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ABSTRACT

The purpose of the Exemplary Practice in Science and Mathematics Education (EPSME) study was to identify high quality science and mathematics teaching, to document exemplary practice through case studies, and to investigate key characteristics common to exemplary teaching in different sites. This paper discusses the case studies which considered some of the cognitive and affective outcomes when two exemplary teachers taught their year 8 science classes over a period of approximately 3 months. Both teachers (one male and one female) were described as "exemplary" by their peers, in terms of subject expertise and teaching ability. Particular emphasis was placed on: (1) whether the teachers could influence students' attitudes toward science (indicating that the teachers did provide a classroom environment conducive to fostering positive attitudes); (2) students' intuitive views and inappropriate observations during a laboratory activity dealing with flotation; and (3) whether exemplary teachers were still exemplary when teaching outside their field of expertise (indicating that the teachers may not always bring about sound scientific understanding in students if they are called upon to teach outside their area of expertise). The classroom inventory scale used is included in an appendix. (JN)

SOME COGNITIVE AND AFFECTIVE OUTCOMES

IN EXEMPLARY SCIENCE TEACHING

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INTRODUCTION

This investigation has, by means of 5 case studies, considered some of the cognitive and affective outcomes when two exemplary teachers taught their mixed ability year 8 science classes over a period of approximately 3 months. Both teachers (one male and one female) were described as "exemplary" by their peers, in terms of subject expertise and teaching ability and they taught at the same Senior High School in the northern suburbs of Perth.

TEACHER PROFILES

Mike was in charge of the science department at this Senior High School. He graduated from the University of Western Australia in 1964 with a B.Sc. degree, majoring in zoology. Mike started teaching immediately after graduation although he freely admitted that teaching was his 'second choice" when he failed to be accepted for veterinary science training.

Mike's teaching style might best be described as "traditional" and teacher-centred. He believed that teachers should be firm disciplinarians and this outlook was reflected in his classroom climate which was very controlled, with students asking and answering questions only under his direction. Students in Mike's class generally did not move around freely, being expected to operate closely to the teacher's wishes.

Anne had been teaching science for approximately 4 years, at the time of this investigation, having completed a B.Ed. degree at the Western Australian Institute of Technology before taking up her first appointment at a district high school. She majored in biology and education and taught years 8, 9 and 10 science classes along with a senior biology class.

Anne's teaching style contrasted sharply with Mikes. She appeared friendly and relaxed with students and this approach was intended:

Interviewer "... what kind of teaching style do you have?"

Anne "A friendly teaching style - I try to relate to them (students) as much as possible."

Students in Anne's year 8 class moved around freely during practical activities, interacting with other group members whilst questions and answers were given in a spontaneous manner by students during class discussions.

CASE STUDY 1: EXEMPLARY TEACHERS: CAN THEY INFLUENCE YEAR 8 STUDENTS' ATTITUDE TOWARDS SCIENCE?

Introduction

There is ample evidence (Ormerod, 1979; Dainton, 1980; Gardner, 1984) of a world-wide decline in student interest toward secondary school science programmes. Indeed, specific studies (James and Smith, 1985) have demonstrated how this decline of interest may commence from the time students leave primary school and enter secondary school.

A number of factors have been identified as contributing to the negative feelings students hold for science, one of which may be the "kind" of science teacher that students encounter on first entering secondary school. Another factor may be the "quality" of science lessons offered.

This investigation considered the attitude toward science as displayed by Year 8 students from "mixed ability" co-educational classes being taught science by teachers identified as "exemplary".[1] Student attitudes towards science in the first year of secondary school were compared with those attitudes that had prevailed before the students left primary school.

The Investigation

Two co-educational year 8 classes were selected for an attitudinal survey (see Appendix A) on the basis that each class was taught science by a teacher identified as being "exemplary" by his/her peers. The classes were described, by those exemplary teachers, as being "mixed ability".

The Use of a Classroom Environment Scale (My Class Inventory)

A modified[2] short form of My Class Inventory Scale (see Fraser and Fisher, 1983) was used to assess the environment in both Anne and Mike's science classes. Three additional questions, concerning student attitudes toward science, were inserted in the survey. These were:

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1. The term "exemplary" is used here in much the same way as in Penick and Yager's (1983) report on The Search for Excellence in Science Education.

2. The modified Classroom Environment Survey is shown in Appendix A.

Q.6 I enjoy science more in this class than I did in my primary school.

Nearly Always   Sometimes   Hardly Ever

Q.12 I am looking forward to doing more science next year.

Nearly Always   Sometimes   Hardly Ever

Q.18 I usually find that science classes are enjoyable.

Nearly Always   Sometimes   Hardly Ever

An additional question asked students about their thoughts regarding a career in science:

Q.29 I think that I would like a job in science when I leave school.

Nearly Always   Sometimes   Hardly Ever

Students were asked to circle their response.

Instrument stability has been discussed in detail elsewhere, as have the results from the "My Class Inventory" (M.C.I.) (Happs, 1985).

Year 8 Students' Attitude Towards Science

A consideration of the survey results, with respect to the attitudinal questions 6, 12 and 18, generally revealed positive feelings towards science by both year 8 classes. However, the results from Anne's class clearly appeared to be more favourable:

Anne's Class (N=32)

Q.6 I enjoy science more in this class than I did in my primary school.

Nearly Always	72%
Sometimes	22%
Hardly Ever	6%

Q.12 I am looking forward to doing more science next year

Nearly Always	56%
Sometimes	31%
Hardly Ever	13%

Q.18 I usually find that science classes are enjoyable.

Nearly Always	56%
Sometimes	41%
Hardly Ever	3%

Mike's Class (N=30)

Q.6 I enjoy science more in this class than I did in my primary school.

Nearly Always	33%
Sometimes	43%
Hardly Ever	24%

Q.12 I am looking forward to doing more science next year.

Nearly Always	24%
Sometimes	47%
Hardly Ever	29%

Q.18 I usually find that science classes are enjoyable.

Nearly Always	27%
Sometimes	57%
Hardly Ever	16%

Interviews were conducted, after the surveys. in order to elicit some of the reasons behind these attitudinal trends. Year 8 students were interviewed individually, with questions being directed toward their perceptions of science in their primary school, year 8 class and future science classes.

The majority of students (72%) in Anne's class indicated that they enjoyed science lessons more (nearly always) in their year 8 group than they did in their primary school. This feeling was reinforced by interview data from Anne's students.

I "so at the end of primary school science you sort of indicated to me that you weren't too happy with science -- weren't enjoying it."

R "No"

I "Well how do you feel now about science?"

R "I like it now"

I "You like it?"

R "It's fun"

I "It's fun now. What are the good things about science <u>here</u> that you like?"

R "We do lots of interesting experiments and it's just cos you work in groups and that. It's just fun to do."

I "What sort of things do you <u>not</u> like about science here?"

R "Hmm (thinking) - nothing really."

Interest in science appeared to be linked with the provision of opportunity for practical activities:

I "Has your opinion - your attitude towards science changed?"

G "Yes"

I "It has?"

G "I like it a lot more"

I "You like it a lot more now. O.K. Tell me about that. Why is that?"

G "Cos we're doing lots more experiments."

I "Yes"

G "Better fun"

I "Better fun. O.K. Well are you happy with the class?"

G "Yes"

I "The class seems to get on quite well - and you're happy with your teacher are you?"

G (Nods)

I "You are. What are the good things in science?"

G "The teacher's (Anne) not strict. The kids are good to do experiments with."

The relaxed atmosphere, within Anne's class, was frequently commented on by students:

I "O.K. So what are the really good things you like about science?"

N "Well it's pretty free"

I "Pretty free. Tell me about that."

N It isn't very strict."

I "Not very strict. Is that good?"

N "Yeah"

I It is good. Why is that?"

N "Because you can't really enjoy your topic."

I "You can't enjoy the topic if it's not -- free?"

N "Yeah - if you can't walk around."

In Mike's class, students made comments about the more strict atmosphere:

I "O.K. How do you feel about it (doing science) now that you're here (at high school)?"

H "It's better than I thought it was."

I "It's better than you thought it was going to be?"

H "First of all I thought - Oh it's going to be awful because I didn't know anything and Mr Brown was a bit strict at first - but now that I understand everything it's much nicer ..."

I "Right, so you feel quite happy?"

H "Yeah"

About one third (33%) of students in Mike's class indicated that they enjoyed science lessons more (nearly always) in their year 8 class than they did in their primary school. Their comments were positive about science:

A "Yeah - science is my best subject ..."

I "O.K. ... any things that you really don't like about science?"

A "No"

I "Nothing at all?"

A "Nothing"

and

I "Are there any things you don't like about it (science)?"

D "No, not really."

I "No - you like ..."

D "I enjoy coming to science."

I "You enjoy it. You enjoy being in that particular class?"

D "Yes"

Several students in Mike's class responded positively to the practical work, as did Anne's students:

I "Are there particular things you do that you enjoy more than others or things that you dislike more than other (in science classes)?"

G "I like doing experiments - that's good fun."

I "You like doing experiments?"

G "Yeah"

In Anne's class 56% of students were (nearly always) looking forward to doing more science in the following year and interview comments supported the survey results in this respect:

I "And what about next year, are you looking forward to science next year?"

R "Yeah"

It is interesting to note that within Anne's class, only 13% of students reported that they hardly ever looked forward to doing more science in the following year. This is in marked contrast to almost one third (29%) of Mike's class. Some negative feelings became apparent during the interviews:

J "... don't know I'm looking forward to it (science) much."

I "Don't know about science yet. Why's that? Can you explain that to me?"

J " ... maybe too hard - I don't know."

Students' Thoughts About a Career in Science

Student responses to the career question 29 showed that most students, from both classes, generally did not think about a career in science:

Anne's Class (N=32)

Q.29 I think that I would like a job in science when I leave school.

Nearly Always	6%
Sometimes	31%
Hardly Ever	63%

Mike's Class (N=30)

Q.29 I think that I would like a job in science when I leave school.

Nearly Always	3%
Sometimes	10%
Hardly Ever	87%

It is apparent from the above data that even in those classes where student majorities enjoy science and look forward to doing more science in later years, few individuals had given much thought to a career in science.

It may be that students, at this age level, do not appreciate the scientific base of many occupations and those jobs which they were clearly interested in may require a scientific component. This possibility was probed to a certain extent in later interviews which tended to reinforce the survey findings about a lack of thought towards a scientific career.

The data obtained, in the form of student answers to Q 29: I think that I would like a job in science when I leave school, were considered in terms of differences emerging between male and female responses.

A score of 3 was assigned when students circled "nearly always", a score of 2 for "sometimes" and 1 for "hardly ever". Score distributions, from each class, are shown below:

Anne's Class

Males	Females
2, 1, 1, 1, 3	1, 1, 1, 1, 2
3, 2, 2, 2, 2	1, 1, 1, 1, 2
1, 2, 1, 1	2, 1, 1, 1, 1
	2, 1, 1
(N = 14)	(N = 18)

Mike's Class

Males	Females
2, 2, 2, 1, 3	1, 1, 1, 1, 1
1, 1, 1, 1, 1	1, 1, 1, 1, 1
1, 1, 1, 1.	1, 1, 1, 1, 1,
	1
(N = 14)	(N = 16)

Table 1: Student responses to the statement: "I think that I would like a job in science when I leave school."

If all students in either class had circled "nearly always", in response to Q 29, a maximum score of 3.00 would have resulted $\left[\frac{\sum \text{scores}}{N}\right]$.

Conversely, had all students responded with "hardly ever", the outcome would have been a minimum score of 1.00. The following results were obtained from the two classes:

Anne's Class		Mike's Class	
males	females	males	females
1.71	1.22	1.36	1.00

It is evident that none of the year 8 girls, from Mike's class, considered science as a career on leaving school. This compares with 18% of girls in Anne's class.
The boys in both groups tended to think more in terms of science as a career with about 21% of boys from Mike's class and 33% from Anne's class considering this possibility. However, what is apparent is the general low interest, at this level, toward a scientifically - based career.

DISCUSSION:

In contrast with other cited studies into student attitudes toward lower secondary school science, this investigation has demonstrated how many year 8 students, from the two classes surveyed, were seen to have a positive attitude toward science and generally appeared to be enjoying the subject more than they did in primary school.

The two science teachers described as "exemplary" in this report, seemed able to provide learners with a classroom environment conducive to their enjoyment of science, to the extent that many of the year 8 students were looking forward to taking more science lessons at the year 9 level.
The affective gains, as witnessed in this investigation of year 8 students, appear to be real and, although it seems axiomatic that exemplary teachers will generate a pleasant classroom environment and positive attitudes toward science, a number of recommendations for all science teachers become evident:

(i) students are likely to come to secondary schools expecting to be involved in a variety of scientific activities. Such activities are generally appreciated to the extent that students look forward to more activity - centred science. These should be provided by teachers, on a regular basis.

(ii) students encountering secondary school science, and science-trained personnel for the first time, may benefit from vocational information concerning science, interrelationships between the various scientific disciplines and the many careers which hinge upon scientific training;

(iii) in respect to (ii), girls need to be told about equal opportunities that exist in scientific careers. It should be emphasised, by science-trained teachers, that science is not a male-only domain;

(iv) it is likely that a friendly non-threatening atmosphere will encourage students to become more enthusiastic toward science classes and, in turn, may lead to students developing a better understanding of scientific principles.

Their first encounters with secondary school science seems important to new students since the impressions they gain during that "crucial" year may well dictate student's future attitudes toward school science. Irrespective of teaching experience and depth of expertise, all teachers need to be aware of, and respond to, student expectations of secondary science and those factors which promote an interest in science. Exemplary teachers in this investigation appear able to foster some of these needs.

It should be stressed here that no claims are made, by this investigator, concerning any positive cognitive gains being made by students from these two science classes, since to substantiate a superior environment for learning would entail a more extensive study.

Case studies which have been documented as part of the overall observation schedule, involving exemplary teachers, suggest that a number of critical barriers to learning are likely to arise in <u>all</u> science classrooms and such impediments to learning are often not recognised, or taken into consideration by teachers. Thus, the problems of text readabilty, student's prior knowledge, inappropriate classroom observations and perceived purpose of experiments may ensure that even experienced and exemplary teachers fail to raise their student's level of scientific understanding to the extent they believe they can. Furthermore, the cognitive gains, that might be achieved by exemplary practice when teachers operate within their field of expertise, may be offset by indifferent gains when they have to teach in scientific areas outside their field of expertise.

Furthermore, the cognitive gains, that might be achieved by exemplary practice when teachers operate within their field of expertise, may be offset by indifferent gains when they have to teach in scientific areas outside their field of expertise. Some of these barriers to learning are discussed within the following case studies.

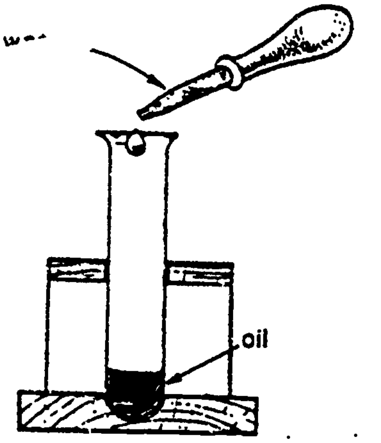
CASE STUDY 2: INTUITIVE VIEWS AND INAPPROPRIATE OBSERVATIONS

This report concerns one of the "mixed ability" year 8 classes during a 1 hour laboratory period dealing with flotation.
The teacher read through an instruction sheet which had been given out to the class, as a prelude to practical activities directed towards finding out about floating and density. The instructions are shown below:

WHICH WILL FLOAT?

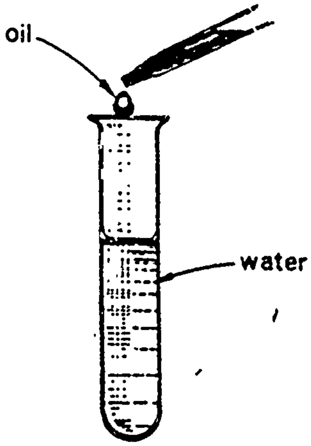
LIQUIDS IN LIQUIDS

Carry out this test



- Pour some oil into a test tube
- Stand it perfectly upright
- Use a medicine dropper or a glass tube to let one drop of water fall into the oil
- DON'T let the drop touch the sides of the test tube
- what do you observe when the drop of water falls into the oil?

Following on from the above, the teacher continued with instructions for the next task involving adding oil to water:



What do you think will happen if you put one drop of OIL into a test tube of WATER?

Prediction: ______________________________

____

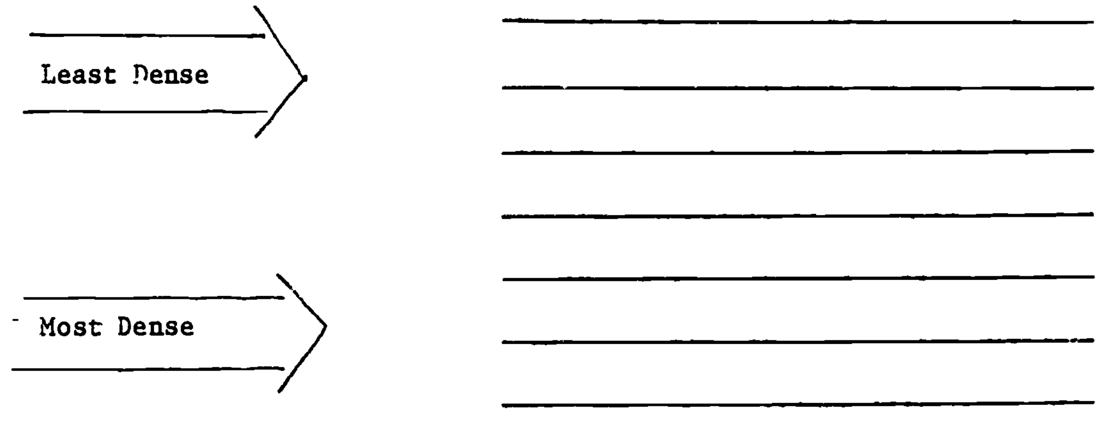
Try it for yourself. Write your observations in the spaces below.

____

____

Other tasks were given, including observing what happened when glycerine, kerosene and oil were placed in water and various solids placed in water. The following table was provided for students to fill in:

Write down the following substances in order, from least dense to most dense; oil, ice, perspex, water, glycerine and lead.



The class was organised into groups and individuals assigned the task of collecting materials and taking these back to the group work areas. The investigator joined a group at the front of the laboratory. This group comprised Peter, Vanessa and Belinda.

Complying with the instruction sheet, Peter had carefully placed one drop of water [coloured red by means of vegetable dye] into a test tube containing oil.

The small droplet of water remained on top of the water surface because of care taken over its deposition, and this observation was noted down by the other group members. Peter tended to dominate in terms of actually implementing the worksheet instructions.

The investigator asked the group for their meaning of the word "density" - a word frequently used on the worksheet.

Peter volunteered:
"Density is how thick material is", reflecting on an explanation given earlier by his teacher.

Predictions were made by the group, largely on intuitive grounds, i.e. whether someone in the group considered one liquid to be "thicker" than the other. Vinegar, methylated spirits and kerosene were seen by all group members to be less dense than water. Oil was seen as an exception and poor experimental procedure tended to reinforce these views which were not re-checked by adding oil to water.

The investigator moved to join another group, towards the back of the laboratory and their findings, concerning the "mixing" of liquids were discussed.

Once again, the idea that density relates to the "thickness" of material was well entrenched with group members:

I	What does the word "density" mean - any ideas?
S	How thick something is.
I	You think its [density] something that's pretty thick?
S	[nods]
I	So is oil thicker than water?
S	Yes
I	So you think oil is going to be denser than water?
S	Yes

[On reflection, the questions posed by the investigator may have been leading ones, although the sentiments expressed by the above student were generally shared by other students within the group.]
The prediction that oil would sink beneath water was made by all group members. [Perhaps not on an independent basis], and the same kind of technique, i.e. gently adding a small drop of water to the oil, had resulted in the former liquid remaining on the oil surface. This tended to reinforce the group's intuitive views.

The teacher appeared to be oblivious to the disparity between the learner's intuitive perspective and the practical observations. A number of students adhered to their initial [incorrect] predictions when experimentation contradicted these.

The teacher did not follow through with a discussion of each observation since the practical activities occupied most of the lesson and 5-10 minutes had been promised to the class for revision towards a test scheduled for the next day.

SUMMARY

Recent work in England, New Zealand and Australia has clearly demonstrated how learners are likely to generate understanding about the world based upon their everyday experience. Intuitive views, such as the one that "oil is denser than water" can easily be consolidated for learners when teachers draw unfortunate comparisons such as "density means the thickness of material." Such a view, held by the children, observed in this lesson sequence, is likely to remain with them for some time, especially in light of this lost opportunity for challenging it.

Teachers, operating with student numbers in excess of 30, have limited opportunities for assessing the individual student outcomes of practical activities such as those described here. A trained observer, who can move around the classroom talking to individual students, is better placed for probing learning outcomes. Furthermore, when teachers are faced with the real need to cover copious quantities of curriculum content, they often ask for, and receive, the "required" response from those few students who can be relied upon to provide the answers sought. Thus encouraged by their apparent success, teachers move on to the next activity or topic, unaware of the lack of understanding that may prevail within their student group. This case study epitomises such a problem.

CASE STUDY 3: EXEMPLARY TEACHERS : ARE THEY EXEMPLARY WHEN TEACHING OUTSIDE THEIR FIELD OF EXPERTISE?

This synopsis considers lesson outcomes when a teacher, identified as being "exemplary", was seen to teach one of the mixed ability year 8 co-educational class about rocks and minerals. Specifically, the teacher intended to demonstrate to the class how slow-cooling magma leads to the formation of large crystals within igneous rock-types, e.g. granite, and how similar magmas [in terms of their chemical compositions], when chilled rapidly, lead to rock types with microscopic crystals, or none at all, e.g. obsidian.

In the first of two lessons, the teacher revised past coverage about the Earth's structure. The following statement initiated class discussion:

T "Tell me about the mantle"

The teacher reminded the class about some of the rock names mentioned previously and asked the class about granite:

T "What minerals are in granite?"

A number of responses were accepted. These included the minerals biotite, quartz, hornblende and muscovite. Later evidence suggested that the teacher was unsure about the distinction between rocks and minerals. Students were asked to examine rock samples, from specimen boxes provided, whilst writing down descriptive words which best explained the appearance of individual samples. The following words were listed on the board, as the children called them out to the teacher:

CRYSTALS	WHITE	SPARKLY	SMALL	COARSE
BLACK	FLAKY	HEAVY	SMOOTH	CREAMY
GREY	HOLEY	DULL	LIGHT	GOLDISH
LAYERED	JAGGED	ROUGH	FORMED	SILVERY
			GLITTERY	SHINY

The teacher sorted this array of words into two groups: Those words which were seen [by the teacher] to be "useful" and those "not useful", in terms of rock descriptions.

The "useful" terms were summarised and comments made:

- the way it's [rock] formed
- crystals and size of crystals, e.g. granite has large crystals
- layered - fairly important
- shiny or glittery

The teacher emphasised one aspect:

T "colour is very important."

It has been emphasised in past studies [e.g. Happs, 1982] that children and adolescents commonly classify rocks and minerals in terms of colour yet this criterion is most inappropriate from an earth scientists's point of view. In this classroom observation the teacher was reinforcing this naive viewpoint.

The teacher, referring to the descriptive word "holey", used pumice as an example of a rock formed with numerous holes in its surface. The teacher went on to explain to the class [albeit incorrectly] that pumice formed when lava came into contact with water, so that steam was generated to so produce "escape holes" in the rock.

A third major error was introduced to the class when the teacher talked about Moh's Scale of Hardness with reference to a list of named minerals. The teacher did not indicate that the names were those of minerals and the following table was written on the board, to be copied down by students:

MOH'S SCALE	STANDARD MATERIAL
1	TALC
2	GYPSUM
3	CALCITE
4	FLUORITE
5	APATITE
6	ORTHOCLASE
7	QUARTZ
8	TOPAZ
9	CORUNDUM
10	DIAMOND

The above table was clearly seen, by students in the class, to be a list of rocks rather than minerals and this was later reinforced by the teacher's comment about the scale:

T "One other thing that no one has mentioned and that's to look at how hard the rock (sic) is. Now rocks are not equally hard - some are very hard, some are very soft and there is actually a scale of hardness that runs from 1 to 10 - and it's called Moh's Scale of Hardness and there are sorts of rock (sic) that are used as standard reference material so, for example, salt - we looked at talc yesterday this is very, very soft. Gypsum is another reasonably soft one...".

The confusion that this generated became evident as the investigator moved around the laboratory to talk with individual students. An interview extract reveals the problem:

I "Tell me - that table on the board - [points to Moh's Scale]. What does that mean to you - with the numbers?"

N "How hard the rocks are?"

I "And where are the rocks?"

N "What do you mean?"

I "Which are the rocks on that board?"

N [laughs] "The ones in the middle."

I "The ones in the middle - O.K. - will you read me out one or two of them."

N "Talc, quartz."

I "O.K. They are all rocks to you?"

N "Yes" [nods].

The above kind of response typified student thinking about the meaning of the table:

I "What about the table on the right hand side of the board - What is that table about? What do you think that table is all about?"

S "Hmm - mainly the hardness of the rock."

Of approximately 10 students interviewed about the table, not one was able to use the term "mineral", when talking about the table and/or hardness. All considered that the table was about rocks.
During the second lesson, the teacher asked the class a number of questions concerning the structure of the Earth, directing attention to the "plastic" mantle beneath the crust. The aim, as perceived by the investigator, was to show how molten mantle material can produce different textures in igneous rocks, depending upon the rate of cooling. Questioning was used, by the teacher, as a vehicle for introducing later practical activities.

The leading question was asked:

T "What do we call the layer underneath [the crust]?"

Several students offered "mantle" as an answer and this was accepted by the teacher who, in response, indicated to the class that the mantle is made up of "magma". This latter term was written up on the blackboard.

Following on from this, the teacher showed the class how igneous rocks might be grouped according to their mode of formation and the following information was written on the board.

ROCKS

IGNEOUS fire-formed (from mantle) e.g. lava, granite, basalt, dolerite, quartz.

Note the occurrence of two errors in this information i.e.

1. Lava is not a rock type, as implied by the teacher. Lava is the name given to magma which has reached the Earth's surface, giving rise to a variety of rock types, depending on the composition and rate of cooling of the lava. e.g. basalt forms when lava has a low quartz content; andesite may form when lava has a higher quartz content; obsidian may form when lava is chilled rapidly in contact with the surface of the Earth.

2. Quartz was recorded by the teacher as an igneous rock, whereas it is a rock - forming mineral, commonly found in sedimentary rocks, e.g. sandstone and some igneous rocks, e.g. granite.

The latter error suggested, to the investigator, that the teacher was not clear about the difference between rocks and minerals and this example tended to reinforce the findings from previous lessons. If the teacher was aware that rocks are comprised of minerals, specific examples were not presented in a clear manner.

The class was told that, since the size of crystals was related to the rate of cooling of magma, then the "speed of cooling influences what the rock looks like".

At this point in the lesson the teacher defined "igneous rocks":

T "(igneous rocks) are formed from the cooling of the magma". This latter term was explained, again, as the semi-solid material of the mantle.

This explanation appeared to overlook the formation of igneous rocks from lava and suggested, to the investigator, that the teacher did not appreciate the difference between lava and magma. Earlier suspicions tended to be bolstered by this observation.
The teacher wanted to move on to providing class instructions about the first practical activity about to take place. Realising that some of the children were still copying down notes from the blackboard, the teacher said:

T "Listen with one ear", whilst a demonstration concerning the practical activity was given.

The teacher wanted to cover two areas during the remaining 35 minutes of laboratory time. These being:

(1) to allow the children to heat some sulphur in a test tube so that some molten sulphur might be poured into cold water to form amorphous [no visible crystals] sulphur via rapid cooling;

(2) To consider a variety of pre-prepared crystals of compounds, such as copper sulphate, to so demonstrate to the children how slow cooling can lead to large crystals.

The teacher made the assumption that the children would compare the two samples (amorphous sulphur and copper sulphate crystals] and make the comparison between cooling rates and their impact.
Instructions were given to the class about how the sulphur should be heated in a test tube and the following two points were stressed:

(a) the test tube should be kept moving in the bunsen flame; this being more important as the solid liquefies;

(b) No class member should be standing in line with the open mouth of any test tube which is being heated.

The following sequence of activities was given to the class:

- collect a test tube with some sulphur in the bottom. The sulphur had already been inserted by the teacher;
- heat the test tube until the sulphur becomes molten;
- pour 2 drops of molten sulphur into a beaker of cold water. Observe the sulphur when it enters the cold water.

The class was reminded, once again, to observe the prepared crystals on the front bench, using a hand lens.

Children seated near the inner aisle, were instructed to collect a test tube containing sulphur whilst children on the opposite sides of the bench were directed to collect boards on which bunsen burners could be placed and used. Other children collected safety glasses, burners, tongs and beakers.

The students were evidently familiar with the location and assembly of apparatus since all groups were quickly organised and the practical activity underway within a few minutes of the last instruction from the teacher. At this stage, the investigator set out to talk to group members in order to determine whether or not, they appreciated the purpose of the first part of the activity, i.e. why they were heating sulphur and then cooling it rapidly. Typically, the question was asked of individuals:

I "What do you think is the purpose of this activity?"

Alternatively [had this first question not provoked a response]:

I "What are you trying to find out in this activity?"

The investigator posed this kind of question to 10 students, selected at random within the class, and not one was able to provide a satisfactory answer. Typical responses involved a shrugging of shoulders or the comment:

"I don't know."

Some alternative comments were:

M "To see how long the stuff (in the test tube) takes to cool."

One student (not M) was actually timing this "cooling process" when the investigator reached his particular group.
Few students, out of the 10 interviewed, recognised that sulphur was being heated in the test tube, despite having been given that information by the teacher. The students provided <u>their</u> interpretation of what was in the test tube.

I "Do you know what the substance (in the test tube) is called?

J "Sulphuric something";

and

D "Some sulphate"

Few students had the opportunity to examine the large crystals on the front bench, since the first practical activity took up much of the available laboratory time.

The investigator moved around the groups, which were actually looking at these crystals, and proceeded to examine their understanding of the purpose behind such crystal inspection. The central question was asked:

I "Can you see a connection, or link, between the activity that you have just completed and those crystals that you are looking at?"

The link that was hoped for, by the teacher, was not seen by any students interviewed [8 in all] and the lesson ended before the teacher could discuss the matter further.

SUMMARY:

These lesson observations emphasised again, to this investigator, how teachers may feel that the purpose of a practical activity has been made explicit to learners, yet many students concentrate on following the practical procedural guidelines whilst losing sight of the reason(s) why the activity is being pursued.

It was also evident, in this investigation, that problems had been inadvertently seeded by the teacher at the beginning of the lessons, when scientifically inaccurate information was provided for the class. It is likely that a teacher with specific expertise in the earth sciences would not transmit this invalid information to his/her class and that (s)he would make clear any links between the two latter activities i.e. the cooling rate of molten sulphur and observation of the prepared crystals.

In conclusion, these observed lessons [as summarised here] suggest, to this investigator, that exemplary teachers may not always bring about sound scientific understanding in students if such teachers are called upon to teach in areas outside their field of expertise.

Outside observers, who may not be trained in monitoring the transmission of information from teacher to learner, could be impressed by the control and logistical organisation encountered in a class being taken by an exemplary teacher. Yet until scientific understanding and long-term retention is probed, the true effectiveness of exemplary teachers [from a cognitive perspective] will be in doubt.

One danger that arises, when an exemplary teacher transmits inaccurate information, is that the dynamic, forceful and "convincing" manner which such teachers display, tends to ensure that learners will take heed of what is being taught. Thus we may have a problem of exemplary teachers teaching invalid information in a most convincing manner.

APPENDIX A: MY CLASS INVENTORY
MODIFIED SHORT FORM

CLASSROOM ENVIRONMENT SCALE

MODIFIED SHORT FORM

DIRECTIONS

THIS QUESTIONNAIRE ASKS YOU WHAT ACTUALLY HAPPENS IN YOUR SCIENCE CLASS. THERE ARE NO 'RIGHT' OR 'WRONG' ANSWERS. ONLY YOUR OPINION (WHAT YOU THINK) IS IMPORTANT.

THINK ABOUT WHAT REALLY HAPPENS IN YOUR SCIENCE LESSONS AND DRAW A CIRCLE AROUND ONE OF THE FOLLOWING:

NEARLY ALWAYS IF IT IS TRUE OR MOSTLY TRUE

SOMETIMES IF IT IS SOMETIMES TRUE

HARDLY EVER IF IT IS FALSE OR MOSTLY FALSE

MAKE SURE THAT YOU ANSWER ALL OF THE QUESTIONS. IF YOU CHANGE YOUR MIND ABOUT AN ANSWER, JUST CROSS IT OUT AND CIRCLE ANOTHER.

THE IMPORTANT THING TO REMEMBER IS THAT YOUR OPINION IS WANTED, YET NO OTHER PERSONS WILL SEE ANY OF YOUR ANSWERS.

NAME ______________________ SCHOOL ____________________ CLASS ______________

Remember you are describing your SCIENCE classroom   ...rcle your answer

1. The pupils enjoy their schoolwork in my science class.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
2. Children are always fighting with each other.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
3. Children often race to see who can finish first.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
4. In our science class the work is hard to do.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
5. In my science class everybody is my friend.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
6. I enjoy science more in this class than I did in my primary school.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
7. Pupils are not happy in science class.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
8. Children in our science class are mean.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
9. Children want their work to be better than their friend's work.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER

Remember you are describing your SCIENCE classroom   Circle your answer

10. Children can do their schoolwork without help.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
11. People in my science class are not my friends.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
12. I am looking forward to doing more science next year.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
13. Children seem to like the science class.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
14. Children in our science class like to fight.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
15. Pupils feel bad when they don't do as well as the others.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
16. Only the smart pupils can do their work.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
17. Pupils in my science class are close friends.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
18. I usually find that science classes are enjoyable.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
19. Pupils don't like this science class.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER

Remember you are describing your SCIENCE classroom — Circle your answer

20. Pupils always want to have their own way.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
21. Pupils always try to do their work better than the others.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
22. Science work is hard to do.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
23. Pupils in my class like one another.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
24. The science class is fun.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
25. Children in our science class fight a lot.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
26. Children in my science class want to be first all of the time.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
27. Pupils in my science class know how to do their work.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
28. Children in our science class like each other as friends.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER
29. I think I would like a job in science when I leave school.	NEARLY ALWAYS	SOMETIMES	HARDLY EVER

For Teacher's Use Only

S ______ F ______ Cm ______ D ______ Ch ______ At ______

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