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ABSTRACT

This paper discusses a research project that investigated the effectiveness of student surveys administered to eighth grade students on student involvement and learning. The surveys are called "Thinking About" and are presented at the beginning of each chapter in Core Science Textbooks. Two exercises were chosen for the study--chemical or physical reactions, and the language of chemistry. Results suggest that a simple survey can reveal students' ideas and act as a suitable starting point for the initial study of science or further study of a topic. (Contains 15 references.) (YDS)

Theory into practice - the translation of research findings into the classroom

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A science teacher, when asked how he is surviving the present curricular changes in NSW, replied "We are continuing to do the best we can". This is, perhaps, an understandable comment in view of the tremendous load that has been imposed on schools in 2001.

The pressures felt by science teachers today did not commence yesterday. In the 1980s ideas about the meaning of teaching and learning changed. The learner emerged as the prime actor in the teaching/learning process. The teacher was seen as a facilitator of learning. This differed significantly from the previous picture of the teacher transmitting knowledge which the learners instantly absorb. Although most classroom teachers did not realise it, it was - and is - a challenge for teachers.

The statement by Ausubel (1968):

> *The most important single factor influencing learning is what the learner already knows; ascertain this and teach him accordingly.*

was built on and interpreted in different ways by Ausubel himself, by Gagne and White (1978), Driver, Guesne and Tiberghien (1985), Osborne and Freyberg (1985) and others. Driver et al (1985) surveyed and interviewed large numbers of children in the UK about their ideas on scientific phenomena. They concluded that

> *children do not adopt new ideas or change their existing ideas radically in the period of time usually allocated to a lesson or even to a sequence of lessons. They may however be encouraged to use accepted scientific ideas in a progressively wider range of situations over an extended period of time.*

The authors add under a heading *Some issues for curriculum planning*

> *Conventionally curriculum planning in the sciences has started with a conceptual analysis of the subject matter itself. Possible teaching sequences are prepared by analysing which are the most basic ideas from a scientific perspective and building the curriculum from there. We would argue that the evidence from this book suggests that our science schemes may make assumptions that children have already constructed certain basic ideas and this may well not be the case. Ideas such as light travelling through space, matter being conserved or the Earth as a sphere in space may be assumed to be a starting point in our teaching schemes yet they may not have been constructed in a meaningful way by pupils taking the science courses.*

Driver's group developed CLIS or Children's learning in science at Leeds University.

Osborne, Freyberg and co-workers were also conducting student-centred research at the University of Waikato in New Zealand. We may be tempted to look at Driver's team and Osborne and Freyberg's team as the Darwin/Wallace pair of children's learning!

Osborne and Freyberg (1985) said:

> *In our interview work over the past few years we have frequently been surprised at*

the extent to which children cling to their existing views and delay accepting an alternative view in spite of learning experiences that have been provided prior to the interviews. Yet as teachers most of us tend to assume that when we have taught something by outlining it verbally - perhaps on just a single occasion - then it will be learnt by those who have heard it or read it in the way we intended. What is in fact generated by a learning experience will vary tremendously from one experiment to another.

And they add

without some appreciation of the learner's existing framework of ideas and the extent of the modification needed for him to appreciate what is being taught, successful teaching becomes more difficult.

These researchers were instrumental in developing the theory of constructivism by which learners construct their own ideas based on what they already know and on what they consequently learn. Learners generate new ideas by modifying prior ideas.

Many teachers have become increasingly aware of the value of engaging students in the pursuit of skills and knowledge and of making learning a shared experience. There have been some notable examples of student-centred learning such as the PEEL project (1992). Yet the majority of teachers do not seem to know where to begin or the extent to which changes to their classroom practice might be feasible. More immediate demands can also interfere with intentions to become more student-centred - for example, curriculum changes.

Australian curricula, including science curricula, have changed to become more outcomes-based. A National Statements and Profiles document for each learning area was prepared in Australia following a declaration on schooling made in Hobart in 1989. This declaration and the Statements and Profiles documents were part of a national initiative in education with a view to implementing a national curriculum. However these initiatives broke down in 1993. Each state and territory then developed its own new syllabuses. These syllabuses retained some or part of the original profiles. As the recent Goodrum, Hackling and Rennie (2001) DETYA Research Report "The Status and Quality of Teaching and Learning Science in Australian Schools" points out:

However there remain features from the national statement and profile in all syllabuses, curriculum and assessment frameworks. These include a rationale for school science based on scientific literacy for all students, a focus on learning outcomes rather than on what should be taught, a link between outcomes and making improvements to students' existing understandings and skills so that learning is seen as progressive and developmental. The focus on content to be covered has been replaced with a focus on development of broad conceptual understandings that help students understand the world around them and become informed and responsible members of society.

And

On the whole, the current science syllabuses and curriculum frameworks provide an appropriate modern and progressive vision of the intended science curriculum.

From this it is evident that research on students' learning has been integrated into the syllabus.

So while attention to the new stages 4, 5 and 6 syllabuses is necessary, teachers might be advised not to lose sight of their classroom practice. The syllabus implies the importance of classroom practice. It is the teacher-student interaction that is at the core of the learning process, whatever the content areas of the syllabus. The teacher plays many roles - adviser, challenger, listener, debator, researcher, informant, facilitator to name a few - as students grapple with new concepts and clarify their ideas. There are initiatives such as the Quality Teaching Program. Yet every teacher has the capacity to begin to make changes to his/her practice.

The views above are supported by Goodrum, Hackling and Rennie (2001) in their report as they discuss the results of their research:

The picture of the curriculum emerging from this research reveals a gap between the intended curriculum of today's science curriculum frameworks and the actual implemented curriculum. -----There is concern that, in some schools, the type of science being taught and the learning outcomes being achieved are not those that prepare students for the future world in which they will work and live. For most lower secondary students, the science they are taught lacks relevance to their needs and interests and fails to develop key aspects of scientific literacy. Only about one fifth of lower secondary students report that science lessons are relevant or useful for them very often or almost always. ----which raises questions about the appropriateness of the selected content and learning contexts.

This researcher has sought ways of helping teachers to implement some research findings into their classrooms. When writing a series of Core Science textbooks aimed at lower and middle secondary school students, (with co-author Marian Haire in NSW and Graeme Lofts and Merrin Evergreen in Victoria), student surveys were included at the beginning of each chapter. They are called "Thinking about". They have been designed to tap into students' minds to collect their views and ideally they should be subjected to a short analysis by the teacher. Feedback of the results to the students is then recommended as a suitable starting point for a unit of science work. This has advantages both before 'new' concepts, knowledge and skills and when reviewing pre-taught concepts (before progressing to develop the concepts further).

Now that the texts are published and in use in schools, it was decided to trial some of the Thinking About exercises in school classrooms. The results have then been used as a model for how they might provide student involvement at the start of a unit of science work.

This paper will describe these trials, their analysis and how the survey results can provide a valuable approach to student learning if they are shared with the students.

Methodology

The Thinking About exercises were chosen from page 53 of Core Science 2 (see Appendix A). Two exercises - Chemical or Physical Reaction and The language of chemistry - were completed by the students.

1. Chemical or Physical Reaction was administered to two year 8 classes (13-14 years old) in two different schools A and B. School A is a Catholic systemic co-educational school and school B is a single-sex (boys) state school. Each class was ungraded and the students had a little experience of the topics (see table 1). On all occasions the survey was administered without any notice to the students so that their views - as they are - were canvassed.
2. The Language of Chemistry was administered to the same year 8 class in school B only. Again it was conducted without any notice to the students.

This information is summarised in table 1.

Table 1. Data on the students who completed the surveys

Survey	Students	Prior experience
Chemical/physical reaction	Year 8 school A. Ungraded class	Physical change had been covered; mention of chemical change
	Year 8 school B Ungraded class	Physical change had been covered; "touched lightly" on chemical change
The language of chemistry	Year 8 school B Ungraded class	Students had very generally covered atoms, molecules, solids, liquids and gases

Results and analysis

There are two parts:

1. the results and analysis for Chemical or Physical Reaction
2. The Language of Chemistry.

The data was processed by:

(a) categorising the responses
(b) counting the responses and finding percentages
(c) listing student comments for each category of response.

This was done to

(a) convert the data into a form in which the teacher-researcher could make some decisions about the format of the discussion when sharing the results with students
(b) produce a short report of the results of the survey for students either as a hard copy for each student or on an OHP

Results 1. Analysis of situations for chemical or physical reactions

This exercise asked students to analyse situations and state if there are chemical or physical reactions occurring in each situation. Explanations were asked for in each case. Not all of the situations have been processed and analysed here. Both the percentage responses and the students' explanatory comments were processed and have been reported on separate tables.

The processed and analysed situations were:

(a) Situation 1. The bike accident and bleeding
(b) Situation 6. The birthday photographs

Results 1. (a)

Table 2.1.
Percentage of students choosing a chemical or physical reaction
(numbers of responses have been recorded in each case and % of responses in brackets)

Situation	School A		School B	
Bike/bleeding	**Chemical**	**Physical**	**Chemical**	**Physical**
falling off bike bleeding arm cleaning the wound resting afterwards	15 (50%)	15 (50%)	7 (33.3%)	21 (66.7%)

Table 2.2.

Some students' explanatory comments for the bike/bleeding situation
(comments within each reason are labelled a), b), c) etc.,)

Scientists viewpoints	Students who chose chemical	Students who chose physical
The loss of blood is physical. The clotting of blood is chemical.	**Reason 1 - There is a chemical reaction in the blood to clot it** a) Yes - as when the skin hit the ground, the chemicals reacted in the blood so the blood would clog and a scab would form.	**Reason 1 - it's just a physical reaction** a) It was a physical wound b) No chemicals involved so no reaction c) When cleaning the wound, you are not actually killing

	b) Yes - it's a chemical reaction because he cleaned the wound allowing the white blood cells to stop the bleeding. **Reason 2 - There is a chemical reaction between the substances used to clean the wound and the blood** c) Yes - you clean the wound with something like Dettol and the bleeding ceases. d) Yes - because there are chemicals in the stuff you clean the wound with. e) The wound is cleaned and what you cleaned it with caused a chemical reaction. f) The disinfectant may interfere chemically with pathogens at the site. **Reason 3 - Blood reacts with water** g) Yes - the blood has a reaction with the water **Reason 4 - a cut causes bleeding** h) The cuts caused it to bleed i) If you get a graze on your leg it bleeds. j) The bleeding happened as a result of the cut from falling off the bike k) As soon as he fell off, the gravel cut him and made him bleed	germs and dirt; you are just washing them away so no reaction d) Bleeding is blood escaping, completely natural just as water would fall out of a jug. e) The blood does not mix with anything f) No chemicals involved g) The cut was caused by a physical action h) The bleeding happens physically inside our body and stops **Reason 2 - the chemicals used to clean the wound stopped the bleeding** i) Cleaning and tending the wound made it stop bleeding j) Only cleaned the wound to make it stop bleeding. **Reason 3 - No chemicals over the boy or in him** k) No - because he fell off his bike and didn't get chemicals poured onto him. l) No - the boy does not have chemicals inside him to cause a chemical reaction **Reason 4 - Healing stopped the bleeding** m) No cleaning the wound did not stop the bleeding; it stopped when the wound started to heal.

Analysis 1

Table 2.1. shows that students were divided in their opinions as to whether chemical or physical reactions were involved.

Table 2.2 shows that different students extracted different mini-situations from the main situation. Most concentrated on the bleeding; a few on receiving the cut. They had some interesting ideas on these mini-situations, for example that it is the chemicals used to clean the wound that are clotting the blood (stopping the bleeding). Two students gave reasons very close to those of scientists' views - reason 1 for chemical. These data are very suitable for sharing with the students and so commencing the unit of work on chemical reactions.

Use of the data to start a unit of work

Ideally these data should be shared with the students. Comments such as "most students think that bleeding is a physical reaction" and "not many students thought of blood clotting" (then reference to some student comments) might be appropriate. This approach shows that the students' views are respected and can form the basis for further exploration.

A discussion at this stage can enable students to reflect on their views ("what **is** a physical reaction?" and "what **is** a chemical reaction?" "what **is** bleeding" etc.,) and suggest what might need to be done to develop further skills and knowledge. The "bottom line" however is "this is what you think now. So —–let's find out". It might be an exciting way to start a study of chemistry.

At no time should individual student's comments be identified. The entire analysis should be anonymous.

Results 1 (b)

Table 2.3. Numbers and percentages of students who chose chemical or physical

Situation	School A		School B	
birthday party	chemical	physical	chemical	physical
photos of blowing out candles photos turned out well will return to developer	18 (64.3%)	10 (35.7%)	18 (64.3%)	8 (35.7%)

Table 2.4. Some students explanatory comments for the photograph situation

Scientists viewpoints	Students who chose chemical	Students who chose physical
Developing photos involves a chemical reaction. Light forces an electron to jump from a bromide ion to a silver ion so that from silver bromide, silver and bromine are formed. Colour photography involves similar principles.	**Reason 1 – chemicals are needed to develop the film (no details)** a) The film and the chemicals used to develop the film cause a chemical reaction and that is how the film is developed . b) The chemical on the paper reacts with the chemical on the film c) As the film is processed it goes through a chemical reaction d) You have to put in some chemicals to make the photo e) Photos are produced using chemicals to bring out the picture f) The photos are processed and they need a chemical reaction to come out the way they do g) The processes used for producing photos is a chemical reaction h) Yes - because it is changed by chemicals i) Yes - because chemicals are used to develop photos j) Yes - the chemicals placed on the photo change into colours **Reason 2 – Light and chemicals are involved** k) Light and chemicals affected the film **Reason 3 – because it is not reversible therefore it is a chemical reaction** l) You can't get it back the way it was m) Because you can't get back the film again n)Yes - because the negative is permanent; you can't change the pictures o) Because the photo cannot go back to a film	**Reason 1 – no chemicals are needed** a) No chemical reaction. The film gets processed by machine b) No the film just gets printed on c) There is no chemical reaction d) No chemical reaction **Reason 2 – because it is reversible is a physical reaction** e) The photos could be processed again

Analysis

The majority of students recognised a chemical reaction as part of the process of developing and printing photographs.

The reasons showed that the interaction of light and chemicals was identified in only one case. The concept of the reversibility/irreversibility of physical and chemical reactions was used by some students.

Killen (1998) reminds us that students frequently use **everyday thinking** yet they need to be more precise and accurate as they develop **academic thinking**. Academic thinking does not come naturally to many students. There are many examples of everyday thinking in the results of the surveys reported here. Killen suggests that we point out this dichotomy to the students and encourage them to put more effort into their learning so that academic thinking can become an additional skill to help them make sense of the world and to make decisions and choices in our ever more complex existence. Students may adopt academic thinking in rote learning for examinations but it may not be internalised. It needs to become a way of thinking that can be developed through classroom practice. Skamp (1998) points out that the earlier in a student's life that this occurs the better.

Use of the data to start a unit of work

As in 1(a), sharing the data with the students, discussing them and deciding a future course of action is appropriate.

Results 2. The Language of Chemistry

In this exercise students were asked to write their definitions of an atom, a molecule, a solid, a liquid and a gas. It was completed by the year 8 students in school B

The definitions of an atom and a molecule were analysed and are reported below.

Figure 1.1. Students' ideas about the nature of an atom (numbers and % of responses in brackets after each response)

(in some cases students' comments have been given)

An atom is:

1. a very small **thing** (6 - 25%)

typical comment: the smallest thing on earth

2. a small **particle** (6 - 25%)

comments:
a) a particle that cannot be broken down further
b) the smallest particle that you can find
c) the smallest type of particle

3. a **molecule** that makes up a substance (3 - 12.5%)

4. a single **element**/part of an element (3- 12.5%)

5. the smallest **form** of a substance (1 - 4.2%)

6. [illegible]

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6.	an **electrode** (1 - 4.2%)

7.	a tiny **cell** (1 - 4.2%)

8.	**no definitions** given but some **property** of an atom
	(comments follow) a) it cannot be broken down any further b) atoms make up a substance c) what everything is made of

Analysis

In general students did not know how to define an atom and this may be a language problem (as evidenced by the definitions in category 8). However a few students did identify it as a small particle which quite an adequate definition for year 8 students. Some of the other definitions are puzzling.

Use of the data to start a unit of work

The suitability of the particle definition could be emphasised in a sharing/discussion session with the students. The other puzzling definitions could be open for discussion. It might lead to "let's find out more about the atom" as the starting point of a unit of chemistry.

Figure 1.2. Students' ideas about the nature of a molecule

These results are presented so that each definition is followed by all the comments that were given

1.	composed of atoms
	a) it is made up of atoms and elements b) made up of many atoms c) a group of atoms d) lots of atoms in a group

2.	atoms joined together
	a) two or more atoms joined together b) more than one atom put together to make a substance

3.	biological definitions
	a) little living things b) a material in a body c) little particles such as water d) a "drop of something" such as water e) part of a cell

4.	miscellaneous
	a) what an object is made up of b) a molecule is made up of two or more elements c) made up of more than one mixture d) what everything is made up of; very small

e) a little part of an object

5.	confusing definitions
	a) a molecule is made from an element b) more elements make up a compound but it just makes up an element c) molecules make up an element d) the atoms that form a substance

Analysis

Many students recognise that molecules are small particles composed of atoms. The students who gave definition 1 did not emphasise that the atoms are joined together. The students who gave definition 2 did recognise this.

The biological definitions are puzzling as are the definitions placed in category 5. These data provide many opportunities for discussion and a lead in to a further study of chemistry.

Use of the data as the starting point for a unit of work

These data provide an excellent opportunity for a productive discussion on molecules.

Following a sharing of the data with the students, the use of models might emphasise the differences in students' definitions. For example to illustrate definition 1, some small balls (ping pong or golf or small rubber balls or other smaller spherical structures) could be used to represent atoms as follows;

> Place the balls (either the same type or a mixture of different types) into a box and ask the students does that satisfy definition 1 (it does, in fact, satisfy definition 1).

This may lead some of them (especially those who gave definition 2) to speak about the fact that the atoms are joined together in molecules. Further discussion with these models might cover the particles – do they have to be the same type of atom or could they be different?

The students could be invited to analyse the biological definitions, miscellaneous and confusing definitions also. If the teacher is puzzled, perhaps the students could help him/her!

Certainly it should clarify concepts and serve as a good introduction to a further study of chemistry.

Conclusion

This report has shown how a simple survey can reveal students' ideas and act as a suitable starting point for initial study of science or further study of a topic. It is based on some of the main features of constructivism – for example that of knowing something of what one's students are thinking so that we may teach them better and they may learn more effectively.

But – if the question still remains "why do it?", the following reasons may prove convincing:

1. Before embarking on new knowledge and skills, it can act as an appropriate **starting point** (many students may already have some ideas about what is going to be learned and taught).

   The teacher's comment "this is what you think. Let's find out" is one of collaboration rather than transmission.

2. When commencing further study of a topic (that involves pre-learned/taught

concepts), it can **inform teachers** about how students have internalised the ideas they have already encountered. Based on this survey we may have to revise these ideas with the students again so that we know from where we are starting.

3. It encourages students to **reflect on their own thinking**.

4. It presents **alternative views** and allows students to **evaluate** them. As Driver et al (1985) have pointed out there is a "right answer" syndrome in which getting the right answer is all that matters. But perhaps there is a need for learning opportunities (call them mistakes if you will) along the way to deep understanding.

5. It can start with the **everyday experiences of the learner**. For example considering the chemical and physical reactions involved in a cut arm, bleeding and blood clotting.

6. If the teacher is looking for an **interesting,** non-boring (to use the students' terms!) way of starting a unit, this is a suitable and educationally productive method.

7. It provides **first-hand learning experiences** for the learner. The students can be presented with the data and the quotes – and they are their quotes.

8. It can encourage students' **curiosity**.

9. It promotes **collaborative working.**

If even some of these reasons are seen as valid and useful, then this strategy is worth adopting. If time is a problem, then it may not be possible for every unit of work. But it could be done with sufficient frequency to increase the sense of student ownership of the learning process. This may be desirable in an age when we may comment that students seem disinterested and disruptive. Perhaps some of them do not feel any ownership of their learning.

Goodrum, Hackling and Rennie (2000) identify five major areas by which science education can contribute to making students scientifically literate:

1. A **science curriculum** that
- is relevant to the needs, concerns and personal experience of students
- is centred on inquiry and encouraging investigations, testing ideas and explanations about the natural world
- provides assessment of learning

2. A **teaching-learning environment** in science that is characterised by
- enjoyment, fulfilment, ownership, engagement of learning and mutual respect between teachers and students

3. **Professional teachers** who are /have
- life-long learners and can build the understandings and competencies required of contemporary best practice
- a recognised career path that includes high professional standards

4. **Resources** for teaching and learning science
- excellent facilities, equipment and support

- class sizes that make it possible to employ a range of teaching strategies and provide opportunities to know each child as a learner

5. A **community** that values science and science education as contributing significantly to the development of persons and the social well-being of the nation.

Goodrum and co-workers emphasise that traditional curriculum content must be replaced with relevant contemporary material. But they add that closing the content gap is only part of the solution. The teaching and learning must also change.

The use of surveys that canvas prior knowledge and the interchange of ideas and thinking that follow (as outlined here) can contribute to this change. It involves a completely new set of teacher beliefs that encourage students to think, analyse and communicate their ideas - a thinking population is one of Australia's prime goals of schooling. To save time, the textbook provides many short surveys which can be modified. Then the only time allowances are for:

- modification of the textbook survey if necessary (teacher)
- completing the survey in class (students)
- analysing the survey (teacher)
- giving feedback, looking at future learning (teacher and students)

Even more desirable is collaboration of teachers between schools (in sharing such data) and possibly with tertiary educators. Then the professional capacity of teachers as researchers may be realised. Even if this happens slowly, it is worth waiting for.

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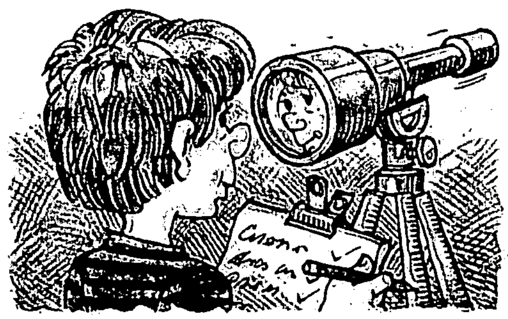
Appendix A

Thinking about *Chemical reactions*

1. What are chemical reactions? Survey yourself!

As you begin this chapter, you will have your own ideas about what a chemical reaction is. Write down your own definition of a chemical reaction in your workbook. Then copy the survey table below, and use it as follows:

(a) Read through the situations presented in the table and decide whether a chemical reaction is involved in each case. Write 'yes' or 'no' in the middle column to indicate your decision.
(b) In the 'Explanation' column, explain why you made this decision.
(c) Discuss your responses with other students and list any questions that arise.



Situation	Chemical reaction or not? (Yes/No)	Explanation
1. You hear a scream outside your door. You rush out into the street and discover that your friend has fallen off his bike and is bleeding from a cut in his arm. You remove the bike and take him into your house, clean the wound and allow him to rest until the bleeding has stopped.		
2. You decide to make a banana milkshake. You have all the ingredients except the milk! You find some powdered milk in the pantry and prepare a jug of milk from it.		
3. A five-set match in the Australian Open tennis tournament is very tiring for players, especially in the early rounds. Beside fatigue, players perspire and must replace lost fluids.		
4. Your parents are going on holidays and they ask you to take care of a small potted fern that they have just bought. You must be doing the right thing because by the time they return, the plant has grown large and is very healthy.		
5. The game of basketball in your backyard with your friends after school is so exciting that you leave your school blazer on the ground overnight. When you remember it the next morning you find a blazer wet from the overnight dew — and school begins in only half an hour!		
6. The photographs of your best friend's birthday turned out well. The cake looks brilliant and so does your friend as she blows out the candles. You decide to have the film processed at the same place next time.		

2. The language of chemistry

Chemistry has a unique language that is rarely found in everyday conversation. Yet all of life depends on the substances and reactions that this language describes. Just like any language, it can be satisfying to master. Remember that you accumulate it over a period of years.

You already know some of the words used in chemistry. Review the meanings for these words before you begin to study this chapter:

atom **element** *periodic table*
solid *liquid*
molecule
compound

In your group or class, discuss your ideas about the meanings of these words.

A new theory of learning and associated methodologies that specifically address the learning difficulties experienced by all individuals whenever change is required in their prior habits, skills or concepts has been developed (Lyndon, 1989, 1995, 1998, 2000). The new theory and new methods provide a distinctive pedagogy that addresses the major issues of unlearning and relearning. When an individual seeks to change already acquired habits, skills, or concepts the approach to such change is by necessity a mediational process that places special demands on the learner. The term, mediation, is here used to mean that an individual consciously attempts to bring about a reconciliation between his or her conflicting habits, skills or concepts.

Mediational Learning theory describes and explains the critical role in conceptual change of psychological phenomena such as proactive inhibition, retroactive inhibition, accelerated forgetting and unlearning. Proactive inhibition is best understood as the effect of conflicting prior knowledge on new learning. Despite a person's best efforts to change, prior habits, skills or concepts quickly regain control over an individual's performance. *Accelerated forgetting* is a fundamental characteristic of human memory. It is an essential aspect of the perceptual process that is activated whenever there is *conflict* between what is already known and what is being taught. It is now understood that proactive inhibition causes the accelerated forgetting of any new but conflicting habit, skill or concept, despite the practice of the newly learned habit, skill or concept.

Mediational Learning theory explains how we may control and redirect accelerated forgetting and thus control the unlearning process. This is achieved through mediational learning strategies such as Old Way/New Way (Lyndon, 1989), which is used to change habits and simple skills; Skill Mediation (Lyndon, 1998), used to change complex educational, work or sports skills; or Conceptual Mediation (Rowell, Dawson and Lyndon,1989; Dawson and Lyndon, 1997; Lyndon, 2000), which is used to change an individual's misconceptions in, for example, mathematics or science. The general sequence for conceptual mediation is presented below:

(i) Firstly a learning model (Lyndon, 1998) that explains the need for mediational learning strategies is presented to students. Students are encouraged to develop competency in the recommended cognitive strategies, which they should apply to the learning for understanding of science concepts. The model provides an essential common learning framework for teachers and their students.

(ii) Students' associated knowledge, beliefs and ideas of a concept are elicited. This can be achieved in a variety of interesting ways such as small group or whole-of-class brainstorming sessions, small-group discussion and poster preparation (for later class presentation), the preparation of concept maps or more simply by the written response of students to a pre-test on the topic.

(iii) The active differentiation of words used in a scientific manner from their common sense usage follows and is a necessary condition for the successful mediation between students' understanding and the scientific concepts associated with a particular topic (Ausubel, Novak & Hanesian, 1978, Gilbert, Watts & Osborne, 1985, Vygotsky, 1987, Sutton, 1992, Wilkinson, 1999).

(iv) Next, the teacher explicitly teaches the new concept and provides opportunities for students to rehearse important aspects of it. This enables later comparison with old perspectives that are initially presented to the class by the students themselves.

(v) Following this there are the three separate phases in the conceptual mediation process: the preparatory phase, the mediational phase and the application phase. In the preparatory phase the teacher facilitates the re-elicitation of the students' old concept and its comparison and differentiation from the new scientific concept. At this stage the material collected during the original elicitation of students' ideas can be presented again to facilitate discussion of their old perspectives. It is essential for the resolution of the natural phenomenon of accelerated forgetting that the students learn to differentiate between the conflicting perspectives. The students' perceptually constructed preconceptions and alternative conceptions must necessarily be re-elicited at this stage and again during the mediational phase.

In the mediational phase of the method the recall of the new concept, and its active differentiation from the alternative perspectives, is fully repeated, in a progressive manner, five separate times. When this process of deliberation is undertaken by the class or by an individual there is a growth in the individual's awareness of how the alternatives differ. There is importantly, also, a corresponding increase in the capacity of the individual to articulate any such similarities and differences. At least three progressive differentiations are necessary for the re-direction of the accelerated forgetting effect to be initiated. This re-direction of the accelerated forgetting from the old to the new knowledge is then consolidated over the following two differentiations. Once the mediational phase is completed, the new concept is then generalized to at least six novel applications or problem solving situations.

The Influence of Conceptual Mediation on Learning

Conceptual mediation has been used as a learning strategy in the teaching of science and mathematics at William Light R-12 School (formerly Plympton High School) since 1994.

Over this time Lyndon, Lloyd and Wilkinson collaboratively explored many of the complex pedagogical and psychological issues that were raised in the practical applications of conceptual mediation.

> As a teacher of mathematics and chemistry of many years experience, I have found it professionally exciting to observe the changes in my students as they have taken on board this new approach to learning and have achieved standards far in excess of my expectations. Because the students are more subject literate and less confused, their reading and problem solving skills are far superior. As they come to realize that success in maths or science is a reality rather then an improbability, they become more "on-task", there are few discipline problems, and attendance improves. There has been a major turnaround in student attitude – from one where they expected to be entertained to one where they see that effective application to their work leads to predictable success – and the reward is the thrill of understanding.
>
> (Wilkinson, 1999, p.15)

Over the past five years this group has also been involved in professional development of many science educators within both public and private secondary schools across South Australia (Lloyd, 1999; Lyndon, Lloyd & Wilkinson, 1995) and also more recently in the Australian Capital Territory at Canberra and Lanyon High Schools.

> It is apparent the CM (*conceptual mediation*) theory "makes sense" to peer teachers in providing both a theory of identifying obstacles in instruction, and techniques students can use to attack these obstacles.
>
> The CM team have conducted (teacher in-service) sessions which have been well-received by peers. This is indexed by evaluations conducted upon conclusion of the workshops, as recorded on anonymous feedback sheets. We have read these sheets and can comment that the feedback is strikingly positive and unambiguous. The CM team should be commended for constructing in-service sessions that meet a strong need amongst our teachers, and for developing successful communication strategies in this connection.
>
> (Yates & Biggs, 1998, p. 7)

An independent evaluation of the influence on student learning of conceptual mediation was commissioned by the South Australian Department For Education Training and Employment late in 1998 and Yates, a psychologist from the University of South

Australia, was appointed to undertake this review. This ongoing study has to date investigated the general impact of conceptual mediation upon students' attitudes to learning.

> The primary goals of CMP involve helping young people to acquire scientific knowledge with greater facility and to achieve a deeper level of understanding in their studies. However, in the course of developing the program and encouraging students to use CM procedures as consistent mental aids, the teaching staff began to be impressed by the feedback they were receiving in the area referred to as *positive learning attitudes*. It was felt that students who had participated in classes in which CM procedures had been employed continued to display and maintain high levels of interest and engagement within their studies. This feedback appeared to emerge also in discussions with school visitors; i.e. visitors were apparently impressed with high levels of motivation and task engagement within classes being taught via CMP.
>
> (Yates, Henderson, Higgs, Lyndon & Wilkinson, 1999, p. 2)

Of the total of 177 students involved in the study, only 73 students from Years 8-10 had been taught mediational learning strategies.

> We were able to capitalise on the fact that by the end of 1998, almost one half of the students in Years 8, 9 and 10 had participated within CMP classes. The other half of the students in those levels had not experienced CMP teaching and therefore constituted a natural comparison group. The CMP had been administered to intact classes. Although it cannot be claimed that student allocation to classes is ever a "random" process, the different classes were not ability streamed, and to our awareness the classes can be viewed as directly comparable.
>
> (Yates et al., 1999, p. 2)

The results of this relatively large cross-sectional study of all the students from Years 8 to 10 demonstrated that the project has, over time, an unanticipated and beneficial effect on student attitudes to learning and to school:

> We can interpret the current data as indicating that CMP is associated with highly desirable educational outcomes of benefit to young people striving to adjust to the demands of current schooling pressures. We submit that any educational procedure or curriculum innovation that can claim to be associated with positive motivational indices, reduced school hostility, and less malaise, has to be taken very seriously.
>
> (Yates et al., 1999, p. 8)

Another significant result noted by Yates was the effect upon students' voluntary attention to the learning task:

> My...student and colleague, Geoff Higgs, conducted classroom observations of a Year 10 Science class using an observational procedure. The engagement level, averaged across a 40 minute period, was 94 per cent. This represents time-on-task, or engaged learning time, and we know from a significant body of data the average engagement level in the average room is likely to be 65 to 70 per cent, and any figure over 80 per cent is considered excellent.
>
> (Yates & Higgs, 1998, p. 1)

A more recent and extensive evaluation of time-on-task was conducted by Yates and the results are as follows;

Year Level	Subject / Comment	% Time on Task
8	Science	94
8	Science: same time and class but with a separate	
	independent observer for a test of reliability	93
11	Mathematics	89
8	Chemistry (extended lesson)	93
11	Chemistry	83
8	Science	88
11	Chemistry and Physics (double lesson)	96
8	Chemistry	95
11	Mathematics	89

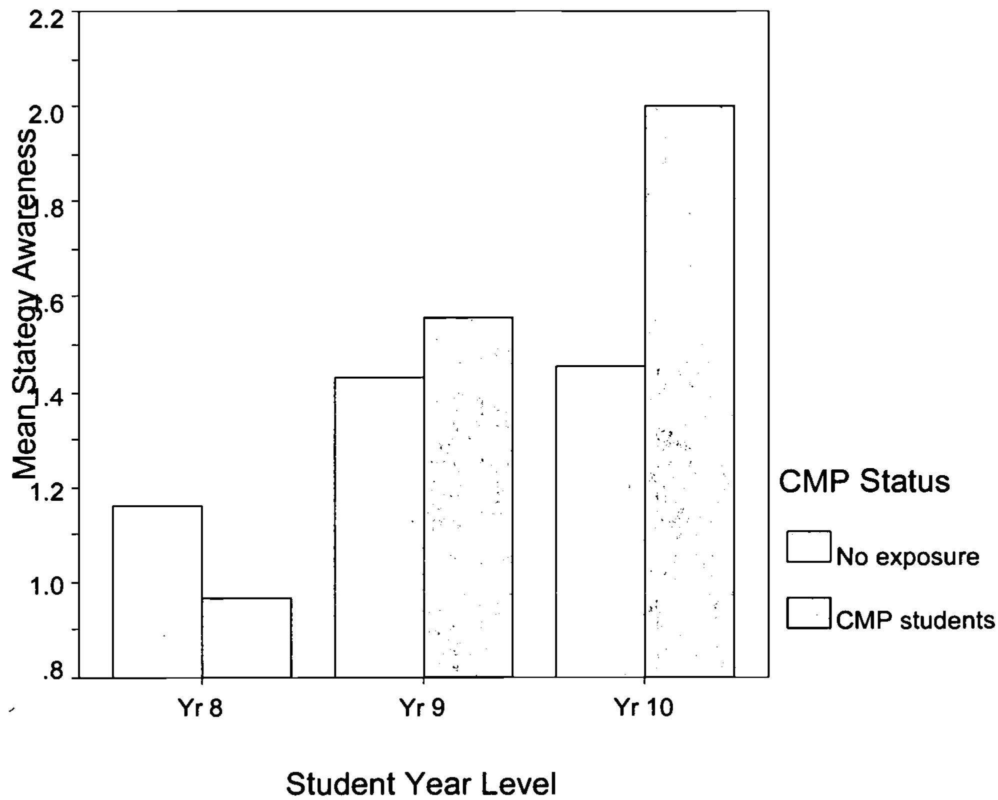
These outstanding results may be attributed to a combination of factors, firstly, to the students' improved understanding of the collaborative nature of learning and secondly to the emphasis that the teachers placed on eliciting and then mediating between the students' and the scientific language used in a new topic. Thirdly, to the confidence students acquire about how to control the learning process when they are confronted by conceptual conflict.

The students in the Yates study were evaluated using two questionnaires: (i) Student Perception of Difficult Subjects Scale and (ii) Magill Personal Belief Questionnaire, which included one item that required students to provide a written response. A "probe" question was used to evaluate students' awareness of problem solving strategies:

> In our administration, the Magill Questionnaire also contained an item that requested that students write their own answers to the following probe: "*Suppose you have a very difficult problem to solve in mathematics or science. What sort of things could you do to help you work on this problem?*" Responses to this item were coded by two raters using the following scheme: 0 "no meaningful response", 1 "non-specific response", 2 "viable strategic response cited", and 3 "response suggests integrated or sequential strategies to a mature level". It may be noted that dependency on others (e.g., "*I would ask for help*") was rated as 1. Agreement amongst the two raters was 96% with disagreements reconciled through discussion.
>
> (Yates et al., 1999, p. 3)

Yates (1999) presented the results for this specific item in graphic form, shown in Figure 2 below.

Figure 2: Strategy awareness across year level and "CMP status"



Source: Yates et al. (1999), p. 7.

Figure 3: Positive attitudes as a function of year level and "CMP status"

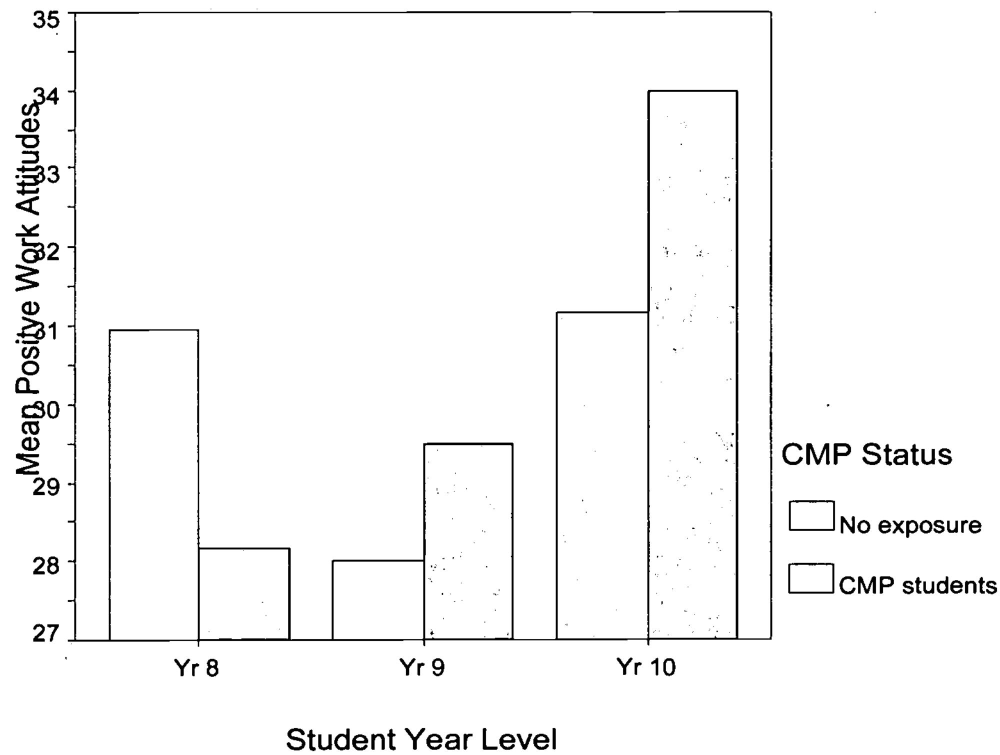
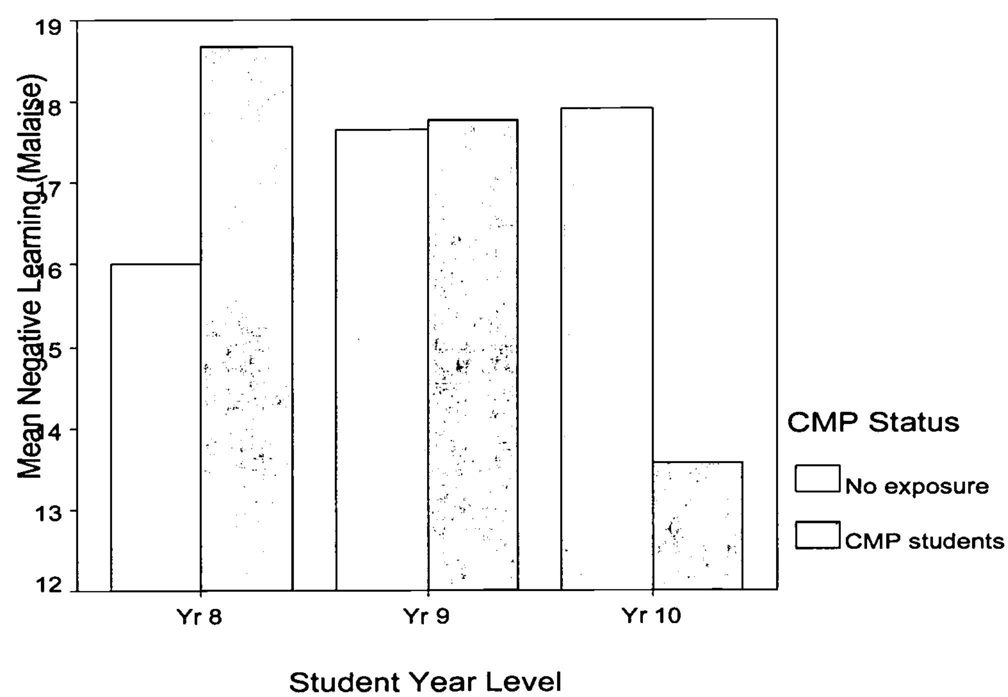


Figure 4: Negative learning indicators (malaise) as a function of year level and "CMP status"



Source: Yates et al., (1999), p. 6.

From this chart it can be seen that there is a progressive increase in the sophistication of approach to problem solving ability by students using conceptual mediation across the year levels, although this sophistication is statistically significant only at Year 10:

> The CMP status by year level interaction term was also significant ($F(2,174) = 3.44$, $p = .034$), due to the fact that at Year 10 the CMP students evidenced higher scores relative to the control students ($F(1,55) = 5.42$, $p = .024$).
>
> (Yates et al., 1999, p. 2)

It is of interest to note that there was no change in strategy awareness between Year 9 and Year 10 when the students had not used the conceptual mediation strategy.

Results also showed an improvement, over Years 8-10, in positive attitudes as a function of year level and "CMP status" (see Figure 3 below) a change which paralleled the changes shown for strategy awareness shown in Figure 2. There was also a significant decline in negative attitudes towards learning shown by these students, presented in Figure 4 below. It is of interest that here again there is no difference in mean negative-learning indicator scores between the Year 9 and 10 students in the non-conceptual mediation group. As Yates notes in his discussion of these results:

> One curious feature of the current data set is the almost linear increase in positive traits from Years 8 to 10 in the case of the CMP classes, as depicted in Figures 3, 4 and 5. Perhaps the students are "happier" via CMP by Year 9, and then begin to perceive real personal benefits by Year 10? These interpretations are well beyond the current data set, but they do suggest that the benefits of CMP are gradual and cumulative. The motivational impact of CMP may reside in that students are able to maintain high levels of *optimism and positivity* about their studies, and also about their ability to successfully negotiate the demands of an increasingly demanding curriculum. (Yates et al., 1999, p.8)

It is relevant however to contrast the results represented in Figure 3 with those represented in Figure 4 and in Figure 5, as shown above.

It would appear from Figure 3 that students in Year 8, who had been introduced to the mediational learning model feel less "personal agency", which can be understood as confidence or optimism and greater negativity or "malaise" than their peers who had not. This differential between the two groups of Year 8 students could be seen as a negative result for the project. However, the questions used by Yates in the "personal agency" section of the Magill Questionnaire do not permit a straightforward interpretation of the results. Questions like, " It takes a good deal of time and effort to acquire knowledge" and "When I see the problems we are expected to do I feel very incompetent" are particularly contextually bound. As Yates has pointed out:

> But what of the findings at Year 8 in which participation within CMP was associated with less desirable outcomes? We do not know how to interpret these data. But two explanations are (a) there is a cohort effect in that one of the CMP classes appeared to contain a number of dissatisfied students who do appear to be influencing their peers, and (b) it could be that learning CMP is initially an "awkward" method which may encounter some resistance from initially unwilling learners more accustomed to more traditional and passive "knowledge-soaking" arrangements. That is, the Year 8 students, in their transitional year, may be uncomfortable in learning via alternative methods.
>
> (Yates et al., 1999, p. 8)

As a consequence of having worked closely with these students, I interpret these apparently negative results as a reflection of a central goal of the project, that is, that students take personal responsibility for their learning. Students regularly complain to their teachers about the additional effort that is necessary when using the mediational learning strategies recommended to them. Although the majority of students complain, sometimes quite assertively, about the extra effort involved they also, almost begrudgingly, acknowledge that their academic results are considerably better than before the project commenced.

This confronts teachers with an interesting and challenging period during which both they and their students accommodate to the reality of a "least-effort principle" associated with learning to change what one already knows. It comes as no surprise that, when the least effort possible to achieve relearning of inappropriate habits, skills or misconceptions is far greater than students may desire, a natural reluctance to undertake the activity is felt and expressed.

Taken together, the results of Yates' study gives a picture of a lengthy but academically beneficial transition from old beliefs and practices about learning to more effective and overall more efficient learning strategies. We believe that this picture is an accurate description of the situation at William Light R-12 School. Some students from conceptual mediation classes entering Year 11, both in 1998 and in 1999, were, due to their advanced level of understanding of scientific concepts, invited to study for Year 12 publicly examined subjects in science. This was a powerful indicator that one of the project's aims, that of teaching for understanding, has been particularly successful for many of the students at William Light R-12 School. Since then we have continued to learn much about the obstacles that confront us as science educators, and are actively seeking new ways of communicating these important new insights about learning for understanding to our students.

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