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Openness of inquiry of laboratory formats currently used in lower secondary Science

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OPENNESS OF INQUIRY OF LABORATORY FORMATS CURRENTLY USED IN LOWER SECONDARY SCIENCE.

BY

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ABSTRACT

Laboratory formats can range from 'recipe' type activities, in which students just verify concepts, to 'open' inquiry activities, in which students design and carry out their own experiments. There is much support in the literature for the use of 'open' inquiry formats.

By way of a questionnaire sent to a sample of lower secondary science teachers, this study investigated the proportions of the different laboratory formats that are currently being used in lower secondary science in Perth schools. The study found that most of the formats used required students to follow set procedures to verify or determine a concept. Few 'open' inquiry activities were used which required the students to design and carry out their own experiments. The thesis also reports the teachers' perceived benefits and difficulties of using 'open' inquiry activities.

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signature

Date 29/11/94

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TABLE OF CONTENTS

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

Introduction

Background

There are a number of formats that teachers can use for laboratory work. They can be located on a continuum ranging from verification type formats, where students are required to follow 'recipe' type instructions without using any inquiry skills, to 'open inquiry' formats where students are required to design and plan much if not all of their experiments themselves. There is much support for an increased use of more 'open inquiry' formats (Hegarty-Hazel, 1986; Hodson, 1990). Such formats are often better suited to achieving the goals of laboratory work, such as increasing positive attitudes and motivation and developing expertise in scientific method.

Theoretical Framework

Laboratory Activities

For the purpose of this study, 'laboratory activities' is used to mean those "contrived learning

experiences in which students interact with materials to observe phenomena. [They]... may have different levels of structure specified by the teacher or laboratory handbook" (Hofstein & Lunetta, 1982). Laboratory activities may include designing, planning, using equipment, measuring, but are not such activities as teacher demonstrations or museum visits.

Openness/Levels of Inquiry

When discussing formats used for laboratory activities, a scale which classifies activities according to openness is a helpful technique because it aids in communication. Such a scale has been used in research (Hegarty-Hazel, 1986; Tamir, 1989) to classify laboratory formats (See Table 1). This scale was first devised by Schwab in 1962 and elaborated to include level zero, the lowest level of inquiry, by Herron in 1971 (Tamir, 1989). Hegarty-Hazel (1986) further elaborated the scale to divide level 2 into levels 2a and 2b to increase discrimination between levels of openness.

At the lowest level of inquiry, (level 0), the problem to be investigated, the equipment to be used, the method to follow and the answer to the problem are all given to the students by the teacher or by a worksheet. At the highest level of inquiry, (level

3), the students are required to determine these things for themselves. Levels 1, 2a, and 2b are sequenced, according to the source of the equipment and methods used, between the lowest and highest levels.

Table 1
Levels of Openness of Inquiry in Laboratory Activities.

Level	Problem	Equipt.	Methods	Answer	Common name
0	Given	Given	Given	Given	Verification
1	Given	Given	Given	Open	Guided inquiry
2a	Given	Given	Open	Open	Open/guided inquiry
2b	Given	Open	Open	Open	
3	Open	Open	Open	Open	Open inquiry

Note: Given: given to the students by the teacher or worksheet
Open: not given to the student so that they have to decide and plan themselves.

(adapted from Hegarty-Hazel, 1986; Tamir, 1989)

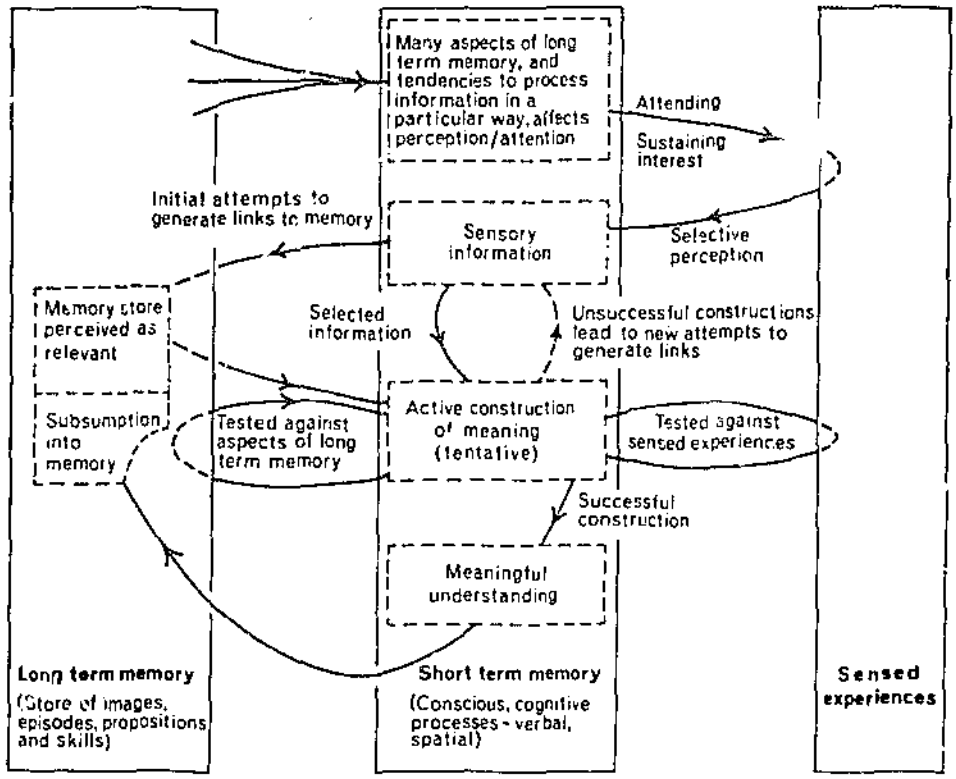
In using this scale, the phrase 'higher level of inquiry' can be used synonymously with 'more open inquiry' as both describe laboratory formats toward the end of the scale in which the students are required to do more decision making, planning and designing themselves. These phrases are used for ease of communication and pertain to responsibilities given to the students because this is essentially where the difference lies.

The following discussions of the research problem and questions, the literature, and the study, revolve around this framework of the levels of openness of inquiry of laboratory formats.

The Generative Learning Model

The generative learning model described by Osborne and Wittrock (1983), is a means of understanding the cognitive processes involved in learning and comprehension. Figure 1 shows a schematic representation of Osborne and Wittrock's generative learning model.

In this model the brain is not a passive consumer of information, but actually constructs its own interpretations and draws inferences in relation to stored memories or concepts. Students come to science classes with their own concepts about scientific phenomena. According to the generative learning model, students' concepts play a large part in how students attend to, perceive and construct new information. Also, information must be processed for meaningful learning to occur. For this reason, teachers need to take into account students' perceptions and, where appropriate, build on them or modify them.



(Osborne & Wittrock, 1983)

Figure 1

Schematic Representation of the Generative Learning Model

This model helps us to understand the relevance of openness of inquiry. Higher levels of inquiry serve to motivate students (Hodson, 1990) increasing the likelihood that students will process information in the short term memory and construct and test concepts against aspects of long term memory. Higher levels of inquiry also give them the opportunities in which this can be done. This model will be discussed further at appropriate points in this thesis.

Problem

The problem is that low levels of inquiry reduce the opportunity for students to process information and generate appropriate meanings and evaluate old and new conceptions which, according to Osborne and Wittrock's learning model, is necessary for effective learning. How much opportunity are lower secondary students given to carry out open inquiry investigation in laboratory activities? What do teachers perceive to be the benefits and difficulties of open inquiry formats?

Rationale and Significance

The openness of inquiry is important for student learning. It increases motivation (Hodson, 1990) and development of concepts and understanding (Roth & Roychoudhury, 1993), both of which are necessary for productive learning according to the generative learning model (Osborne & Wittrock, 1983). Information on the use of inquiry formats can be useful as a starting point for understanding students' current skills and conceptions. The level of inquiry used, along with teachers' perceived benefits and difficulties of laboratory formats, can be useful for determining an emphasis in teacher education and

inservice and for the development of lower secondary science courses.

Therefore, accurate information on the use of inquiry laboratory formats is needed because no recent published studies were found to have revealed the current situation. The last studies found of this nature were published in 1986 (Tobin; Costenson & Lawson).

Research Questions

The purpose of this research was to obtain information about laboratory formats with respect to the openness of inquiry, as determined by the levels of openness of inquiry scale (Table 1), currently used in lower secondary science in Perth metropolitan schools, and to sample teachers' views on higher levels of inquiry.

The specific research questions to be answered in this study were as follows:

1. What level of inquiry do teachers report that they are using in laboratory activities?

2.a. Is there any difference in the reported level of inquiry between teachers in government and non-

government schools?

2.b. Is there any difference in the reported level of inquiry between male and female teachers?

2.c. Is there any difference in the reported level of inquiry between teachers with different lengths of teaching experience?

2.d. Is there any difference in the reported level of inquiry between the teachers of different teaching fields?

2.e. Is there any difference in the reported level of inquiry between lessons given to Year 8, Year 9 and year 10 by teachers in all schools?

2.f. Is there any difference in the reported level of inquiry between Biology, Chemistry, Earth Science and Physics lessons?

3. What do teachers perceive to be the major benefits and difficulties for students and teachers of using open inquiry formats?

Outline of the Study

A questionnaire was used to gather the information from teachers in the Perth Metropolitan area. The sample of 197 teachers was made up of male and female teachers who were teaching lower secondary science at the time of the study. They were from government and non-government schools.

CHAPTER TWO

Literature Review

The Goals of Laboratory Activities

The goals of laboratory activities are most commonly seen as increasing knowledge and comprehension; developing manipulative skills; developing positive attitudes and increasing motivation; developing scientific methods, the processes of scientific inquiry and problem solving; gaining an appreciation of how scientists work; and developing scientific attitudes and interests (Hegarty-Hazel, 1986; Hodson, 1990; Tamir, 1991; Woolnough & Allsop, 1985).

Whether laboratory activities actually achieve these goals is often the subject of debate (Hegarty-Hazel, 1986; Hodson, 1990) as is how effective various formats are for achieving these goals.

Benefits of Higher Level Inquiry Formats

The benefits of higher level inquiry laboratory formats can be discussed in relation to their

achievement of the goals of laboratory work.

Hegarty-Hazel (1986) suggests that the goal of increasing knowledge and comprehension may be better attained through texts and more lecture, demonstration and discussion type instruction, although laboratory activities can be useful to provide some concrete experiences of scientific phenomena. Laboratory activities for this purpose have the danger of being recipe type which can be confusing because students lose sight of the purpose of the various steps involved, in which case they would be a waste of time (Hodson, 1990). Some guided inquiry activities which aim at students 'discovering' concepts are criticised because students cannot be expected to discover in a short period of time what took scientists years to discover (Woolnough & Allsop, 1985). Nor can it be expected that uninformed observations can lead to the acquisition of new concepts; theoretical considerations must precede experimental inquiry. 'Discovery' activities can compound misconceptions (Hodson, 1990).

A more open inquiry format is useful for attaining the goal of increasing knowledge and comprehension because it provides opportunity for information to be constructed and understandings generated. White (1991), believes that concepts can become meaningful

when they are processed by the students. According to the generative learning model, information must be actively constructed in order for learning with understanding to occur. Open inquiry formats require that students develop definitions and understandings of concepts in order to effectively design experiments and communicate results (Roth & Roychoudhury, 1993). Developing definitions and understandings to carry out investigations involves linking new constructs to old ones and restructuring existing ideas. This processing increases comprehension and helps students to remember (Osborne & Wittrock, 1983).

White (1991) believes also that relevance and ownership of the methods and ideas enhances processing and therefore meaningful conception. Relevance and ownership are increased with the use of open inquiry activities (Woolnough & Allsop, 1985). Laboratory activities also become more meaningful when the students experience all stages of the experiment (Yager, 1991).

Laboratory activities are necessary for the acquisition of science related manipulative skills and techniques. These however are often not learned in the traditional verification activities (Hodson, 1990). When open inquiry activities are undertaken,

students themselves will find that they need manipulative skills and this is perhaps the key: the skills are learned when they are seen by the students as both useful and necessary (Hodson, 1990). In this light, manipulative skills can be viewed, not so much as a goal of practical work but rather a requirement of 'successful' practical work (Hodson, 1990).

Another often stated goal of laboratory work is to increase motivation and positive attitudes toward science. Recipe type laboratory activities are often seen as only "less boring" than class work not involving laboratory work (Hodson, 1990). This is somehow missing the goal of increasing motivation. Motivation and positive attitudes come from activities that are of personal interest, that enable students to own their investigation and solve their own problem. This can be achieved through open inquiry, by allowing the students to pursue their own investigation their own way (Hodson, 1990; Schamel & Ayres, 1992; Skinner, 1993; Woolnough & Allsop, 1985). Motivation, increased by open inquiry, also gives students the drive to test tentative constructions against sensed experiences and aspects of long term memory and to develop meaningful understanding. This is a necessary part of generative learning (Osborne & Wittrock, 1983).

Instead of offering students the benefit that science will be useful in the future, open inquiry gives them the opportunity to put science to use, there and then, in personally relevant situations (Gott & Mashiter, 1991). Allen, Barker & Ramsden (1996) found students to rate inquiry based practical lessons higher in terms of interest than verification laboratories.

Increased motivation results in a higher quality of work (Woolnough & Allsop, 1985) and the desire of students to generate new hypotheses based on interpretations of previous results (Roth & Roychoudhury, 1993). Students doing low inquiry practical activities often see them as pertaining to the classroom and not being useful for their life outside school (Denny, 1986). School work becomes more useful when it focuses on the students' own questions, their own explanations, their tests and their own actions resulting from problem resolution (Yager, 1991).

It has been said that few teachers seem to understand the aim of students learning scientific method (Skinner, 1993). In low inquiry type laboratories, students do not have the opportunity to perform or perform poorly in such skills as defining a

problem, formulating an hypothesis, defining variables, and planning systematically a complete experiment including controls and replication (Friedler & Tamir, 1984; Hackling & Garnett, 1993). One reason may be that in recipe verification type activities students do not have a clear understanding of the purpose of the activity and get so tied up in the tedium of data collecting and calculating that they forget why they were doing the activity in the first place (Amend & Furstenau, 1992). These scientific process skills can be improved with the use of open inquiry activities involving students in designing and carrying out their own experiments because they are involved at all stages of the experiments (Hegarty-Hazel, 1986; Krugly-Smolska, 1990; Roth & Roychoudhury, 1993; Woolnough & Allsop, 1985). Open inquiry type laboratories can also help develop problem solving skills (Tamir, 1989) and are ranked higher by students on this dimension (Allen et al, 1986). Inquiry activities reward students for knowing how to do science and applying it to everyday problems, rather that just knowing about science (Medve & Pugliese, 1987; Skinner, 1993).

A further goal of laboratory work is to develop scientific attitudes and an appreciation of how scientists work. Verification type activities do not convey these attitudes as they encourage students to

believe that there is only one right answer and to discard results that they think are incorrect (Hodson, 1990; Krugly-Smolska, 1990; Schamel & Ayres, 1992; Woolnough & Allsop, 1985). Students' work in school laboratory activities mostly corresponds to that of a technician rather than a scientist (Tamir, 1991). Open inquiry investigations, although not prescriptive, are closer to how a problem-solving scientist works and are more likely to develop in students those scientific, intellectual and practical skills that can be used outside school.

Researchers continue to study the effectiveness of open inquiry investigative type laboratory formats. Although studies to date have been positive and many benefits can be seen, as noted above, not all results have been supported comprehensively in all areas and circumstances of high school science. For example, many studies are at university level laboratories (e.g. Amend & Furstenau, 1992) and/or in only one area of science, such as Biology (e.g. Friedler & Tamir, 1984). Also, Tamir (1991) notes that even when high levels of inquiry are employed, it may not achieve the goals of laboratory work because of the way it is implemented.

Previous Studies of Formats Used by Teachers

There has been some research into what levels of inquiry are used in school classrooms. A few studies have investigated the openness of inquiry of curriculum materials in Israel, Thailand and Australia and found them to be mostly very low (Friedler & Tamir, 1984; Saowalak, Butts & Deer, 1985; Tamir & Lunetta, 1981).

Other studies have investigated the activities conducted in the classroom. Tobin (1986), using ethnographic techniques, studied 15 teachers and their lower high school classes in two Western Australian schools and found that laboratory activities tended to be of a low inquiry recipe type which emphasised the collection of data by following set procedures and had little emphasis on planning an investigation or interpreting results. Costenson and Lawson (1986), interviewed 12 science teachers in the Phoenix area of the United States and found that they did not use inquiry methods. Many reasons for not doing so were given including, for example, too much time and energy required, being too slow, and student immaturity. In Costenson and Lawson's opinion many reasons were valid but all could be overcome to the extent that they were not sufficient to prevent the use of more open inquiry formats.

Fraser, Giddings and McRobbie (1992), developed and used the Science Laboratory Environment Inventory (SLEI) which aimed to assess teacher and student perceptions' of their laboratory environment in five categories. One of the categories was openness and it was found in universities in the six countries studied, that low inquiry laboratory activities dominate much of science education. This inventory requested generalized perceptions of the teachers and students, so it was not used in this study.

Finally, Skinner (1993), found that students in Western Australia entering a particular university course generally rated school laboratories as having low levels of inquiry.

Summary of Chapter

In this chapter it has been argued that the goals of laboratory activities are more likely to be achieved, when higher levels of inquiry are used, compared with verification type formats. This is because open inquiry formats can help to increase comprehension, develop science related manipulative skills, increase motivation and positive attitudes,

develop the processes of scientific inquiry and develop scientific attitudes and interests.

Previous studies of the laboratory formats used by teachers were also discussed in this chapter. Using various methods, all studies found that low levels of inquiry were used most of the time in their areas of study.

CHAPTER THREE

Methodology

Introduction

A questionnaire was constructed to determine the openness of inquiry of the laboratory formats currently used in lower secondary science. The lower secondary science teachers in randomly sampled schools were asked to complete this questionnaire. It asked for demographic information, information about the level of inquiry that they use and personal views on using open inquiry.

Design of the Study

The Head of the Science Department of each school sampled was contacted by telephone. Each was briefly told the nature of the study and requested that they participate. The number and names of teachers teaching lower secondary science in their school was obtained, to determine the number of questionnaires to be sent to the school and to label the introductory letters. The Head of Department was assured that the questionnaire would not take very long and would be

anonymous.

A letter to the Head of Department, addressed by name, was sent (see Appendix one), along with a letter to each of the identified teachers (see Appendix two). Questionnaires and envelopes in which to return the questionnaire to the Head of Department were stapled to each of the teachers' letters. A large stamped self-addressed envelope was included for the school return.

After the due date for questionnaire returns, schools for which returns had not been received were contacted by telephone. This involved six schools. Five schools sent their returns shortly after the telephone conversation. The remaining school's Head of Science Department had sent their returns a week before the due date but these were not received.

Sample

Teachers selected to participate in the questionnaire were those who taught lower school science classes in the randomly sampled schools. This method of sampling constitutes cluster sampling and was used because it is a more expedient method of sampling than random sampling (Gay, 1981, p. 93) and

because a list of individual teachers who taught lower secondary science in the Perth metropolitan area at the time of the study, could not be readily obtained. Twenty-nine schools were contacted, starting at the top of a randomly sorted list of 113 schools in the metropolitan area. The list of schools comprised the 57 government and the 26 catholic high schools listed in the Telecom White Pages for Perth, and 30 other non-government schools listed in the Association of Independent Schools of Western Australia's 1994 Member Schools booklet.

The sampling gave 247 lower secondary science teachers. Of the teachers in the study, 125 were male and 72 were female. Also, 124 teachers taught in government schools and 73 taught in non-government schools.

Instrument

The instrument used to obtain the data was a questionnaire (see Appendix Three) made up of three sections. The first section included demographic questions about the teacher and his/her class. In the second section, questions were based on the last laboratory lesson that the teacher had taught, to

determine the level of inquiry used. The third section involved more open-ended questions about the teacher's perceived benefits and difficulties of open inquiry laboratory activities.

A questionnaire was thought to be the best method to gain an accurate overall picture of the laboratory formats used, because a questionnaire has the advantage of obtaining information from a large number of teachers who are geographically dispersed and because there was insufficient time and resources to gain this information from such a large sample through more personal methods. The use of a questionnaire does have the disadvantages of only obtaining limited amounts of information and of some teachers not answering correctly, even with due steps were taken to make the questions as clear as possible (for example, some teachers missed questions). Despite these disadvantages, sufficient information for this study from a large sample of teachers was obtained using a questionnaire.

Questions in the second section of the questionnaire were constructed in direct relation to the levels of openness of inquiry (see Table 1). For each factor that determines the openness of inquiry according to the scale (i.e. problem, equipment, methods and answer), a question was constructed to

determine whether this factor was given to the students by the teacher or worksheet, or not given to the students. This helps to maintain content validity because the questions directly relate to the levels openness scale and could therefore be used to determine the level of inquiry used according to the scale. Three other people (university lecturers and teachers) were consulted to establish appropriate wording for the questions.

Questions in the third section of the questionnaire were open ended. Options were not given for the teachers to tick because this may have caused some teachers to choose responses that they had not previously considered and because the options for the teachers to choose from may not have reflected the teachers' own ideas. Although constructing open-ended questions made the data collation more difficult and time consuming, it was felt that the understandings gained were more internally valid. Approximately nine people (University lecturers and teachers) were consulted to establish appropriate wording for the questions.

In the questionnaire used, teachers were required to answer the questions in the second section based on the last laboratory lesson they taught, to help

eliminate the problem of believing and/or conveying the idea that they use a more open inquiry format than they actually do. In this way they were required to be more specific rather than giving an overall impression of format they used. This technique has the drawback that teachers may in fact use a more open inquiry format at other times than the last lesson. Random sampling overcomes this problem, showing if open inquiry is used in any significant amount overall in the whole sample, in the topics taught at the time the questionnaire was administered.

The questionnaire was designed so that it did not take the teacher much time to complete and so that data collation could be performed easily.

Pilot

The questionnaire was administered to a small sample of nine teachers prior to sending out the questionnaires. These teachers were asked to time how long the questionnaire took them to complete. They indicated that it took them about five minutes. The teachers were asked to add comments to the questionnaire where they could see any problems or errors. These teachers were also interviewed casually as a group after their completion of the questionnaire to determine whether they understood what the questions are asking and to establish face validity.

Teachers responded positively but also gave helpful suggestions for improvement of question wording. Testing the questionnaire with a small group of teachers proved very worthwhile and a number of alterations were made to the questionnaire.

Summary of Chapter

In this chapter the methodology of data collection was explained. Cluster sampling of schools was used to select an initial sample of 247 teachers to participate in the study. Questionnaires were sent to the Heads of the Science Department at the randomly sampled schools, who distributed them to the lower secondary science teachers. The questionnaire was constructed to determine the level of inquiry used by these teachers in their last experiment/investigation lesson, to obtain information about the teachers' perceived benefits and difficulties of open inquiry laboratory activities. A trial was conducted by submitting the questionnaire to a small sample of teachers before it was sent to the teachers in the study.

CHAPTER FOUR

Data Analysis

Introduction

There were three parts in analysing the questionnaire data. The first part involved determining frequencies for each of the levels of inquiry used in the teachers' last experimental/investigation lesson and answers research question 1. The second part involved statistical tests of differences in the level of inquiry used by different groups, and answers research questions 2a, 2b, 2c, 2d, 2e and 2f. The third part involved determining the teachers' perceived benefits and difficulties of using higher levels of inquiry and answers research question 3.

Teacher Identification of Level of Inquiry Used

Using the answers to questions 7 to 10 in the questionnaire (See Appendix Three), the level of openness of inquiry for each teacher was determined. This was done by using the 'Levels of openness of inquiry of laboratory activities' from Table 1. As an example, figure 2 shows how a teacher responded to questions 7 to 10 in the questionnaire.

7. In this lesson, the problem to be investigated or the question to be answered was
given by the teacher or worksheet... ☑
chosen by the student... ☐

8. The materials/equipment was
specified by the teacher or worksheet... ☑
chosen by the students... ☐

9. The method/procedure to be followed to solve the problem or answer the question was
specified by the teacher or worksheet... ☑
designed by the students... ☐

10. The answer to the problem or question was
outlined in general terms before the activity... ☐
unknown by the students before the activity... ☑

Figure 2
An Example of a Teacher's Response to Question 7 - 10 of the Questionnaire.

Using Table 1, this response was identified as level 1 because the problem, equipment and methods were given to the students by the teacher or worksheet and the answer was not given to the students.

The level of inquiry used by each teacher was identified. The frequency and percentage for each level of inquiry was calculated.

Responses to question 11 were coded as either 'very well', 'satisfactorily', or 'poorly'.

Open-ended comments reflecting how often identified levels of inquiry were used were grouped into four categories: always or almost always; usually

a variety; usually higher/lower; and comment absent or unrelated. These were cross tabulated with, the level of inquiry used was low (i.e. level 0 or 1), or, higher (i.e. level 2a, 2b or 3). For example, a teacher identified as having used inquiry level 1, wrote, "Most investigations are not open ended - time restrictions ... dictate a fairly rigid procedure". This teacher was tallied as using a low level of inquiry always or almost always. A teacher identified as having used inquiry level 3 wrote, "A range of experiments are carried out - some are very much teacher directed, yet others rely on students developing an experiment to solve a problem based on theories/principles currently studied". This teacher was tallied as having used a higher level of inquiry and usually using a variety.

The researcher did all of the coding to help maintain reliability of the categorization.

Differences in level of inquiry between various groups

Grouping teachers or lessons according to school type, teachers' gender, teachers' main teaching field, teachers' length of teaching experience, the lesson Year level and the lesson's main emphasis, was carried out using information given by teachers in response to

questions 1 to 6 of the questionnaire.

To calculate the mean level of inquiry used by each group the inquiry levels were coded. Level 0 was assigned to the numeral 1, level 1 was assigned 2, level 2a was assigned 3, level 2b was assigned 4 and level 3 was assigned 5. This meant that if a mean level of 2.09 was obtained, it would be very close to most teachers in the particular group using inquiry level 1.

The number of teachers in the study from government and non-government schools was calculated. The mean level of inquiry used by the teachers of the two school types was also calculated. Difference in level of inquiry between teachers of government and non-government schools was tested for significance using a two-tailed t-test which tested the null hypothesis that there was no difference in the level of inquiry used by government school teachers and non-government school teachers.

The number of male and female teachers was calculated along with the mean level of inquiry used by the two groups. Difference in level of inquiry between male and female teachers was tested for significance using a two-tailed t-test

which tested the null hypothesis that there was no difference in the level of inquiry between male and female teachers.

The number of teachers in the study with lengths of teaching experience for each of the groups: less than three years; three to five years; six to 10 years; 11 to 20 years; and greater than 20 years, was calculated along with the mean level of inquiry used by the teachers in each group. Difference in level of inquiry between the groups of teachers with different lengths of teaching experience was tested for significance using a 5 x 1 ANOVA which tested the null hypothesis that there was no difference in the level of inquiry between teachers of differing lengths of teaching experience in the different groups.

The number of teachers in each of the main teaching specializations biological science, physical science, mathematics or other, was calculated along with the mean level of inquiry used by the teachers in each of the specializations. Difference in level of inquiry between teachers of the major teaching fields was tested for significance using a 4 x 1 ANOVA which tested the null hypothesis that there was no difference in the level of inquiry between teachers with teaching specializations in Biology, physical science, mathematics or another subject.

The mean level of inquiry was calculated for lessons in each of Year 8, 9 and 10. Difference in level of inquiry between lessons in these years was tested for significance using a 3 x 1 ANOVA which tested the null hypothesis that there was no difference in the level of inquiry between lessons in Year 8, 9 and 10.

The number of lessons in the study which had an emphasis in Biology, Chemistry, Earth Science or Physics were calculated along with the mean level of inquiry for each of the lesson types. Difference in level of inquiry between Biology, Chemistry, Earth Science and Physics lessons was tested for significance using a 4 x 1 ANOVA which tested the null hypothesis that there was no difference in the level of inquiry between lessons with a Biology, Chemistry, Earth Science or Physics emphasis.

The above tests were appropriate because in each case the data was numerical in nature. Since it may be questionable as to whether the levels of inquiry actually constitute a parametric distribution, the non-parametric test, the Kruskal-Wallis One Way ANOVA, was also conducted to determine if non-parametric tests obtain the same results. For all tests .05 level of significance was chosen.

Benefits and Difficulties of Higher Levels of Inquiry

The perceived benefits and difficulties for students and teachers of doing laboratory work in which the students can plan and carry out their own experiment were recorded by teachers in question 12 and 13 of the questionnaire. All comments were separated into four main groups: benefits for students; difficulties for students; benefits for teachers; and difficulties for teachers. The former two groups were from question 12 of the questionnaire and the latter two groups were from question 13.

Comments were recorded and where comments recurred they were tallied under existing comments. For example, one teacher wrote that a difficulty for teachers was that, "It takes too much time". Another teacher wrote that, "This type of laboratory work is too time consuming" and so was tallied as essentially the same comment.

The comments were then categorized into groups of comments that were closely related in some way. For example, all comments relating to time and curriculum constraints with regard to amount of content to be covered in the available time were grouped into the

category 'Curriculum constraints / takes too long'.

The teachers responses to questions 12 and 13 of the questionnaire were then tallied again so that if one teacher made more than one comment within one category, only one tally was made for that category for that teacher. For example, a teacher wrote that benefits of this type of laboratory work for the students was, "1. Increases co-operation. 2. Develops adaptability". These two comments were grouped into the same category of 'Personal Skills Development' so only one tally was made.

One problem with collating the teachers' responses to questions 12 and 13 of the questionnaire was that frequently teachers would not put the responses under the correct headings for teachers or students. Some teachers realized their mistakes and changed the headings to match their answers. For the teachers who did not correct their mistakes, the researcher determined the most appropriate category. For example, a teacher wrote under the heading of Difficulties in question 12 (question pertaining to the students), "Makes classroom management difficult". It was assumed that this was meant to be a difficulty for the teacher and was tallied under the 'Behaviour management / Safety' category in the difficulties for

teachers group of categories.

All categorizing and tallying was done by the researcher to help maintain consistency in the way in which comments were assigned to a particular category. Consequently the labels used as headings for each category represent the meaning ascribed by the researcher.

Summary of Chapter

In this chapter the method of data analysis was explained. There were essentially three parts. The first part related to research question 1 and involved determining frequencies for each of the levels of inquiry used. Responses to questions 7 to 10 were used to determine the level of inquiry according to the scale of openness of inquiry. Levels were coded so that calculations could be made.

The second part related to research question 2. Teachers' responses were grouped according to responses to questions 1 to 6 and difference in level of inquiry between various groupings was tested for significance using relevant statistical tests.

The third part related to research question 3.

Teachers responses to questions 12 and 13 of the questionnaire, regarding the benefits and difficulties of open inquiry, were coded and grouped into categories containing similar comments.

CHAPTER FIVE

Results

Questionnaire Returns

Questionnaires were returned by all 29 schools but returns from only 28 schools were received. Out of the 247 questionnaires sent, 197 were received giving an 80% return rate. This is a good return rate as, according to Gay (1981, p. 164), a return rate over 70% is acceptable for maintaining validity.

Teacher Identification of Level of Inquiry Used

Table 2 sets out the frequency and percentage of each level of inquiry as identified by all teachers as being used for their last experimental/investigation lesson.

Table 2
Frequency of Use of Each Level of Inquiry as Identified by Teachers.

Level	Frequency n=197	Percent	Low & high %
0	73	37.1	
1	92	46.7	83.8
2a	21	10.7	
2b	8	4.1	16.3
3	3	1.5	

It can be seen from the table that the most commonly used level of inquiry was level 1, in which the students are given the problem, the equipment and the method but not the answer to the problem to be investigated. Forty-six point seven percent of the teachers implemented lessons at this level of inquiry. Level 0, in which the students are given the problem, the equipment, the method and the answer was also very common, being used by 37.1% of the teachers.

Level 0 and 1, low levels of inquiry, constitute 83.8% of the laboratory lessons. Higher levels of inquiry, level 2a, 2b, and 3, constitute only 16.3% with level 3, in which the students choose their own problem to investigate, constituting only 1.5% of the laboratory lessons.

Overall, it was found that low levels of inquiry were identified by teachers as being used for their last experimental/investigation lesson.

These results are likely to be representative of the other laboratory lessons in the classes identified by the teachers, by virtue of the fact that the teachers answered the questions based on the last practical lesson rather than choosing a lesson for which they could convey the response they desired or

just giving an overall impression of the format they use. This claim is supported by the responses to question 11, which determined how well the last laboratory lesson represented the laboratory lessons usually taught. Responses are set out in Table 3.

Table 3
Teacher Rating of the Representative Nature of the Identified Lesson.

Response option	Frequency n=197	Percent
Very well	94	47.7
Satisfactorily	98	49.8
Poorly	4	2.0
Response missing	1	0.5

Only 2% of the teachers rated the last laboratory lesson as a poor reflection of the laboratory lessons usually taught in the specified class.

Comments on how well the last laboratory lesson represented the laboratory lessons usually taught are tabulated with regard to whether the level of inquiry for the teacher was low (level 0 and 1) or higher (level 2a, 2b and 3) in Table 4 and 5 respectively. Most of the teachers comments reflected how often this type of format (level of inquiry) was used. Thirty-nine point six percent of the teachers made no comment or comments unrelated to the representation of laboratory lessons usually taught (e.g. "This lesson was about conductivity").

For the responses from teachers that were identified as using low levels of inquiry in their last lesson, it appears that the highest number of teachers (88) commented that this format (i.e. level of inquiry) was always or almost always used (see Table 4). One teacher commented in question 13 that he/she had never tried an open approach before. For responses from teachers that were identified as using higher levels of inquiry, the highest number of teachers (13) commented that lessons were usually varied (see Table 5).

Each superscript 'a' indicates a comment in the structured part of question 11 associated with those teachers who rated the last lesson as poorly representing the laboratory lessons usually taught.

Table 4
Comments Reflecting How Often Low Levels of Inquiry are Used.

Comment	Frequency n=165	Percent 83.9%
Always or almost always	88	44.7
Usually a variety	9	4.6
Usually higher	1[a]	0.5
Comment absent or unrelated	67[a]	34.0

Note: [a]: one comment associated with lesson rated as poor representation

Table 5
Comments Reflecting How Often High Levels of Inquiry are Used.

Comment	Frequency n=32	Percent 16.2%
Usually	5	2.5
Usually a variety	13	6.6
Usually lower	3[aa]	1.5
Comment absent or unrelated	11	5.6

Note: [a]: one comment associated with lesson rated as poor representation

Difference in Level of Inquiry Between Different Groups

Teachers of Government and Non-government Schools

Table 6 shows the proportion of teachers of government and non-government schools. It also gives the mean level of inquiry used in the two school types.

Table 6
Proportion of Government and Non-Government Teachers in the Study Mean Inquiry Levels and Standard Deviation.

School type	Number	Mean level	S.D.
Government	124	1.88	0.92
Non-government	73	1.88	0.78

Using a two-tailed t-test, no significant difference was found in the level of inquiry used between teachers from the two school types ($t = 0.34$, d.f. = 195, $P = .74$).

Male and Female Teachers

There were more male teachers than female teachers in the sample. Table 7 shows the proportions of the respective genders and the mean level of inquiry used by each.

Table 7
Proportion of Male and Female Teachers in the Study Mean Inquiry Levels and Standard Deviation.

Gender	Number	Mean level	S.D.
Male	125	1.83	0.88
Female	72	1.92	0.10

Using a two-tailed t-test, no significant difference was found in the level of inquiry between male and female teachers ($t = -0.65$, d.f. = 195, $P = .51$).

Teachers with Different Lengths of Teaching Experience

Table 8 shows the lengths of teaching experience of the teachers in the study and the mean level of inquiry used.

Using an ANOVA, no significant difference was found in the level of inquiry used and the length of teaching experience ($F = 0.16$, d.f. = 4,192, $P = .96$).

Table 8
Proportion of Teachers in the Study with Various Lengths of Teaching Experience Mean Inquiry Levels and Standard Deviation.

Experience length	Number	Mean level	S.D.
< 3 yrs	21	1.95	0.86
3 - 5 yrs	22	1.86	0.99
6 - 10 yrs	46	1.91	0.94
11 - 20 yrs	67	1.81	0.80
> 20 yrs	41	1.85	0.88

Teachers of Different Teaching Fields

A small percentage of the teachers in the study (7.1%) did not have main teaching specializations in biological or physical science. The proportions of teachers in the teaching specializations are tabulated in Table 9 along with mean level of inquiry used.

Table 9
Proportion of Various Teaching Specialisations in the Study Mean Inquiry Levels and Standard Deviation.

Specialisation	Number	Mean level	S.D.
Biological Science	98	1.89	0.95
Physical Science	85	1.87	0.80
Maths	5	1.60	0.89
Other	9	1.67	0.71

Using an ANOVA, no significant difference was found in the level of inquiry used between teachers of different teaching specializations ($F = 0.33$, $d.f. = 3,193$, $P = .80$).

Lessons Given to Year 8, Year 9 and Year 10

Lessons in Year 8, 9 and 10 were fairly evenly represented in the study. Proportions and mean levels of inquiry are shown in Table 10.

Table 10
Proportion of Year 8, 9 and 10 Lessons in the Study Mean Inquiry Levels and Standard Deviation.

Year level	Number	Mean level	S.D.
Year 8	61	1.74	0.85
Year 9	68	1.96	0.90
Year 10	68	1.88	0.86

Using an ANOVA, no significant difference was found in the level of inquiry between lessons given to each of the three year levels ($F = 1.03$, d.f. = 2,194, $P = .36$).

Biology, Chemistry, Earth Science and Physics Lessons

Most of the lessons in the study had a Chemistry emphasis and only a few had an Earth Science emphasis. Proportions of the science subjects and mean levels of inquiry are tabulated in Table 11.

Using an ANOVA a significant difference was found in the level of inquiry between science subjects ($F = 2.67$, d.f.= 3, 192, $P = .049$).

Table 11
Proportion of Various Science Subjects in the Study Mean Inquiry Levels and Standard Deviation.

Subject	Number	Mean level	S.D.
Biology	48	1.88	0.79
Chemistry	84	1.71	0.75
Earth Science	12	1.58	1.16
Physics	52	2.09	0.91

Using L.S.D. (Least Squares Differences) method the difference was identified as being between Chemistry and Physics. That is, the level of inquiry is significantly higher in Physics than in Chemistry. Between any of the other science subjects there is no significant difference.

Table 12 shows the frequency of levels of inquiry for the various science subjects. Compared with Chemistry lessons a greater proportion of the Physics lessons are inquiry level 1 than level 0, in the study.

Table 12
Frquency of Levels of Inquiry for the Various Science Lessons in the Study.

Level Subject		0 n=73	1 n=92	2a n=21	2b n=8	3 n=2
Biology	n=48	16	24	6	2	-
Chemistry	n=84	37	36	9	2	-
Earth Sci	n=12	8	3	-	-	1
Physics	n=52	12	29	6	4	1

Other Tests

Kruskal-Wallis 1-Way ANOVA, a non-parametric test, was also conducted for each of the t-test and ANOVA tests above. The results of the Kruskal-Wallis 1-Way ANOVA tests are shown in Table 13. It can be seen that all results confirm those found by the parametric tests above, including the statistical significance of a difference in the level of inquiry for Physics at the .05 level.

Table 13
Kruskal Wallis 1-Way ANOVA for Differences in Level of Inquiry Between Different Groups.

	N	Chi-square	P
School type	197	0.002	0.96
Teacher gender	197	0.54	0.46
Teaching experience	197	0.58	0.97
Teaching field	197	1.09	0.78
Year level	197	2.79	0.24
Science subject	196	9.93	0.02

Benefits and Difficulties of Higher Levels of Inquiry

Benefits for Students

The benefits for students of higher levels of inquiry, as perceived by the teachers, are listed in Table 14 in order from most to least frequently written.

The first category contained comments such as: "Gives a feeling of involvement", "Presents a challenge", "Students own their work", "Intrinsically motivating", "Relevant to students", "Increased motivation because of ownership" and "More enjoyable".

Table 14
Benefits for Students of Higher Levels of Inquiry as Perceived by Teachers.

Category	Frequency n=412
Greater interest / ownership / motivation	88
Students learn more / have greater understanding	84
Personal skills development	67
Learning of scientific procedures and design	41
Sense of achievement / self esteem	33
Useful for students of certain abilities	37
Develops problem solving skills	27
Promotes creativity	27
Real scientists' work	5
Variety	3

Although 'ownership' seems different to 'motivation', they were grouped together because many of the teachers comments linked the two together. The second category was made up of comments such as: "Greater understanding", "Makes students think for themselves", "Students remember more", "Students learn by their mistakes", "Greater understanding of why certain things are done" and "Reduces misconceptions because students have to test their own ideas". In the third most rated category were listed development of personal skills such as: Co-operation, Planning, Leadership, Curiosity, Responsibility, Analysis and

Adaptability. These top three categories show that teachers believe that more open inquiry results in students learning more.

Difficulties for Students

Table 15 lists the difficulties for the students of higher levels of inquiry as perceived by teachers. Comments in the miscellaneous category were varied (e.g. "Should be started at primary level", "It lowers student self esteem") and none were tallied more than once.

Table 15
Difficulties for students of Higher Levels of Inquiry as Perceived by Teachers.

Category	Frequency n=148
Students can't work without set procedures	71
Hard/impossible for students of low abilities	31
Inaccuracies / Misconceptions	14
Students not sharing work load	11
Getting started	11
Miscellaneous	10

Benefits for Teachers

The benefits for the teacher of higher levels of inquiry are listed in Table 16. Thirteen teachers commented that they felt there were no benefits or only limited benefits for teachers.

Table 16
Benefits for Teachers of Higher Levels of Inquiry as Perceived by Teachers.

Category	Frequency n=135
More facilitating and less spoonfeeding	26
Better teaching and achievement of objectives	22
Students more on-task/motivated	18
Personal job satisfaction/reward	16
More time to circulate among students	14
No benefits / limited benefits	13
Guaging student understanding/skills	12
Less effort and time for teacher	11
Interest/variety for teacher	3

Difficulties for Teachers

The difficulties for teachers of higher levels of inquiry are listed in Table 17. The miscellaneous category consists of varied comments such as "Outside pressure", "Teachers lack the skills necessary", "The teacher is reduced to the status of just another resource".

Table 17
Difficulties for Teachers of Higher Levels of Inquiry as Perceived by Teachers.

Category	Frequency n=386
Curriculum and time constraints	99
Equipment demands	84
Behaviour management / safety	74
Number of students / managing all expts. at once	45
Organisation and preparation demands	33
Students require more help	16
Assessment	12
Students at different levels of completeness	7
Miscellaneous	16

The most numerous category contained comments such as: "Takes too long", "Takes longer for concepts to be covered", "Experiments digress from the curriculum", "Curriculum constraints", "Curriculum too content packed", "Already enough to cover in the time available", "Curriculum materials are not sufficient for this" and "Must complete unit by the end of the term". Curriculum constraints and time constraints were grouped together because many teachers' comments linked the two within one comment. The second most numerous category consisted of comments such as: "Too much diversity of equipment required", "Equipment not always available", "Too much to expect from the lab technicians", "Ordering in time" and "Students not aware of the materials available". The third category was made up of comments such as: "Students off-task", "Stimulates inappropriate behaviour", "Students too immature", "Students are not responsible enough", "Too dangerous", "More accidents" and "75% of the students would blow themselves up!".

The comments show that teachers believe that the use of more open inquiry is difficult, mostly because of curriculum time constraints, equipment demands, and behaviour and safety management problems.

Summary of Chapter

This chapter reported the results of the study. It was found that low levels of inquiry were reported by teachers as being used for their last experiment/investigation lesson, with 83.8% of the lessons being identified as level 0 or 1.

It was found that the only significant difference in the level of inquiry used by any of the groups, was between the science subjects in which the Physics lessons used a significantly higher level of inquiry than the Chemistry lessons in the study.

The greatest number of comments made about the benefits and difficulties of open inquiry were benefits for the students and difficulties for the teachers. The most often rated student benefit categories were "greater interest / ownership / motivation", "students learn more / have greater understanding" and "personal skills development". The most often rated teacher difficulties categories were "curriculum and time constraints", "equipment demands" and "behaviour management / safety".

CHAPTER SIX

Discussion

Low Levels of Inquiry Used

It can be seen from the results that most teachers in the study used the lowest two levels of inquiry (see Table 2). These low levels of inquiry are generally always, or almost always, used (see Table 4).

Within the limitations of this study it would appear that the levels of inquiry are used within Perth metropolitan schools. Low levels of inquiry are used regardless of whether the school is government or non government, the teachers' gender, the length of the teaching experience of the teacher, the teachers' main teaching specialization, the year level of the students or the science subject being taught.

However it was seen that Physics lessons in this sample had a statistically significantly higher level of inquiry than Chemistry lessons. This may be because in Physics experiments variables are easier to manipulate and measure than in Chemistry. Although the difference is statistically significant,

examination of the mean level of inquiry for Physics reveals that the mean level is still low, being 2.09, (see Table 10). Therefore Physics lessons still have low levels of inquiry as do Chemistry lessons and the other science subjects.

Overall this means that students are not being given much opportunity to do laboratory work in which they can learn how to do science investigations themselves. As discussed previously, open inquiry activities whereby students design and carry out their own experiments improve the learning of scientific method (Hegarty-Hazel, 1986; Krugly-Smolska, 1990; Roth & Roychoudhury, 1993; Woolnough & Allsop, 1985). It is not surprising therefore that researchers such as Hackling and Garnett (1993) found that Year 10 students cannot plan and carry out a simple experiment scientifically.

However it is interesting that the Education Department of Western Australia's 'Monitoring Standards in Education Project' (Profiles of Student Achievement, 1994) found that Year 10 students randomly chosen from Western Australian government schools were able to perform on average at Performance Level 3 in the 'Working Scientifically' strand, a higher level than any other science strand. The 'Working Scientifically' strand involves the key

elements of planning and conducting experiments. The performance levels range from level 1 to level 6. At performance level 3, students can "suggest ways of doing their investigations... organize and use equipment to gather and present information... draw conclusions on the basis of collected information and personal experience... evaluate the 'fairness' of a test they have designed and carried out and compare ways of solving problems and finding explanations" (Education Department of Western Australia, 1994, p. 26).

This means that despite the findings of this study that students are not being given the opportunity to carry out all stages of laboratory experiments themselves, they are able to respond to questions about experimental variables, the purpose of a control, the need for reliability or fairness in investigations and the need to evaluate the results at performance level 3. It does not mean that students are able to plan a whole investigation themselves as the 'Monitoring Standards in Education Project' asked students to answer questions in relation to parts of an investigation rather than to design a whole investigation. In this way, the students were prompted by the questions to think about various parts of an investigation.

Is level 3 the optimum level of performance for Year 10 students? The performance levels were designed with performance level 6 being set at the standard likely to be attained by between 70 and 80 percent of the students at or before the end of Year 10 (Marsh, 1994, p. 121). Year 10 students are therefore performing at a lower level for their age than was intended when the performance levels were written. If students are given the opportunity to carry out investigations at higher levels of inquiry in science laboratory activities they are more likely to perform at a higher performance level, for example level 5. At level 5 at which students can "select an appropriate method for an investigation given its purpose and the resources available and use instruments and techniques to provide accurate and reliable results" (Education Department of Western Australia, 1994, p. 26)

It can be assumed that experiencing higher levels of inquiry in science laboratory activities has the possibility of raising the performance level of lower secondary students as it provides opportunities to practice the skills listed in the student outcome statements at the higher levels.

Teachers Acknowledge the Benefits

Teachers in this study acknowledge the benefits for the students of using higher levels of inquiry where students can plan and carry out their own experiments/investigations. The frequency that benefits were written by the teachers in the study is higher than the frequency that difficulties were written. All teachers could see at least one benefit for the students of more open inquiry.

The benefit for students most frequently identified by teachers was that of greater interest, ownership and motivation. This benefit is well worthwhile for the students for making science more desirable (Hodson, 1990; Schamel & Ayres, 1992; Skinner, 1993; Woolnough & Allsop, 1985). The Education Department of Western Australia's 'Monitoring Standards in Education Project' identified that students' positive attitudes to science drop between Year 7 and Year 10 (Education Department of Western Australia, 1994, p. 123-124). Open inquiry enables students to feel that they have done their work themselves, that their work is relevant to them and that they own their work. This increases their motivation and interest (Hodson, 1990; Skinner, 1993; Woolnough & Allsop, 1985).

Increased motivation has great implications for increasing the quality of work and learning achieved by the students (Woolnough & Allsop, 1985). According to the generative learning model, motivation gives students the drive to process information which in turn increases comprehension and memory (Osborne & Wittrock, 1983).

This increased learning and understanding was also highly rated by the teachers in this study as a benefit of open inquiry. A few teachers commented that it makes students think for themselves. This is what increases comprehension and learning according to the generative learning model (Osborne & Wittrock, 1983). The Education Department of Western Australia's 'Monitoring Standards in Education Project' identifies that students do not perform as well in conceptual strands like 'Earth and Beyond' and 'Energy and Change'. Roth and Roychoudhury (1993), suggest that open inquiry improves conceptual understanding because students are required to define concepts in order to carry out the steps of the investigation. Open inquiry could help increase performance in the Education Department's conceptual strands, although instructional methods such as lectures, demonstrations and discussion, may be the key methods for attaining conceptual understanding

(Hegarty-Hazel, 1986).

Teachers believe that open inquiry increases the students' personal skills such as co-operation, planning, analysis responsibility and adaptability. These skills are useful outside school and help to link science to everyday activities (Medve & Pugliese, 1987).

Learning scientific procedures and design through open inquiry is also useful to everyday problems (Medve & Pugliese, 1987). It seems that Skinner's suggestion (1993) that few teachers seem to understand the aim of students learning scientific methods is correct. This benefit was not rated very highly in the study.

Fewer benefits were stated for the teacher although there were still a considerable number. Many of the benefits for the teachers relate to the increased motivation and learning of the students.

If teachers can generally state the benefits of higher levels of inquiry, why don't they use higher levels of inquiry?

Why Open Inquiry is Not Used - The Difficulties

Teachers in this study are not using open inquiry because they see too many difficulties or see the difficulties as too large. Open inquiry laboratory activities do take longer than verification activities because they require the students to do more work for themselves. Teachers in this sample feel that there is not enough time to allow for open inquiry as there is too much content to be covered in the time available. Some teachers feel that the unit curriculum does not give the extra time required to do open inquiry experiments. Whether this assertion is true or not is irrelevant. If the teachers perceive the curriculum as being crowded, they will reduce that which they see as 'frills'. Also, teachers in this study feel that the curriculum materials do not provide guidance in conducting open inquiry investigations.

Another difficulty listed by many teachers is providing the equipment for open investigations. Equipment availability and organization are problems that teachers face, particularly when conducting open inquiry experiments.

The third most often listed difficulty is the students' immaturity. Many teachers in the study felt

that students are not mature enough to handle the increased responsibility and freedom which makes student behaviour and safety management very difficult (see Table 17). Teachers also felt that the students cannot work without set procedures and that open inquiry tasks are too hard or impossible for students of low ability (see Table 15).

Overcoming the Difficulties

Curriculum Changes

An effective change would be some alteration of the expectations portrayed in the curriculum. This change must come about from those responsible for developing curriculum resources. Quality curriculum resources can outline suitable high inquiry activities for teachers to use with students that overcome the difficulties outlined by teachers and that help develop group investigation skills that enhance conceptual development (Goodrum, personal communication, November 10, 1994).

With or without this change, teachers are not powerless to overcome this difficulty. Costenson and Lawson (1986), ask who it is that actually sets the test and writes the teaching program. Is it not the

teachers themselves? In Western Australia however, the teaching program is frequently department based which presents the problem of convincing the department that changes are worthwhile. Because the program/curriculum/text is so content packed it requires teachers "to instruct at a shallow and superficial level and forces students to learn through rote memorization" (Costenson & Lawson, 1986). They suggest that using open inquiry methods means that the material 'covered' is less but that the concepts mastered are more.

Equipment Ingenuity

Inquiry can be taught without expensive or elaborate equipment. It may require some creativity (which is an advantage in itself). Equipment can be brought from home and cheap items purchases from the local shops (Costenson & Lawson, 1986). Improvisation of simple equipment has other advantages such as cheapness, increasing the amount of equipment, less concern over loss or breakage, students being made aware of scientific principles of everyday things, enhancing self-reliance, increasing use of local resources, and less need for following complex instructions for the use of the equipment (Allsop, 1991).

Lesson programing can be organized so that student

groups can plan the experiment and order equipment in one lesson and carry out the experiment in another lesson (Schamel & Ayres, 1992). This can solve the problem of knowing in advance what equipment the students will need. If they are taught to order well it should not be too difficult for the laboratory technicians. A few days between the two lessons could be programed to give technicians time to organize the equipment. Teachers also need to elicit the support of the technicians. Teachers could make it a requirement that they check the students' equipment list before handing them in so that the teacher can check that the equipment is available and give extra suggestions.

Co-operative Learning and Gradual reduction in Structure

The problem of students being off-task is a problem for any mode of instruction. Costenson and Lawson (1986), suggest that in open inquiry modes the off-task behaviour tends to be more noticeable, which may explain one reason why teachers list off-task behaviour often. The problem of safety means that it is very important that teachers develop techniques that will maintain student participation in the required task.

Small group co-operative learning strategies, for example those outlined in the Primary Investigations Project Teacher Resource Book 7 (Goodrum, 1994, p.xviii-xx), enable better classroom management because students working in co-operative groups take responsibility. According to Goodrum (personal communication, October 25, 1994) these strategies are relevant to high school. Co-operative learning involves assigning all students within each group a 'team job' such as 'team manager', 'team speaker', 'team coach' and 'team director'. The assignment of such jobs means that all students are directly responsible for a specific role, yet enables all students to take part in all stages of the investigation. Even with team jobs students need to be taught how to work co-operatively.

It is true that students may abuse the freedom given in open inquiry formats. Costenson and Lawson (1986), recommend that students begin with fairly structured inquiries which require little student autonomy and only gradually move on to reduced structure and increased autonomy. In this way the students learn responsibility gradually and do not find suddenly that they have more freedom than they know how to handle maturely. Roth and Roychoudhury (1993), suggest that it takes from four to eight weeks for students to adjust to student-centered methods.

Teachers also need to help students link the problem to be solved to memory stores and to new information, to help them begin to generate constructs and solve problems (Osborne & Wittrock, 1983).

Primary students can participate well in properly designed and carried out inquiry lessons and they are not more mature than high school students (Costenson & Lawson, 1986). Therefore secondary students should be able to work well in inquiry activities.

Abilities

Students of low science ability can benefit from open inquiry experiments because they can choose experiments, or at least methods at their level, that they understand. This means that the lower ability students can work at a level in which they can achieve success (Schamel & Ayres, 1992). Open inquiry increases motivation and feelings of achievement which low ability students are sometimes lacking (Schamel & Ayres, 1992).

Lower science ability students then, show developments as well as the stronger students (Roth & Roychoudhury, 1993). At the very least, if they fail science when open inquiry is used it is more than likely that they would fail when low levels of inquiry

are used. The only loss to these students collectively, is when open inquiry is not used and many students would have benefited from it.

Teaching Students to Work Without Set Procedures

Students can often only work with set procedures because they have not been taught how to work without them. This takes time. Experiments should become more open over time, so that students can gradually learn how to plan an investigation which tests the hypothesis and controls all variables systematically and how to devise an appropriate method.

When students have learned how to investigate problems devised by the teacher, they can then tackle ones they suggest themselves (White, 1991). One way to engage students in thinking about procedures, useful even when using recipe activities, is to jumble up the order of the procedures given to the students. This requires them to think about the procedures and get them into a sensible order (White, 1991).

Future Research

Future research could investigate ways to help teachers more successfully implement inquiry based

investigations with lower secondary science students and how to overcome the very real constraints such as time and equipment. This may involve developing curriculum resources which give the teachers suggestions about how to introduce the curriculum to the students; how to organize the students into groups and assign tasks; how to arrange the ordering of equipment; and how to teach students to work independently, exploring how effective these suggestions are for helping the teachers overcome the difficulties of open inquiry laboratory investigations.

Limitations of the Study

The major limitations of the study relate to issues of design. The research design has the strengths that it incorporates the area of Perth and was powerful to obtain clear, generalisable information on simple issues. The study gained a general picture of the levels of inquiry used and the general issues involved with the use of open inquiry.

The major limitation is that the information gained is not indepth. The study is limited in delving deep into teachers individual use of open

inquiry and their individual experiences and needs. Such a study would need to use appropriate interview procedures. The survey design provides accurate information that can be generalized over a large population. The interview approach provides richer information but this can only have limited generalisability.

Summary of the Study

Laboratory activity formats can be classified into five levels according to a scale of openness of inquiry (Table 1). This scale ranges from low levels of inquiry, where the teacher or a worksheet determine the problem to be investigated by the students; the equipment and methods to be used; and often outline the answer to the problem, to higher levels of inquiry in which these factors are decided and designed by the students.

As discussed in chapter two of this thesis, there is a lot of support in the literature for an increased use of higher levels of inquiry. Open inquiry formats are believed to be often better suited to achieving the goals of laboratory work, such as increasing positive attitudes and motivation, and developing scientific method and conceptual understanding.

It was the aim of this study to obtain information about laboratory formats currently used in lower secondary science in Perth metropolitan schools, regarding the openness of inquiry as determined by the levels of openness of inquiry scale, and to determine the teachers' views on higher levels of inquiry.

Using a descriptive survey format, a questionnaire for lower secondary science teachers was designed to obtain this information. The questionnaire asked for information on the last experiment/investigation lesson taught by the teacher. This information was used to determine the level of inquiry used for that lesson. The questionnaire also asked for the teachers' perceived benefits and difficulties of open inquiry formats. These were coded, categorized and tallies were made.

Two hundred and forty-seven teachers were selected to answer the questionnaire using a cluster sampling method in which schools were randomly sampled from a list of government and non-government metropolitan schools. Eighty percent of the questionnaires were returned.

The study found that most teachers (83.8%) used the

lowest two levels of inquiry and only 16.3% of the teachers used higher levels, with only 1.5% using the highest level.

Teachers listed many benefits of open inquiry formats. Most benefits were for the students. Those most commonly identified were categorized "Greater interest / ownership / motivation", "Students learn more / have greater understanding" and "Personal skills development". Teachers also listed many difficulties of open inquiry formats and most of these were for the teacher. Those most commonly identified were "Curriculum and time constraints", "Equipment demands" and "Behaviour management / safety".

The last chapter of this thesis included a discussion about how these difficulties might be overcome. Future research could focus on this area.

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APPENDIX ONE

LETTER TO HEAD OF SCIENCE DEPARTMENT

Dear

RE : A STUDY OF THE LABORATORY FORMATS CURRENTLY USED IN LOWER SCHOOL SCIENCE.

Thank you for your willingness to participate in my study of laboratory activities.

Please would you distribute these questionnaires to those teachers you identified during our telephone conversation as teaching lower high school science in your school.

Please ask the teachers to return their questionnaires to you. I have enclosed a large addressed envelope for the combined school return. I ask that you please return them by the **26th August**.

Your school's response is a necessary and appreciated part of my research. Thank you for your help.

Yours sincerely,

[redacted]

Helen Bryce.

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APPENDIX TWO

LETTER TO SCIENCE TEACHERS

Dear

Introduction.
I am a postgraduate student at Edith Cowan University and I am undertaking a study of laboratory formats. My aim is to gather information from science teachers in order to build up an accurate picture of the laboratory formats currently used in Perth schools.

As your school has been randomly sampled I request your support in completing the attached questionnaire. All replies are **anonymous and confidential.** No person or school will be identified in my thesis. Your school is coded with a number but this is only for follow-up purposes if needed.

The questionnaire has been designed using mostly boxes to tick so that it should only take about **five minutes** to complete. Some items however, are more open to help my understanding of the laboratory format you use.

Last Experiment/Investigation Lesson.
For some questions in the questionnaire you need to consider the last lesson you taught in which your students carried out an experiment or investigation.

Questionnaire Return.
Please return your questionnaire in the envelope supplied to the Science Coordinator so that he/she can send back a combined school return by the **26th August.**

I hope that you will give this questionnaire sincere consideration. Your response is a necessary and appreciated part of my research.

I look forward to receiving your return and in advance thank you very much.

Yours sincerely

[redacted]

Helen Bryce.

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APPENDIX THREE.

QUESTIONNAIRE - THE LABORATORY FORMATS CURRENTLY USED IN LOWER SCHOOL SCIENCE.

PART I : GENERAL INFORMATION.

Please tick the appropriate box.

1. The school I teach in is

government .... ☐

non-government .... ☐

2. I am

male .... ☐

female .... ☐

3. The number of years of my teaching experience is

< three .... ☐

three - five .... ☐

six - ten .... ☐

eleven - twenty .... ☐

> twenty .... ☐

4. My main teaching specialisation is

biological science .... ☐

physical science .... ☐

maths .... ☐

other (please specify) .... ☐

continued next page...

PART TWO : SPECIFIC LABORATORY FORMAT INFORMATION.

For questions 5 - 10 please base your answers on the last experiment/investigation lesson you taught in Year 8, 9 or 10.
Please tick the appropriate box.

5. This experiment/investigation lesson was in

Year 8 .... ☐

Year 9 .... ☐

Year 10 .... ☐

6. The emphasis of this investigation lesson was in

Biology .... ☐

Chemistry .... ☐

Earth Science .... ☐

Physics .... ☐

7. In this lesson, the problem to be investigated or the question to be answered was

given by the teacher or worksheet .... ☐

chosen by the students .... ☐

8. The materials/equipment was specified by the

teacher or worksheet......... ☐

chosen by the students .... ☐

9. The method/procedure to be followed to solve the problem or answer the question was

specified by the teacher or worksheet .... ☐

designed by the students .... ☐

continued next page...

10. The answer to the problem or question was

outlined in general terms before the activity ... ☐

unknown by the students before the activity ... ☐

11. How well does this last practical lesson represent the practical lessons usually taught in this class?

very well .... ☐

satisfactorily .... ☐

poorly .... ☐

Please explain briefly.

____

____

____

PART THREE : GENERAL LABORATORY FORMAT INFORMATION.

For the following questions please use the above class but
answer in general terms.

12. What do you see as the main benefits and/or difficulties for the students of doing laboratory work in which they can plan and carry out their own experiments/investigations?

Benefits__________________________________

____

____

____

Difficulties________________________________

____

____

____

continued next page...

13. What do you see as the main benefits and/or difficulties for you as teacher of doing laboratory work in which the students can plan and carry out their own experiments/investigations?

Benefits ______________________________

____

____

____

Difficulties ______________________________

____

____

____

End of Questionnaire.