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ABSTRACT

The purpose of this investigation was to explore the ideas and beliefs of high school science students (n=37) about the processes of observation in their learning of science, and how these students approached the task of observing during their science experiments. Findings include: many students saw observation as a teacher-directed process; observation was often seen to have a contextual dependency; when groups of students undertake laboratory experiments, the size of the student group is a significant variable impacting on students' approaches; many students undertaking high levels of intellectual engagement reported during observing; three problems commonly intruded on students' approaches to observing were the teacher, the specific experiment, and other students; students had no word to describe inferences and poor conceptions of inference; student time off task in laboratory work was common, conscious, and seen as justified; and the commonly reported gender differences in participation in laboratory work were observed. Includes interview protocol. Contains 12 references. (MKR)

# OBSERVATION IN SCIENCE CLASSES: STUDENTS' BELIEFS ABOUT ITS NATURE AND PURPOSE

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## INTRODUCTION

The fundamental purpose of the investigation reported in this paper was to explore the ideas and beliefs of high school science students about the processes of observation in their learning of science, and how these students approach the task of observing during their science experiments. As part of a wider investigation, the ideas and beliefs of a small number of high school science teachers about observation and student learning of science were also explored. These data are only briefly referred to in this paper.

An examination of almost any school science curriculum document will reveal that student observation is held to be central to the learning of science. A systematic inspection of such documents from the U.K., Australia and New Zealand that was undertaken at the beginning of this study provides many examples of this. We give just one here, taken from the school science curriculum document from that part of Australia in which the study was conducted.

> Observation and direct experience are crucial in concept development and in challenging existing beliefs and understandings. (Malcolm, 1987, p.72)

While there is widespread, perhaps even universal, acceptance of the centrality of observation to the learning of school science (and to the learning of science at other levels of education), there is little known about how students construe the nature and value of observation in their science learning. As an illustration of this assertion consider the recent handbook of research in science education (Gabel, 1994). The index for that volume contains no entry under "observation", nor any entry about observation under "Learning", "Science Laboratory" or "Student".

What is known about student learning and observation is that existing cognitive knowledge and beliefs held by an observing student influence both the nature and interpretation of his/her observations (e.g. Appleton, 1990; Driver & Bell, 1986; Gunstone, 1993; Rowell & Dawson, 1988). That is, however a student construes the nature and process of observation, the observation is theory-laden. This adds to the importance of this study - not only do we know little about students' ideas and beliefs about observation in science classes, we do know that observing is not a simple matter of direct reproduction of stimuli, that "'Looking at' is not a passive recording of an image like a photograph being reproduced by a camera" (Driver, 1983, p.11). Thus we have evidence of complexity in at least some aspects of the process of observation, an issue that enhances the need to understand more about students' ideas and beliefs about observation.

## THE NATURE OF OBSERVATION IN SCHOOL SCIENCE

While "observation" is often described as one of the processes of science, a number of authors (e.g. Millar, 1990) have noted that observation is not a process that is exclusive to science. A major consequence of this is that a necessary beginning point to this study is to clarify our position on how observation is seen to be conducted in science. We take the views of Russell et al. (1993) about what they term "scientific observation" to be an appropriate guide to the issues about observation on which this study should focus. In summary these views are:

* Scientific observation is not a process to be carried out in isolation. It forms part of a whole investigation, and serves some particular purpose in that investigation.

* Scientific observation has a specific meaning, and that meaning is closely related to the purpose of the investigation.

* Though it may appear straightforward, scientific observation is actually a very complex process.

* Conceptual knowledge cannot be removed from the process of scientific observation as it guides the selection and interpretation of observations made.

* The observer's perception of the purpose of the task interacts with the knowledge and experience of the observer in the observer's decisions about what features are relevant.

These views are consistent with those of other authors (eg. Driver, 1983; Gunstone, 1991) and indicate the ways in which we conceptualised scientific observation as we planned this study.

## THE METHODOLOGY AND PROCEDURES OF THE STUDY

The study was undertaken via interviews, with subsequent use of the interview schedule as a pencil and paper instrument with a larger group. The statements about scientific observation in the previous section of this paper were a strong guide to the construction of the interview schedule, as were a number of small pilot investigations. These pilots are not detailed here, but were most varied: many interviews using a variety of questions and approaches with young and adolescent students in out-of-school settings; informal interviews during laboratory classes with first year university science students; observation (including videotape) of final year high school science student teachers undertaking a series of observation tasks, and questionnaires completed by these student teachers about the experience. All pilot studies were undertaken by the first author.

The interview protocol that resulted had 6 sections. These sections were designed to probe:

(i) what students said they paid attention to while observing during science experiments;

(ii) whether they perceived differences in the ways they observed and what observation meant to them in different experiments, and how they saw observation in terms of their science learning;

(iii) an actual act of observing (a piece of chocolate) and which of a number of given propositions were seen as observations (these propositions contained statements that we see as observations, e.g. "The chocolate is brown", and statements that we see as not observations, e.g. "The chocolate contains sugar");

(iv) reactions to a number of statements about observing in school science experiments, presented as statements from other students;

(v) any thinking and questioning undertaken by students during the conduct of experiments;

(vi) students' understanding of the meaning and significance of "inference" in science experiments.

As part of preparation for the interviews, and as clearly required by some sections of the interview schedule, the first author spent considerable time observing (both during classes and via videotapes of these classes) the three science classes from which the interviewees were drawn. These observations resulted in the addition of a further section to the protocol. This addition probed

(vii) students' perceptions of the ways the groups in which they worked during science experiments proceeded with the task, and how this was influenced by the size of the group.

The final protocol is given as an Appendix to this paper.

All interviewed students were drawn from Grade 10 science classes in a typical large government high school in Victoria (Australia). At this level of high school in Victoria, science is a single subject (rather than there being separate subjects called "physics", "chemistry", etc) and is undertaken by all students. Three classes were targeted, with a total of 37 students being selected for interview. Selection from each class was by the class teacher, and was based on our request to give a variety of levels of science achievement. All interviews were conducted by the first author who, because of the prior observations of the classes and some emergency teaching in the school, was already well known to the interviewees. The interviews were conducted in an office in the school. All 37 interviews were taped and transcribed. In this paper we report analyses of these transcripts, with some additional reference to the data obtained from interviews conducted with the teachers of these students.

## RESULTS

The data obtained in this study are rich and extensive. Our approach to reporting in this paper is to give some of the more significant findings as assertions, and, for each assertion, to elaborate and give examples of supporting data.

Assertion 1: Many students saw observation as a teacher-directed process

A clear majority of students at some point in the interview described observations in science in ways that clearly implied that they saw this as a teacher-directed process. This emerged across a number of the seven sections of the interview protocol, in both forced choice and open-ended stimuli. For some students this view appeared with only one interview question (and therefore may be a contextually specific issue), while other students were consistent in expressing the view.

For this latter group the view was often expressed in language that implied antipathy towards observing and laboratories. For example:

> [I pay attention] to only what the teacher asks me to. (Section (i), Q1, Student 2-C)[1]. Science has always been [pause] not easy, but not really exciting either for me, so we don't usually pay attention, just do what we are told to do.
> (Section (i), Q1, Student 2-C).

> First one, I pay attention only to what the teacher said.
> (Section (i), Q1, Student 4-A).

However, there were other students for whom the link between observing and teacher direction was more of the form of science experiments having predetermined consequences that were the only things to be observed.

> ...if you are experimenting the reactions between two chemicals you watch the reaction and not how hot it got and something like that. (Section (i), Q3, Student 1-A).

There are clear links here with the theory-laden nature of observation already discussed.

Still other students saw teacher demonstrations as central to observing in the science laboratory, particularly because of the teacher directedness inherent with a demonstration.

> I think it is better if the teacher does the experiment so that we actually watch properly. (Section (iv), Q3, Student 3-C).

One of the clear trends in the data relevant to this assertion is a teacher effect — each of the three classes had different patterns of relevant responses, and these patterns were broadly consistent with the general views of the three teachers. Table 1 gives one example.

Table 1 about here

[1] Coding indicates the section and question from the protocol to which this response was given; this respondent is the second interviewee from Class C.

In this table responses to Section (i), Question 3 are categorised. This question probed students' perceptions of how they decided what to pay attention to when they observed. The obvious issue here is the clear difference between Class C and the other two. In interview, the teacher of Class C consistently expressed views consistent with the following two quotes:

> I make the connections for them. I might do some explaining, summarising on the board. I find that most of the time I have to do the connections for them.

> Most of my students would pay attention to what I say to pay attention to. No matter what other interesting thing comes up in the prac they are not interested in it. They just want to get the job done. As far as observations are concerned they are to observe a certain thing, which I tell them to.

It seems clear that at least some of the student views of observation as a teacher-directed process are learned responses, derived from coping with some teachers.

<u>Assertion 2: Observation was often seen to have a contextual dependency</u>

There were two general forms of contextual dependency found to often interact with students' approaches to observation: whether or not the experiment had intrinsic interest for the student, and the area of science involved. While these two aspects were hard to separate in some cases, there were a number of students for whom scientific observation appeared to be a different process in different areas of science. Sixteen of the 37 interviewed students responded in this way when asked directly if there were any differences in the way they observed in experiments in Biology, Chemistry and Physics (Section (ii), Q3), with other questions in this section also giving this response. However, issues of intrinsic interest were also present in some of these 16 responses.

> Differently? With that chemistry one [chemical reaction] if something happens it happens straight away. With the other ones, like the car one [a ticker-timer experiment] you just watch and after the second one it is boring.
> (Section (ii), Q3, Student 2-A).

> Because in like ticker tape, you do not observe much. But in chemistry you watch for fires and that, or if I find it more interesting I would observe more.
> (Section (ii), Q4 Student 8-A).

> It is different when you dissect a rat, you have to look not carefully. With chemicals you have to like, um [pause] you have to concentrate more, make sure you have not taken something wrong and stuff like that.
> (Section (ii), Q4, Student 1-B).

> I always think .omething is going to happen straight away, in chemistry it does so I observe that differently. In some other subjects [areas of science] it doesn't happen straight away, sometimes in other subjects I wonder if I have done something wrong. (Section (ii), Q4, Student 6-B).

There are some general trends in the responses of students who saw differences in observing by content. If the observation was in a chemistry topic, then observing was seen as a direct act that focussed on what could be seen as two chemicals reacted. Here observation tended to be seen as direct because it involved a changing context, as needing clear attention because of that change and, sometimes, as being potentially dangerous and therefore demanding greater attention. In a quantitative physics topic however the acts involved in measurement became central, and observing in the sense implied in a chemistry topic just did not occur. Less attention was demanded by the experiment, there was little or no sense of imm.diacy. Biology was seen as involving more static contexts and to have clear negative affect, both of which diminished the perceived need to observe in the direct manner associated with chemistry.

There is also a suggestion in our data that the immediacy of the observation in a chemistry topic might be significant in terms of motivation to engage with the experimental task (see, for example, Student 2-A quote above). Other references to the influence of interest in the topic were more general, and thus less informative.

> If I am interested in it I observe full on. (Section (ii), Q4, Student 11-A.)

A third aspect of contextual dependency was raised by a small number of students. That was the impact of believing that one already knew the content associated with the observation. Sometimes this meant the observation was taken more seriously:

> ... some you know exactly what happens, some you know the after effects and stuff like that. (Section (ii), Q4, Student 1-B)

and for other students this meant that less attention was given to observing:

> If I don't know what is going to happen I look at it more, if I know and he has told us I don't really look. (Section (ii), Q4, Student 11-C)

(Note also in the last quote the issue of teacher direction, again from Class C.)

Assertion 3: When groups of students undertake laboratory experiments, the size of the student group is a significant variable impacting on students' approaches

This assertion has links with Assertion 7 below. These links are briefly noted in the discussion of Assertion 7.

The central issue with Assertion 3 is that almost all students saw their own approaches to experiments, and the approaches of those with whom they worked in laboratory groups, to be substantially changed by the size of the group in which they worked. When in a group of two, nearly all students reported reasonably constant task engagement (although this engagement often did not include observation in the way intended by the teacher). In groups of three or more, students reported significant periods where they were off task, and these periods resulted from conscious choice by the students. We illustrate this by giving extracts from interviews with three different students. All are responding initially to Section (vi), Q2.

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|---|---|
| Student 8-A: | If I am doing it by myself I'll do it and if it is in a group I may let others do it and I'll do something else like sit back and watch and catch up on some work that I have missed, and I copy [the observations] afterwards. |
| Interviewer: | For you, what would be better? |
| 8-A: | I think one [individual experimenting] is better for me, so I will have to do it. |
| Interviewer: | Would one be better than two? |
| 8-A: | If it is twos you can discuss it with your partner while it was happening, but then someone can take over again and the other person could tend to slack off and sit and watch anyway. For myself one is better. |

Student 5-A: You concentrate more when you have two people because you haven't got other people to do it. So you have to do it yourself, so you concentrate more.

Interviewer: You mean when you work alone you do your own observations, when there is two ...?

5-A (interrupting): We are still more likely to do it together, whereas in fours one person does it and others copy. You don't pay attention as much.

.....

Interviewer: Why do you think you do that? You know that it is good to observe individually, and you find yourself in a different pattern. Are you aware of it?

5-A: Usually being in a group of three or four someone says "I'll do it". Then you say "Okay, you do it" and then we talk about the weekend.

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Student 7-A: If you have different amounts of people you have a different amount of jobs. You know if there is a big group there is less for each person to do but if there is a small group you have more responsibilities.

Interviewer: What else is different?

7-A: The cooperation I suppose. [pause] If there are two, you have to either agree on that or if you disagree you have to see which one is right, but if it is four people two might observe and the others won't do the observing.

Interviewer: In what ways does that affect the way you observe?

7-A: It is better in twos, usually two people show interest and they do everything, observe ... If it is in fours you just sit back.

Interviewer: Can you tell me any other things about observation when you work in groups?

7-A: Usually teachers go around and ask you what you are doing and you sort of make things up from what you hear from others in the group.

In the above extracts there is a clear message about how appropriate students see the strategy of division of labour when working in groups of greater than two. This is generally typical of all student responses. We have used extracts from Class A students as these students were rather more articulate and reflective in expressing this position. In passing, we note that this Class A difference is consistent with the teacher of the class being involved in the Project for Enhancing Effective Learning (the PEEL project; Baird & Northfield, 1992), and therefore being explicitly concerned with developing enhanced metacognition among the students.

There is also a suggestion in a number of student responses that individual experimenting demands greater engagement (e.g. student 8-A above). However, other students were clear about the advantages of social interaction to learning, and therefore advantages in working in pairs (e.g. student 7-A above). When explicitly asked in Section (vi) of the interview what their preferred group size was, two was the overwhelming response. ("Two" was nominated by 29 students, "one" by two students, "three" by four students, "two or three" by one student, "five" by one student.)

As noted in the early sections of this paper, we are focusing here on interview data from 37 students. This research also involved extensive observations of the three science classes involved, with videotaping enabling repeated observations of the same event. We do not intend to focus on these observational data here. However, it is highly significant that the students' perceptions of the impact of group size on their approaches to observing are strongly supported by the observational data.

Assertion 4: Many students reported thinking during observing; the nature of this thinking varied

Some students reported undertaking quite high levels of intellectual engagement during the act of observing, and did so in terms sufficiently general as to clearly imply that this engagement occurred across laboratory contexts. Most of these more insightful responses came in response to the initial question on this issue; these responses were often already clear to the students giving them and were not created by the need for a response.

> Just sort of questions like, you know what, [pause] what are we learning, what are we doing this for, for what purpose, like with those car things [ticker timer experiments], "What am I doing this for?", "Where am I going to use this?".
> (Section (v), Q2, Student 13-A)

> I wonder how it got there, and why it did that? I always ask myself questions. I don't necessarily go out ten minutes later to find the answer, but I wonder.
> (Section (v), Q1, Student 7-B)

How does it happen? Why did it happen? Um, what is it used for? Is it true or not?
(Interviewer: What do you mean if it is true or not?)
Some of the things that you do you can't actually see them. Hydrogen you can't see, you can't smell, can't feel, can't make any noise, so how do you know that it is there? And wondering if there is anything else that is in there too; hydrogen used to be confused with other gases.

(Section (v), Q1, Student 9-C)

For the majority of students there were more specific and less exciting responses in this area, including some responses that indicated thinking other than attempts to understand the observation. In a number of instances this type of response emerged after more questioning than for the more general types of response discussed above.

Did I do it right, and I just [pause] look around to see if everyone else got the same as me, if I did right or not. (Section (v), Q2, Student 2-A)

Sometimes [I ask questions] ... Have I done something wrong? Or is this right?
(Section (v), Q1, Student 5-B)

If the teacher has not explained the actual [pause], what the chemical does, I ask through my mind what does it contain, how would it react?
(Section (v), Q2, Student 5-C)

In a small number of cases, students rejected any notion of thinking during observation. While most of these responses were simply "No" one student had a clear reason for adopting this stance.

... I just write it down. I do what I am supposed to do. Trying to figure it out is pretty hard, so I don't bother.
(Student (v), Q1, Student 8-A)

Assertion 5: Three problems commonly intruded on students' approaches to observing

These three problems arose from three different sources: the teacher, the specific experiment, other students.

When teachers made clear before the experiment what would be observed, or otherwise gave premature explanations, some students claimed this impacted upon their approach to the observation task.

> If I don't know what is going to happen I look at it more ... If he [the teacher] has told us I don't really look.
>
> (Section (ii), Q4, Student 11-C)

Where an experiment was seen by some students to be uninteresting, or already familiar, these students reported reacting in predictable ways.

> ... There are some experiments that are sort of boring, and just no one does anything...
>
> (Section (ii), Q2, Student 13-A)

> If you give kids the same experiment over and over again ... exactly the same experiment to find out the same thing. The magnesium ribbon, the pop test for hydrogen gas I have done probably three or four times at this school ... I suppose that bores the kids.
>
> (Section (iv), Q2, Student 7-B)

Similarly predictable, particularly in the light of Assertion 3 above regarding the impact of group size, was that students reported disruption from other students impacting on their approaches to observing when groups were large.

> ... there is always somebody who doesn't want to learn and distracts you and messes up your observing. You can't concentrate as much.
>
> (Section (vi), Q1, Student 9-B)

Assertion 6: Students had no word to describe "inferences", and poor conceptions of "inference"

Section (iii) of the interview involved asking students which, of a set of given propositions, were observations regarding a piece of chocolate. Many students performed quite well on this task. However, the next question, which asked what the propositions not seen as observations would be called, produced interesting data. No student used the word inference. Words that were volunteered included "guesses", "knowledge", "facts", "acknowledgments", "thoughts". Many students chose to not give any word at all.

The startling data came from introducing the word "inference". It was planned that students who did not use this term would then be given the word and asked if they had ever heard the term. Thus this was done with every student. Only one claimed they had heard the term, but could not give any notion of what the word meant.

This makes it very difficult to be at all clear about the conceptions these students had of what we would call inference but these conceptions do appear inadequate.

The obvious response to these data is to assert the need to teach students about inference and its relations with observing as part of enabling observation to play the role in learning that is usually assumed in the science laboratory. However, our teacher interviews point to a major problem with this assertion: teachers, at least those teachers involved in this research, also have inadequate understanding. Teacher B had no word to describe the propositions he saw as not observations ("I wouldn't know what to call it"), and appeared most uncertain about how to consider these propositions. Teacher C was a little better, calling the non-observations "calculated guesses based on prior knowledge". Teacher A initially called the propositions he saw as not observations "believable assumptions". Eventually in his interview he did use the term "infer". Of the three, only Teacher A appeared to have an adequate conception of inference.

Assertion 7: Student time off task in laboratory work was common, conscious, and seen as justified

Part of the justification given by students for choosing to spend time not engaged with a laboratory activity was the issue of personal interest, already noted in Assertion 5. Two other issues emerged here. A number of students justified periods off task on the grounds that many experiments were "too long" (by which they meant the task did not hold their motivation for its duration), and/or were not sufficiently demanding as to require them to spend all available time on the task.

This might appear to be a pair of contradictory ideas. We do not think so. Rather, we believe, these students were reacting to a rather ritualised approach to laboratory work — experiments taking a full science class regardless of the length of time needed for completion of those aspects of the experiment central to the learning task, a strong focus on outcomes (particularly in Class C), and inadequate explicit linkages between the laboratory experience and the science classes preceding and following it. Students with these rationalisations for going off task tended to be students who saw experiments as tasks to be completed, rather than tasks to assist learning.

In giving these conjectures we do not intend harsh criticism of the three teachers; rather we intend harsh criticism of much science laboratory work. Much laboratory work would be dramatically improved if "students spent more time interacting with ideas and less time interacting with apparatus" (Gunstone, 1991, p.74).

We are much less conjectural in commenting on links between Assertions 3 (impact of group size) and 7 (that currently under discussion), and 4 (students reporting intellectual engagement) and 7. These all form a consistent picture, a picture with links to our points about ritualised laboratory. The issues in Assertions 3, 4 and 7 are consistent with a majority of these students being reasonably seriously committed to what they see to be approaches consistent with learning, and also adopting strategies to allow them to better cope with the demands of a variety of school subjects, social activities and other more personally relevant concerns. That is, what White (1992) describes as the Principle of Minimum Expenditure of Energy is operating. It is common human behaviour to seek strategies for coping with recurring experiences; many of these students appear to be adopting such strategies.

Assertion 8: The commonly reported gender differences in participation in laboratory work were observed in this study

There were no data from the interviews on gender issues. However, we believe it important to note that the extensive class observations undertaken as part of this study showed that, in laboratory groups of mixed gender, boys very commonly took the active roles of manipulators of apparatus and girls were commonly recorders. This recorder role often included being the observer for the group, and then also the recorder of the observation.

## THREE GENERAL COMMENTS ON THESE DATA

Before turning to some conclusions, we believe it to be important to make three further points about the data. Our mode of presentation of data, via assertions, has been valuable for us in allowing valid descriptions of a very large quantity of information. This mode however has not allowed three significant aspects of the data to emerge.

The first aspect is that some students were quite profoundly insightful in their approaches to answering the interview questions. The nature and depth of student thinking was in a few cases quite extraordinary. The following response by Student 4-A to Section (iv), Question 3 ("Tell me something more which can help me understand the way you do the observing during science experiments") is a good example of the length and insightfulness of some student responses.

Student 4-A: When we do experiments we normally go in groups [pause] and normally if it is in a group of four, two of us do the observing and two of us write down the results and later on we'll be discussing the results in sort of, like, in a group. And I think most of the experiments were done like that. Some experiments were done individually, so we had to observe by ourselves and which I thought was pretty hard. That is what I thought because in a group you've got, you know, people to talk, things like that [pause]. Or when you are an individual, when we had to talk about the coin in water.[2] [Change of audiotape.] The washer in water, you know, what we had to do we had to observe, um, it had to do with reflection [sic] and all that. We had to observe and all that. And then when it comes to the questions I sort of did not understand the questions [pause] and I didn't, like, [pause] I have to keep doing the observations to try and keep thinking what the questions meant, and that, but finally I sort of went for the answers. I didn't really get the answer until he finally told us [pause] and I thought if something like this happens it is hard. But if you observe in a group you can still ask people around you what is happening. When we were doing it by ourselves I thought it only became hard when we had to answer what we, what we had observed, and I thought that is a hard part about observations, just answering the questions, something like you might have observed different to other people so you have written down what you observed, but that might not be right.

[2] Student 4-A is referring to a short experiment done individually where a coin was placed in a beaker, water poured in, and the coin observed. Questions were to be answered about this.

Of course many students did not give answers of such length, or answers that attempted to explore subtleties. Indeed some students were almost monosyllabic, and indicated little real engagement with observing in science. But we are impressed by those responses of the nature of that just given.

The second general aspect of the data is illustrated in a passing way by the above extract. It was of great significance to the quality of the interview data that the first author had spent considerable time observing in each of the three classes. This allowed for much more clarity in the interviewer's interpretations of the specific instances described by the students (e.g. the coin in water experiment in the above extract). At a relatively minor level this meant the interview was not "interrupted" by questions like "what was that experiment about?", "Can you describe that experiment to me?". These questions would have been essential to establish context if this context had not already been carefully observed. More significant than this was the way in which real understanding of a context by the interviewer enabled the interviewer to probe student responses that were embedded in that context. This resulted in a number of instances of substantially richer data.

The third general aspect of the data that does not emerge through our assertions is the impact of the teacher. We have shown in Table 1 the impact of teachers of these three classes on the extent to which their students saw observing as a teacher-directed process. There is clear teacher impact in the data underlying all the other assertions except Assertion 8. (Recall that Assertion 8 involved issues of gender and derived from classroom observation rather than interview.) The specific pattern of teacher impact is not the same in all cases; sometimes responses from Class A as a group are clearly different from Classes B and C, sometimes Class C is clearly different from Classes A and B, sometimes all three classes are different. However there is a clearly consistent general pattern, the pattern shown in Table 1. Whenever one class is distinguished by the positive and insightful nature of student responses, it is Class A. Whenever one class is distinguished by the inappropriateness or inadequacy of the student responses, it is Class C. The impact of the teacher on student' ideas and beliefs about observation is strong in this study.

## CONCLUSION

We take two approaches to summarizing these data.

It is possible to extract from the transcripts clear indications of the views of these students about the value of observation to their science education. We have grouped these views and describe the groups below in terms used by at least some of the students. The number of instances of students expressing each view is given. (Some students expressed more than one view during their interview, and more than one variation on the view represented by the grouping.)

- **Observation "helps to gain understanding"**

  (23 instances). Variations on this theme included helping to gain understanding when observation "relates to notes", observation is better "than when reading" or "than when writing", "practice" helps students to "understand more".

- **Observation "helps to find out"**

  (3 instances). Elaborations of this included "the teacher can 'tell' the student but the student finds out by observation", observing allows the student to "find out what really happens".

- **Observation "helps to gain knowledge"**

  (6 instances). One elaboration involved comparing observing with copying notes; when copying the student "can't really know".

- **Observation "helps to get answers"** (3 instances).

- **Observation "helps to learn or learn better"** (11 instances; 7 from Class A).

- **Observation "helps to remember"**

  (4 instances). Elaborations were of the form 'I do, therefore I remember'.

- **Observation "helps to see what is happening"**

  (11 instances; 5 specifically referred to Chemistry experiments).

- **Observation "provides safety"** (3 instances).

  These responses were of the form 'things can be dangerous; if you don't look you will get hurt'.

- **Observation "makes science interesting"** (5 instances).

- **Observation "helps to relate to the notes"** (one instance).

- **Observation "helps only in chemistry"** (one instance).

Two students did not see value in observing ("...the truth is I don't observe much", "I don't know [what value observing is]"). There were also a number of other statements that had something to say about the value of observation, but it was difficult to decide precisely what was intended by the student (e.g. "observation is what science is", if a student "has to observe the colour, observation helps in the learning of science").

As our second approach to summarising these data we present below four different patterns of linkage between approaching observing, purpose of observing and desired consequences. These four patterns account for all of the interviewed students.

| | APPROACH | | PURPOSE | | DESIRED CONSEQUENCE |
|---|---|---|---|---|---|
| (1) | Do NOT use senses for observing | | (Obtain results from other students) | → | Complete the experiment. |
| (2) | Use sense of sight without purpose. | → | May not get results. | → | Complete the experiment |
| (3) | Use sense of sight and other senses with purpose. | → | Only to get results. | → | Complete the experiment. |
| (4) | Use sense of sight and other senses with purpose. | → | To get specific results, and learn. | → (Processing) | Complete the experiment to learn and understand. |

## A POSTSCRIPT

As we have noted earlier in the paper, the first author spent considerable time in the school that was the site of the research prior to conducting the interviews. This time involved both observing regular science lessons for all three science classes and acting as an emergency (substitute) teacher for classes that included these three.

After completing interviewing the first author withdrew from the school. Some weeks later she returned for a day as an emergency teacher. One of her classes was Class A. In the corridor prior to this class, and before students of Class A were aware that she was to be their teacher for science on that day, a number of class A students approached her to ask (with evident interest, even enthusiasm) about her research. As a consequence, a lively discussion about observing took place during the science lesson. Although our data collecting for this impromptu event had to comprise notes written by the first author (as, for obvious reasons, she did not have a tape recorder with her), these data records are clear in showing two significant things. Students were genuinely interested in the research and ways in which it could relate to them and their science learning; students expressed, again, many of the views about observing that had been revealed in the interviews.

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**Table 1: How students determined what to pay attention to in observing**

| Class | Teacher direction | Teacher direction and classroom discussion | Classroom discussion | Aim of experiment | Other |
|---|---|---|---|---|---|
| A (n = 14) | 5 | 3 | 1 | 2 | 3 |
| B (n = 11) | 5 | - | 3 | - | 3 |
| C (n = 12) | 10 | - | - | - | 2 |

## APPENDIX: INTERVIEW PROTOCOL

The protocol given below is that for the student interviews. The ways in which the teacher interview protocol differed from the student protocol are described at the end of the student protocol.

The protocol appears in the seven sections described in the text of the paper, with a heading for each section being given to remind the reader of the emphasis of that section. This heading was not given to the interviewee. The interview refers to recent experiment(s) done by the intrviewee. Each section has the following structure:

(a) A "scenario" is given. This scenario was described to the interviewees in the way indicated by the quote ascribed to "Interviewer".

(b) An "event card" is given in a box. The material in this box was printed on a card and placed in front of the interviewee.

(c) A series of questions was then asked of the interviewee. These appear in another box labelled "Questions", with the questions numbered Q1, Q2, etc for each section

### Section (i) - PAYING ATTENTION

Scenario (i)

Interviewer: "When talking about paying attention to a particular thing whilst observing during science experiments, some students said: 'I pay attention to only what my teacher has asked me to pay attention to'. and others said: 'I pay attention to what I think I should pay attention to'."

Event card (i)

- I pay attention to only what my teacher has asked me to pay attention to.
- I pay attention to what I think I should pay attention to.

Questions (i)

Q1. Which of these two did you do during this experiment?
Q2. What do you usually do during science experiments?
Q3. How do you think you decided/knew what to pay attention to?

### Section (ii) - TO OBSERVE

Scenario (ii) [Based either on a relevant written laboratory report done by the interviewee or reference to a very recent laboratory experiment undertaken by the interviewee]
Interviewer: "Here you have written the word observation."
*OR*
"Yesterday your science teacher asked you to perform the experiment on ____."

Event card (ii)

**Observation.** *The ......*

Questions (ii)

Q1. What did the word observation mean to you during this experiment?
Q2. What do you think you did when you were asked to observe?
Q3. Were there any differences in the way you observed the three different experiments? (In Biology, Chemistry and in Physics?)
Q4. If yes what were they?
Q5. Do you think observation is important in science learning? Yes or No?
Q6. Why do you think observation is/is not important in learning science?
Q7. In what way do you think observation is important in learning science?
Q8. How does observation help you in science?

Scenario (iii)

## Section (iii) - EXAMINING A PIECE OF A CHOCOLATE

**(A piece of chocolate, unwrapped, is given to the student.)**

Interviewer: "I want you to touch, taste, smell and look at this chocolate.
I am now going to give you a card that contains statements made by some Year 9 science students about this chocolate."

Event card (iii)

Statements made by Year 9 students about this chocolate.
1. The chocolate is light brown.
2. The chocolate was made in Australia.
3. The chocolate is hard.
4. The chocolate must contain some sugar.
5. The chocolate will melt easily.
6. The chocolate contains cocoa.

Questions (iii)

Q1. Read the statements aloud and tell me which statement, or statements is or are observations.
Q2. Why did you say that this statement/these statements is/are observations? Explain to me.
Q3. What are the other statements?
Q4. Why do you think they are ..................? Why do you say so?

## Section (iv) - WAY OF DOING THE OBSERVING

Scenario (iv)

Interviewer: "A few days ago, in another school I was talking to some students about the way in which they perform their observations during science experiments. Some of their responses have been written on this card."

Event card (iv)

1. Christina: "One person does the observing."
2. Tonia: "Every person does her own 'observing' in our group."
3. Brendan: "My science teacher does not ask us to observe individually, so we copy the observations of the person who does the observing."
4. Jenny: "The person who does the observing dictates the observations ... and others copy."
5. Ian: "Sometimes I copy the observations made by others and sometimes I do the observing."
6. Michael: "Only one member of the group does the observing, but in our group we discuss about what we are observing."
7. Nadia: "We do not discuss during the observation part of the experiment ... only after the observations are copied by all of us, in the discussion part."

Questions (iv)

Q1. Which of the above statements, about the way students "do their observing during science experiments", do you think applies to you ?
Q2. Tell me something different about the way you think you do the observing during science experiments.
Q3. Tell me something more which can help me understand the way you do the observing during science experiments?

## Section (v) - THINKING DURING OBSERVING

Scenario (v)

Interviewer: "I was trying to explore ideas that year 10 science students have about observation during science experiments. Whilst we were talking about the thinking that goes on during observing, Mark said: 'I do two different things, one in my mind, and the other to write questions and wonder. I understand what I am learning after this wondering'."

Event card (v)

| |
|---|
| Whilst we were talking about the thinking that goes on during observing, Mark said: "I do two different things, one in my mind, and the other to write down in the Prac report. In the Prac. report I write what the teacher wants, but in the mind, I ask questions and wonder, I understand what I am learning after this wondering." |

Questions (v)

| |
|---|
| Mark refers to the questions that he asks himself in his mind.<br>Q1. Has this happened to you, whilst you were observing an object or happening during a science experiment?<br>Q2. What sorts of questions do you ask? Tell me about them. |

## Section (vi) - GOING ABOUT DIFFERENTLY

Scenario (vi)

Interviewer: "When I was watching the videotapes of your class I thought that you were going about the prac. differently when you were working in the group of three or more."

Event card (vi)

| |
|---|
| When I was watching the video tapes of your class I thought that you were going about the prac differently when you were working in the group of three or more. |

Questions (vi)

| |
|---|
| 1. Do you think you go about your prac differently?<br><br>If "Yes"<br>2. What do you think is the difference?<br><br>If "No".<br>2. What do you think could have given me that impression? |

## Section (vii) - INFERENCE

Scenario (vii)

Interviewer: "Sometimes some science teachers use the word infer or the word inference; these words also appear in science text books."

Event card (vii)

| |
|---|
| **INFERENCE** |
| **INFER** |

Questions (vii)

1. What does the word inference mean to you?
2. What does the word infer mean to you?
3. What do you think you do when you are asked to infer?
4. Were there any differences in the way you inferred during the three different experiments?
5. If yes what were they?
6. Do you think inference is important in science learning? Yes or No?
7. Why do you think inference is/is not important in learning science?
8. In what way do you think inference is important in learning science?

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Teacher Interview Protocol

In all but two cases the above questions were slightly rephrased so that teachers were asked about how they thought their students went about observing. The two exceptions were the above Sections (iii) (observing the piece of chocolate) and (vii) (inference). In these two cases the teachers were probed for their own views.