the research, but he did not associate the investigations with science, "I don't think [science was useful] so much for this project, but for some of the other projects."

One possible explanation for this lack of recognition of the science aspects of the technology project is that the students saw science more as a content oriented subject rather than a skill or process oriented subject. Most of the students recognised the process of doing mathematics, however, few students recognised when they were doing science.

The findings of this study were very positive in terms of the students' understanding of the forces associated with the bridge and load structure, especially considering this was not a science class, but a technology class. The results show a wealth of potential scientific learning experiences that may possibly address well recognised alternative conceptions held by a large number of students. While recognising the difficulties in attributing outcomes to particular teaching strategies, there are several aspects of the course that may have contributed to the students' understanding. These included the hands-on aspects of the bridge construction, complex problem solving, testing of beams and structures that assisted decision making, attention to aesthetics, social

interaction within and between groups of students, the structure of the project and the background knowledge of the teacher. It does seem that the pedagogical features of this kind of project offer considerable potential for enhanced learning of science concepts.

Note: This paper was drawn from one submitted to *The Journal of Design and Technology Education.*

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Learning With Freebody®: Importance of Student Collaboration

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Abstract

This paper outlines a study of students' learning of qualitative physics concepts while using the intelligent computer-based instructional program, Freebody (Oberem, 1996). Students' force and motion conceptions, which underpin their ability to construct free-body diagrams, were assessed before and after use of the program and some positive change was noted, but not for all students. The program helped students to confront inconsistencies in their reasoning about Newtonian physics. Students were actively engaged, both physically and mentally, while using the program, contributing to its apparent effectiveness as a teaching tool.

Introduction

Despite the widespread use of computers in learning institutions, there is still little research on the effectiveness of computer programs in bringing about higher order learning and conceptual change in difficult subjects such as physics. In addition, teachers are making little use of instructional technologies, few effective programs are available and teachers often report disappointing results.

Background

Physics is a difficult subject for most students. Many of the basic concepts and ideas of Newtonian physics are at variance with children's understandings of the world (Carey, 1985). Children's alternative conceptions about force and motion, for example, persist into adulthood and prove highly resistant to change (Driver, 1989). Bliss and Ogborn (1994) suggest that an infant's whole concept of 'cause and effect' is learned through and embodied in the conception 'effort produces motion'. Many students rote learn Newton's Laws in school science, assimilating this new knowledge along side existing discrepant or contradictory information. At some time later, or given a new context, they revert to their pre-existing intuitive beliefs (Posner, Strike, Hewson & Gertzog, 1982).

Earlier research (Yeo, Loss, Zadnik, Harrison, & Treagust, 1998) with students learning conceptually-difficult physics using an interactive multimedia program, found that students proceeded too rapidly from one screen to the next, often ignoring instructions, key segments or important details. It was suggested that students placed their own, often

incorrect, interpretations on what they looked at or simply ignored that which contradicted their prior conceptions. Although learner control is increasingly favoured in educational multimedia programs, if such control enables users to avoid confronting and/or resolving their incorrect alternative conceptions, then the program will not be effective.

A free-body diagram is a formal representation of the forces acting on one object. Such diagrams are particularly useful for the study of particle dynamics and in representing information in diagrammatic form prior to solving problem. Some of the difficulties students experience in drawing free-body diagrams relate to being unable to identify all forces present in a given situation, proposing non-existent forces, for example, a force of motion, being unable to identify the objects between which a force is acting and/or suggesting incorrect directions for the force on each. Underpinning students' ability to draw free-body diagrams, therefore, are their conceptions of force and motion.

An intelligent tutoring program consists of three 'models', the Expert Model, Student Model and Instructional Model. The Expert Model contains all the relevant subject-based knowledge in a criterion-referenced knowledge base. The Student Model contains the framework for identifying a user's misconceptions and sub-optimal performance. It contains a database of student misconceptions and missing conceptions. A missing conception is an item of knowledge which the expert has but the student lacks; a misconception is an item of knowledge that the student has but the expert lacks. Problem conceptions are identified from the literature, observation of student behaviour and learning theory of the content domain. In its ideal form, the Instructional Model actively builds up a picture of the user, their strengths and weaknesses, and adapts or designs instructional strategies to meet their ever-changing needs and proficiencies.

Freebody is a commercially-available, computer-based intelligent tutoring program based on the natural language processing system, ALBERT (Oberem, 1994). It assists students to identify forces and practice drawing free-body diagrams. Students are given physical situations and asked to draw the free-body diagram for a named object using the mouse. The program discusses students' diagrams with them in plain English dialogue. The software recognises certain 'misconceptions' about forces and attempts to correct them through discussion. Finally, it asks the student to confirm whether or not the object is accelerating and whether or not there is a net force acting on it. If the student's free-body diagram is inconsistent with either the problem description or their text description, the program tries to negotiate a correct resolution. In this way, Freebody attempts to model a human tutor.

Aim

The aim of the study was to evaluate the effectiveness of Freebody. Two questions guided the research program:

- Are students' conceptions of force and motion changed as a result of using Freebody?
- What factors affect the learning process?

The decision to assess conceptual change rather than students' ability to draw free-body diagrams was made because it was felt that deeper knowledge revision underpinned students' learning to construct such diagrams.

Method and Data Collection

A mixed methods approach was taken in this study. The first question was addressed by analysis of pretest/posttest data. The second question was addressed using an interpretive methodology focusing on student dialogue and actions.

Subjects

The study involved 64 students from five different classes, four at high school and one at university (Table 1). The classes had different teachers. All school students (N=59) were in Year 12 Physics classes and had studied physics in Year 11. The university students (N=5) were studying an approximately equivalent Physics unit but had less formal physics backgrounds. Six students were withdrawn from the data analysis, two because of previous exposure to the program and four because they did not complete the posttest, leaving 58 subjects. There were 26 females and 32 males. Most used the program in pairs although some students expressed a preference to work on their own.

Table 1. Distribution of subjects by school and class.

School/institution	Class/group	N
School A	1	12
School B	2	15
	3	13
School C	4	13
University	5	5

Pretest and posttest

The pretest/posttest was based on the force-concept inventory described by Masur (1997). The selected items were modified in several ways.

- Some contexts were made more familiar to local students.
- The multiple choice format of many items was modified so that students were required to agree or disagree with each of a number of statements relating to a given context.
- For a number of questions, students were asked to give a written explanation for their selected answer.

There were 45 questions in 19 different items. Of the 45 responses, 26 were about the identification of forces acting in given situations and 19 were about the relationship between force(s) and motion.

Other data

The software recorded all student - computer actions and dialogue to provide a 'user history' of interactions, referred to as *log files.* In addition, four pairs of students were videotaped so that their interactions with the program, collaborative actions and dialogue were recorded simultaneously. The computer screen signal was combined with the video and audio signals to produce a single picture-in-picture videotaped image, which facilitated analysis of concurrent student dialogue and actions.

Procedure

Prior to using the program, each student completed the pretest and then after the program were given the same questions as a post-test. Half the students completed the pretest one or two days before using the program and then the posttest immediately after using it. The other half completed the pretest immediately prior to using the program and then the posttest one or two days later. This was to fit in with the timetable restrictions of the schools involved. Students took about 25 minutes to complete pretest and posttest. Most had 75 minutes to work on the program, although Group 3 students had only an hour. Not all students completed the 10 exercises in any of the sessions.

Results

Table 2 lists the pretest and posttest results for all participants and Table 3 shows the results by class groups. The average improvement of 3.8 (14%) out of a total of 45 is significant ($p<0.01\%$). Four of the groups (1,2,4 and 5) made a similar improvement (see Table 3), although one of these (group 5) cannot be shown to be statistically significant because of the small number in the group. Group 3 showed some improvement, however this was not statistically significant.

Table 2. Data for all students on pretest and posttest. (N=58)

Pretest		Posttest		Difference
Mean	StDev	Mean	StDev	between means
27.2	5.8	31.0	5.3	3.8*

* Denotes significant at 0.01% confidence level.

Table 3. Pretest and posttest results for the five different groups.

Group	N	Pretest		Posttest		Difference between means
		Mean	StDev	Mean	StDev	
1	12	27.5	5.1	32.0	5.2	4.5*
2	15	28.2	6.2	32.1	5.9	3.9*
3	13	28.8	5.5	31.0	4.7	2.2
4	13	24.8	5.1	29.4	5.4	4.6*
5	5	25.6	8.8	29.8	5.2	4.2

* Denotes significant at the 0.01% confidence level.

Females (N=26) scored significantly lower than males (N=32) on the pretest but the difference between male and female results on the posttest was not significant as shown in Table 4.

Table 4. Pretest and posttest results by gender

	Mean (pretest)	Mean (posttest)	Difference between means
Female (N=26)	25.0	30.1	5.1
Male (N=32)	28.9*	31.8	2.9

* Denotes significant at the 0.01% confidence level.

Reliability of the test was estimated by a split-half method. The Spearman-Brown coefficients for pretest and posttest were 0.89 and 0.84 respectively.

Discussion

There were large differences between the groups' average pretest results which may be explained by a number of factors; the physics topic they were currently studying, the skills of their particular teacher(s), the students' academic ability or socio-economic status. However, the similar improvement in results for four of the five groups suggests that initially, these students shared some common misconceptions and the program was successful in addressing a certain number of them. The third group had less time to work on the program as well as some computer malfunctions and these factors possibly account for this group's poorer posttest result.

Although the average improvement was about four, the differences between pre- and posttests for all students ranged between -4 and +12. Figure 1 shows the improvement of each student (difference) graphed against their pretest score. A negative correlation was expected, with students having more misconceptions showing greater improvement. The Pearson Correlation Coefficient was -0.43 but for the lower one third of students, the correlation was negligible, suggesting that other factors are important in determining some students' successful use of the program.

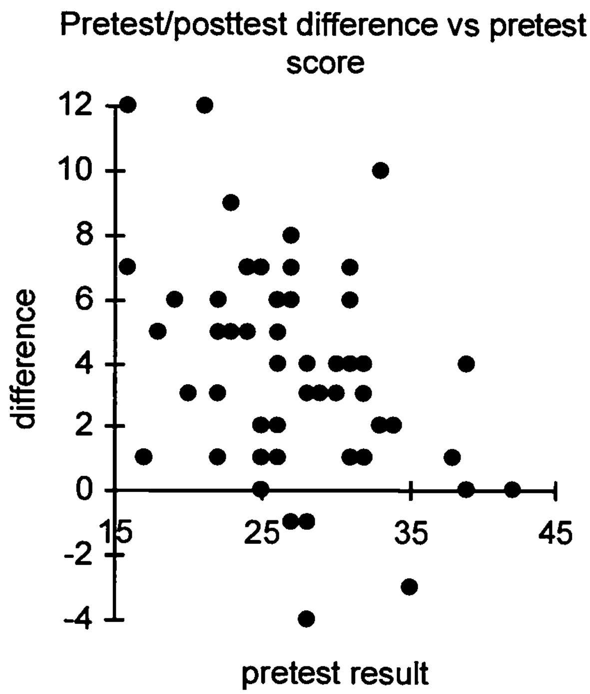

Figure 1. Pretest/posttest difference vs students' pretest score

Females are widely reported as not performing as well as males on standard force-concept inventories although their improvement in this instance was significantly better than the males. Females tend to rote learn their work more effectively (or more often) than males (Novak, 1989) and in this particular topic, rote learning seems a likely way of coping with material that is intrinsically hard to understand. Since this program engaged students in directly confronting some of their naïve conceptions and questioned their expression of rote-learned material, it is possible that the females were forced into a different learning mode. Another explanation is that males under-performed while using the program. A frequency plot of students' average improvement (Figure 2) shows that most students who made little or no improvement were males. One lad, when asked how he went with the program, replied "It didn't teach me anything I didn't already know." Neither this lad nor his partner made any significant improvement. The three who made the

greatest improvement (+12) were all females, each of whom scored below average on the pretest. A large component of the improvement of females may have simply been due to these three students.

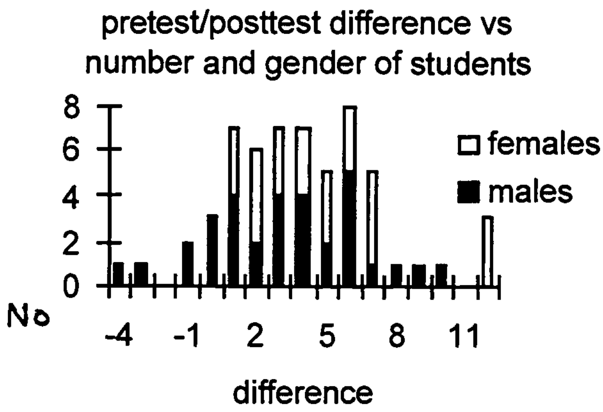

Figure 2. Pretest/posttest difference vs number and gender of students.

Students' attitude to conversing with a computer was not investigated directly, but the study revealed differences in the ways students 'talked' to the computer. Not all students were comfortable with this form of communication, although teachers who were present commented favourably on the animated and collaborative way in which their classes were engaged with the program. There was much argument and debate. Students who worked on their own made slower progress than did students working in pairs, and often demonstrated frustration when they were unable to resolve ideas which were incompatible with those of the computer. Partners shared ideas and experiences and this appeared to place more control of the interaction with the students instead of the computer. While collaboration is not necessarily mutually beneficial (Tao & Gunstone, 1998), in this study it appeared to result in a more positive use of students' time.

The instructional design of the program, which discusses students' ideas and leads them to see inconsistencies or contradictions in their beliefs (where they exist), adopts a constructivist rather than instructivist approach. Sam and Adam had difficulty with Exercise 8, which shows a boy having thrown a rock in the air. They (incorrectly) drew an upward 'propelling' force on the rock. Freebody encouraged them to consider the inconsistencies in their logic.

C: What kind of force is force #1?

S&A: normal force

C: What exerts this normal force?

S&A: boy

C: On what is this force being exerted"

S&A: rock

C: A normal force is a contact force. The boy is not in contact with the rock. Can the boy exert a normal force on the rock?

S&A: no.

C: So what is exerting this normal force which you drew?

S&A: boy.

C: A normal force is a contact force. The boy is not in contact with the rock. Can the boy exert a normal force on the rock?

S&A: Yes

C: I don't see how this can be. A contact force implies contact between the objects.

Sam and Adam's belief in the existence of the force was strong enough for them to assume that their problem was not being able to name the force, rather than it not existing. Sam and Adam then called it a "non-contact force", a "velocity force", a "vertical force", "up" and then back to "contact force". Finally they asked for [my] help.

Int: It [Freebody] wants you to tell it what's exerting that [upward] force.

Adam: The boy, the boy's hand.

Sam and Adam still did not reconsider the idea that there was no force propelling the rock upwards.

Int: Is it possible that there isn't, in fact, any upward force?

Sam: Well, he's thrown the rock straight up.

Adam: [Indecipherable].

Sam: There has to be a vertical [force] cause there's no horizontal component. The rock's going upward so therefore there must be a vertical component.

[pause]

Int: I can't see anything pulling the rock up or pushing it up.

Adam: Well, there's going to be ... gravity.

Sam: There's only gravity.

Int OK, try gravity.

They changed their upward force to a downward force and satisfactorily described it. Sam was still unhappy about their diagram which had only a downward force on the rock.

Sam: There has to be another force.

Adam: I don't reckon there is another force.

These two could not agree to reject the upward force and Freebody was unable to negotiate a satisfactory resolution. Adam reached a conclusion about which he was not sure, but the alternative was at least plausible. Sam remained unconvinced; for him the alternative was still not plausible.

Finally, they settled on only one force, and were able to proceed with the exercise, but the question remains as to the reasons each had for finally agreeing to delete the 'upward' force. They either rejected their original idea because there was nothing which *could* exert a force upwards or they rejected the idea because it became the only solution to the dilemma that they faced. If the first, it represents an important cognitive step for these two. If the second, then it may simply be a rote-learned response, and not necessarily transferable to another context. The question in the posttest was perhaps similar enough in context for these two to apply their new 'knowledge'.

Sam and Adam were a typical pair. They had difficulty thinking about forces from 'first principles' and often quoted half understood statements or ideas as justification for their ideas.

Alan: Yes, I'm sure there is [a force acting down the plane], I've seen it in a physics book.

In this case, Alan has confused a resultant force vector with applied forces. At no stage did they try to identify the second object involved in the action of any of the forces, suggesting that the ideas behind Newton's third law were not an integral part of their thinking. This is also evidenced by their unsuccessful attempts to name the type of force by its apparent effect rather than by its nature or origin.

Hence, some of the factors affecting the conceptual change process for Sam and Adam were:

- the high status or strength of their naïve force and motion conceptions.
- their failure to understand or account for the action of forces between two objects.
- their mutual collaboration which enabled each to examine their beliefs and understandings.

Conclusion

Freebody provided a successful learning experience for most of the students in the study. The interactions between the students and computer resulted in many of the students reassessing some key force/motion conceptions. It did not prove effective for all students and this result needs further investigation. It should also not be inferred that the measured conceptual change is permanent; a delayed posttest would be needed to examine stability of changes. Females appeared to gain more by using the program than males. The collaboration between students also contributed to their successful use of the program.

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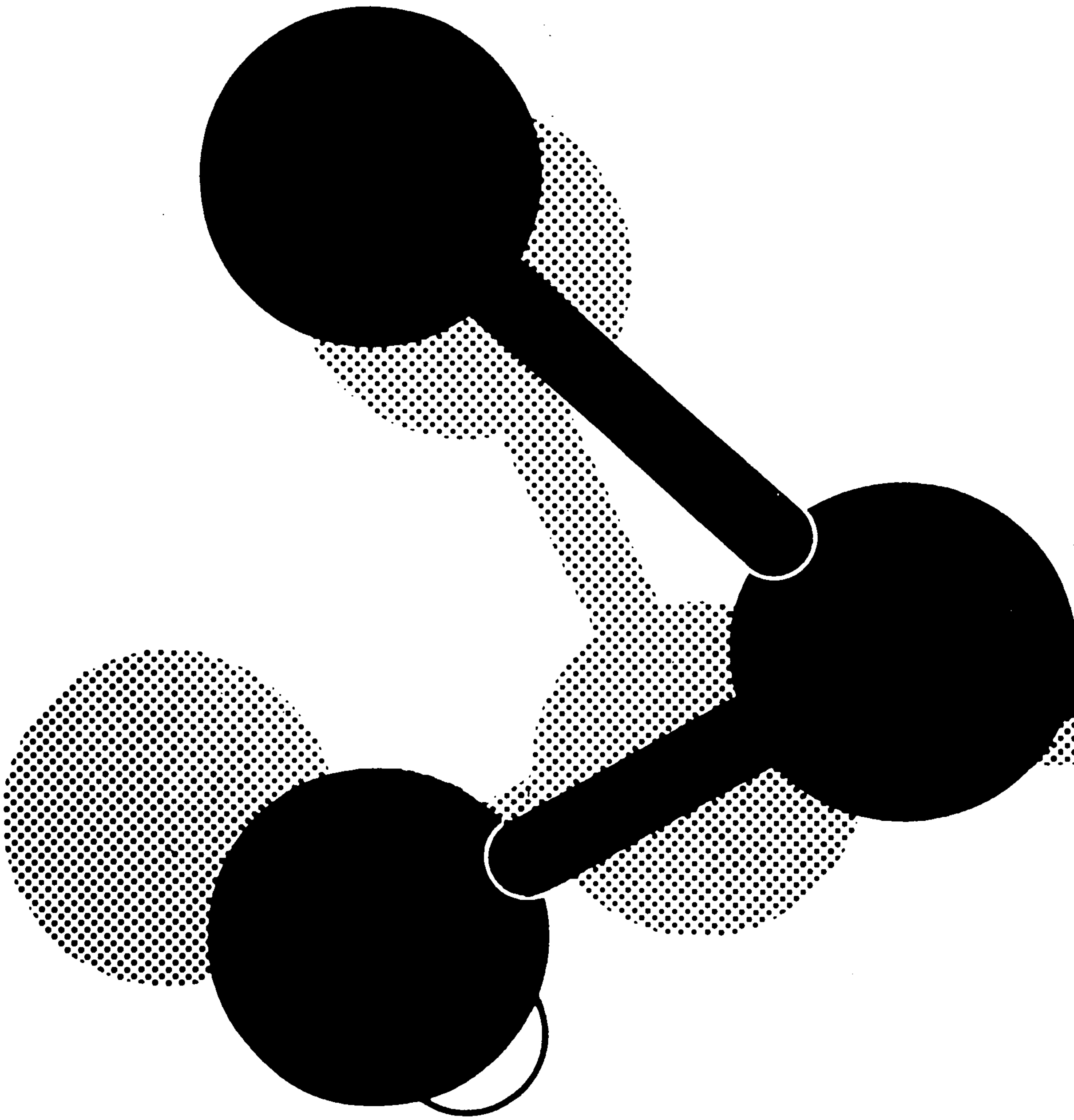

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