

1984

**Proceedings of the Tenth Annual Conference of the Science
Education Association of Western Australia : Western Australian
College of Advanced Education, Perth, October 1984**

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Science Education Association. (1984). *Proceedings of the Tenth Annual Conference of the Science Education Association of Western Australia : Western Australian College of Advanced Education, Perth, October 1984*. Perth, Australia: Western Australian College of Advanced Education.

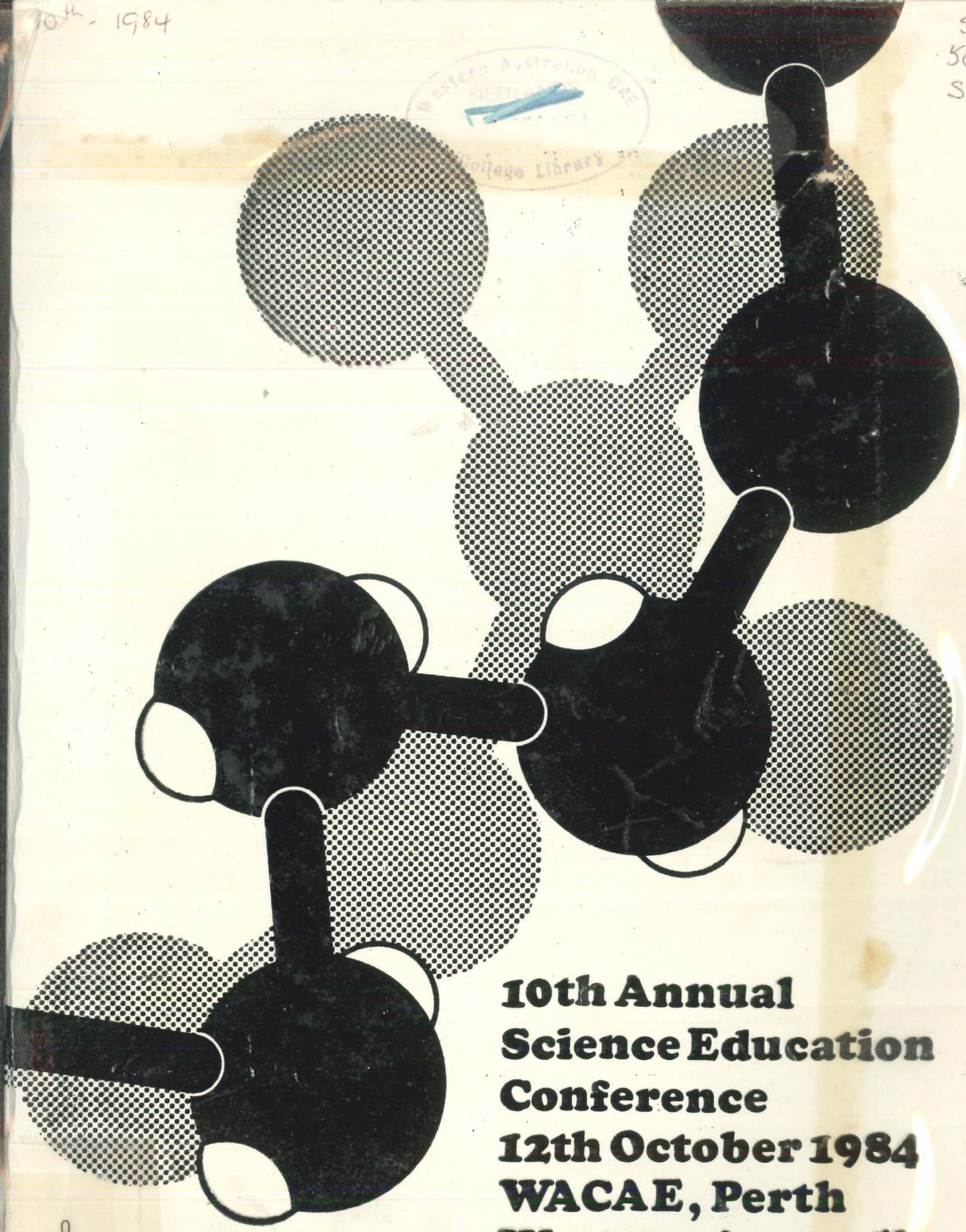
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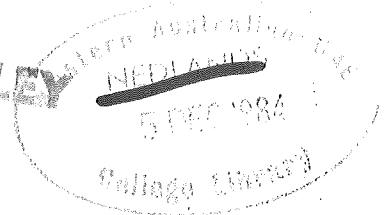
**10th Annual
Science Education
Conference
12th October 1984
WACAE, Perth
Western Australia**

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PROCEEDINGS OF THE TENTH ANNUAL CONFERENCE OF THE
SCIENCE EDUCATION ASSOCIATION
OF WESTERN AUSTRALIA

WESTERN AUSTRALIAN COLLEGE OF ADVANCED EDUCATION
Perth, October 1984

MOUNT LAWLEY



Planning Committee

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J Rowe	W.A. College
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D Treagust	W.A. Institute of Technology
M Dynan	W.A. Institute of Technology
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PROGRAMME

Opening Address
9.10 - 9.15

Dr D Jecks
Director, W.A. College

Symposium
9.15 - 10.45

Implications of the Beazley and McGaw
Inquiries for Secondary Science Education

Speakers:

Mr Ken Betjeman, Superintendent,
W.A. Education Department
Dr Eric Speed, Principal, All Saints'
College
Dr Wayne Welch, Professor of Science
Education, University of Minnesota.

Chairperson:

Dr Patrick Garnett, Head, Department of
Science, W.A. College

Session 1
11.00 - 11.20

- A. Implementation of science curriculum innovations : Lessons from the past.
Muredach B Dynan
- B. Diagnostic tests to evaluate student misconceptions in science.
David P Treagust

Session 2
11.20 - 11.40

- A. A model of the strategies used by experts to solve genetic pedigree problems.
Mark W Hackling
- B. The four phase model : Perspectives of a novice.
John D Rowe

Session 3
11.40 - 12.00

- A. A new direction to teaching problem-solving in physics.
John A Deacon
- B. Ultraviolet light, the exciting detective.
C Meredith and E Ashcroft

Session 4
12.00 - 12.30

A. Secondary science laboratory investigations.
Kenneth Tobin

B. Why does the point of educational research fail to penetrate the hide of classroom practice?

John C. Happs

Session 5
12.30 - 1.00

A. "Hands on" science : How often and whose hands?

Leonie J Rennie, Lesley H Parker and

Pauline E Hutchinson

B. Measuring science teachers' perceptions of their school environment.

Barry J Fraser

Session 6
2.00 - 2.20

A. Arguments for and against science education.

Gordon A. Cochard

B. Importance of the darling scarp in field geology courses.

K Sappal and S Wilde

Session 7
2.20 - 2.40

A. Self-paced learning modules for use with senior college physics classes.

David Berry and Bob Svendsen

B. Are there gender-related differences in year 10 students' attitudes towards, and knowledge of energy?

Stephen J Vlahov

Session 8
2.40 - 3.00

A. The role of cognitive factors in chemistry achievement.

Sarath Chandran

B. Secondary students' ability to accurately read scales of scientific instruments.

Trevor Carboon and David F Treagust

Session 9
3.00 - 3.30

A. Sex-stereotyped attitudes about science : Can they be changed?

Lesley H Parker and Leonie J Rennie

B. Students, science and the mass media : Australian Studies.

Renato A Schibeci

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IMPLEMENTATION OF SCIENCE CURRICULUM INNOVATIONS :
LESSONS FROM THE PAST

Muredach B. Dynan

Faculty of Education

Western Australian Institute of Technology

INTRODUCTION

An Historic Time

This conference is being held at a time which will undoubtedly be regarded in the future as one of the most significant in the history of education in Western Australia. While the year 1984 will continue to evoke Orwellian images, it is not too fanciful to suggest that the name Beazley will have more real meaning for the lives of future citizens of this State. This statement assumes, of course, that the recommendations in the Beazley Report (1984) will be implemented - and there may well be some cynics here who believe that the report will simply gather dust in the time-honoured fashion of many Government initiated reports. While such cynicism is understandable, I feel that there will be serious efforts to implement many of the Beazley recommendations. The political and community attitudes appear to be favourable and the teachers have given general support to the conclusions of the Beazley committee. However, if the implementation of the recommendations relating to curriculum change in schools is to be successful, then it is important to take cognizance of lessons from the recent past in respect of curriculum innovation.

Scope of Paper

In this paper I will first review briefly some of the general findings of research studies on curriculum innovation. Next, I will examine some of the research on science innovations, with particular reference to Australia. Finally, I will put forward some tentative guidelines relating to implementation processes and strategies for change.

RESEARCH ON CURRICULUM IMPLEMENTATION

Failure in the Sixties

At the end of an exciting period of imaginative curriculum reform in the U.S.A., Britain and other Western countries, which had seen the investment of large amounts of financial and human resources in curriculum development and dissemination, unease began to emerge at the apparent failure of many of these innovations to take hold in the schools. Commenting on the situation in the U.S.A. Goodlad (1971) stated:

The year 1970 has come. These innovations and more are indeed, here - but only at the periphery. The task of the seventies is to get reforms out of the clouds and into tens of thousands of classrooms.

A similarly negative view was presented by McDonald and Walker (1976) who commented on the British educational scene as follows:

The last decade has seen a change of mood. The optimism of the pioneer innovators is now muted, in part, because planned change has turned out to be a more formidable problem than was initially assumed.

Research interest became more focused on the problems of bringing about change and there has been a resultant growth in studies relating to all aspects of educational innovation. It should be stated here that research in this area had been carried out prior to the 1970's, (e.g., Miles, 1964) and considerable research had already been carried out on the processes of diffusion of innovations in social systems other than education (e.g. Rogers, 1962). Some of the theoretical constructs and research findings from these studies have been used frequently in subsequent discussions by researchers and others.

Definition of Terms

Because of the confusion which arises from different usage of terminology by writers in this area, it is useful to define some key terms used in this paper:

Innovation. This implies some degree of intention or conscious planning with regard to change. Innovation may occur at individual, group or system-wide level. While the effects of innovation may not always be positive, the intention is to make improvements from the existing situation.

Dissemination. This refers to planned procedures for communicating information about innovations. The term may be used in relation to information about various aspects of an innovation or to the innovation itself.

Diffusion. This refers to both planned and unplanned communication of information about an innovation. It therefore encompasses the notion of dissemination while being broader in scope.

Adoption. Some authors perceive adoption as a process but here the term is used to refer to the actual decision by individuals or institutions to initiate action relating to an innovation.

Implementation. This is the process of putting into practice the innovation idea or product. In the case of curriculum innovations, this occurs in the adopting schools, involving teachers, students and administrators.

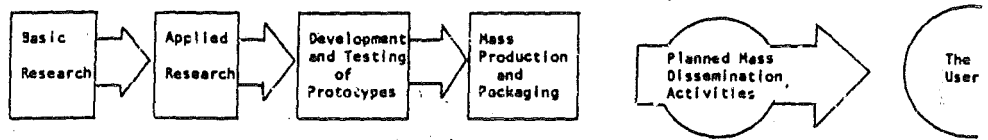
Implementation is central to the overall process of innovation. It should be noted that the term is often used by policy-makers and administrators to refer to the processes leading up to adoption as well as to on-site implementation.

Theoretical Constructs

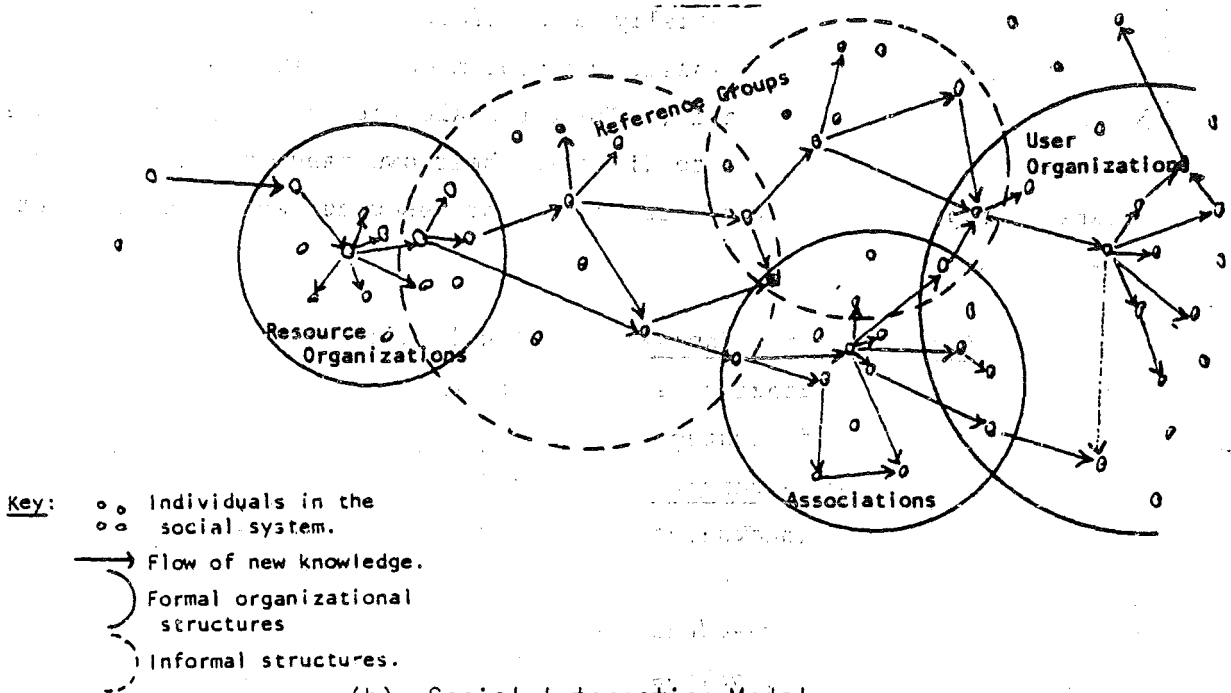
In the various research studies on innovation processes, two broad frameworks have been commonly used to represent or discuss the findings. These are models of innovation and innovation strategies.

(i) Innovation Models. On the basis of analysis of processes of innovation in a variety of social contexts, Havelock (1971) proposed three models of innovation which have become part of the jargon in this area of study. These are the research - development - diffusion (RDD) model, the social-interaction (SI) model and the problem-solving (PS) model (see Fig. 1). The RDD model implies large-scale planning and dissemination by a central innovating body and a systems approach to the process. The SI model assumes that an innovation exists and emphasises the importance of personal contact amongst people in various groups. The PS model differs markedly from the RDD model, in that the user of the innovation has a major controlling role, not only in identifying the need for change, but in seeking a solution, with or without the help of outside change agents or consultants. Lesser known models such as Schon's (1971) Centre-periphery

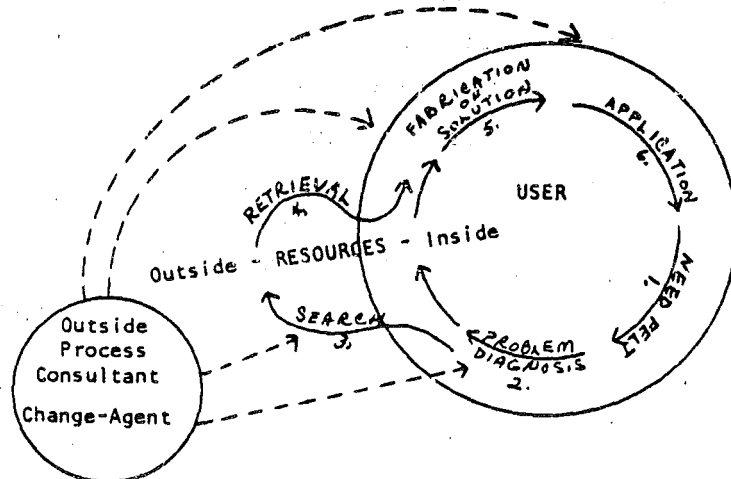
Figure 1: Three Models of Innovations (Havelock)



(a) Research-Development-Diffusion Model



(b) Social-Interaction Model



(c) Problem-solving Model

and Shifting-centres models and a wide variety of refinements on those proposed by Havelock have emerged from the research literature.

It has been shown that the RDD model was generally followed in the planning and diffusion of most of the major innovations in the USA. The same picture emerged from a major OECD research study which examined the ways in which educational innovations were initiated and implemented in many European countries. The CERI (1973) report modified the RDD model, essentially by the addition of an initial Planning phase.

The apparent failure of this general model of innovation led many of those concerned with educational improvement to look toward the problem-solving model as being potentially more effective. Hence, there was a stronger emphasis on school-based curriculum development (SBCD) in many countries, including Australia. The rationale for this was that schools were more likely to be able to diagnose their own needs and to adopt or create appropriate solutions, if sufficient resources and encouragement were provided.

(ii) Strategies for Innovation. A well-known descriptive categorisation of strategies is that proposed by Chin (1967), who derived three types of strategy, rational-empirical, normative-re-educative and power-coercive. In the first type, the change agent assumes that, if the innovation is shown to be worthwhile on the basis of empirical evidence, then adoption and implementation will follow rationally. Normative-re-educative strategies seek to facilitate changes in the norms and values of the clients thus leading to adoption of innovations through the re-educative process. As the name suggests, power-coercive strategies are based on the overt or hidden use of power to ensure adoption and implementation.

While power-coercive strategies are often linked with the RDD model, it should be stated that many of the innovations which followed the RDD model in the 1960's relied as much on a rational-empirical strategy as on the use of power. This was certainly true in the British context where schools were free to use innovations if they wished.

A useful theoretical construct in respect of Australian public school

systems, which tend to be centrally organised by State Education Departments, is the paradigm of the innovation-decision process proposed by Rogers and Shoemaker (1971). They identified three kinds of decision-making in relation to adoption of innovations:

optional decisions, which are made by individuals

collective decisions, which members of a social system make by consensus

authority decisions, which are forced on individuals by someone in a superordinate position.

It can be fairly argued that State Education Departments administer Government schools as an Authority-Innovation-Decision-System, - critics may perceive the acronym AIDS as an apt description. The term 'top-down' is a more common description for this kind of decision-making. In respect of the relative effectiveness of the three types of decision making, these writers state:

Generally, the fastest rate of adoption of innovations results from authority decisions In turn, optional decisions can be made more rapidly than the collective type. Although made more rapidly, authority decisions are more likely to be circumvented and may eventually lead to a high rate of discontinuance of the innovation.

Focus on Implementation

In a comprehensive review of research findings, Fullan and Pomfret (1977) pointed to the over-emphasis on input-output models of curriculum processes in previous research:

The whole area of implementation, what the innovation actually consists of in practice and why it develops as it does, was viewed as a "black box" where innovations entering one side somehow produce the consequences emanating from the other.

One major study on implementation was the Rand Change Agent Study (1973-77) which examined federally sponsored innovation programs in the U.S.A. In one of several reports of this study Berman et al. (1975) proposed the concept of mutual adaptation as an interactive process "between the project as planned and the institutional setting", which was necessary for effective implementation. In many instances they found that effective implementation did not occur and they identified

three kinds of failure, namely, co-optation so as to make the innovation fit traditional patterns, pro-forma "implementation" or breakdown.

The notion of adaptation of curriculum plans in the institutional context contrasted sharply with previously held perspectives on implementation which focused on the degree of fidelity of the implementation.

In reviewing the Rand Study findings together with those from a large number of smaller studies, Fullan and Pomfret identified a number of determinants of implementation within four categories as follows:

A Characteristics of the Innovation

- 1. Explicitness
- 2. Complexity

B Strategies

- 1. In-service training
- 2. Resource support
- 3. Feedback mechanisms
- 4. Participation

C Characteristics of the Adopting Unit

- 1. Adoption process
- 2. Organizational climate
- 3. Environmental support
- 4. Demographic factors

D Characteristics of Macro Sociopolitical Units

- 1. Design questions
- 2. Incentive systems
- 3. Evaluation
- 4. Complexity

While it will not be possible to discuss all of these variables in this paper, their listing may serve to illustrate the complexity of the processes of implementation. They also highlight the importance of taking account of the four categories, only one of which relates specifically to the innovation itself.

RELEVANT RESEARCH STUDIES ON SCIENCE INNOVATIONS

It may be useful at this stage to look at some relevant findings in relation to the implementation of science curriculum innovations, with

some reference to the Australian content. A number of studies relating to the dissemination and implementation of the Australian Science Education Project (ASEP) materials have yielded interesting results. These materials were designed in modular form for use in lower secondary science teaching. Northfield (1980), identified ASEP as a "complex" innovation:

ASEP appears to be an innovation which is difficult to define and in fact, has a number of characteristics which invite teachers to define the curriculum in different ways.

He examined a number of aspects of the implementation of ASEP in science classes including the relationship between modes of implementation of ASEP and changes in the learning environment. In a later article reflecting on experiences with ASEP and other curriculum innovations Northfield (1983) presents data relating to the use of the ASEP unit 'Places for People' in 18 classes to show a wide diversity in implementation patterns from teacher-centred presentation on one hand, to varied group activities by students, with teachers acting as facilitators, on the other.

The great diversity of use can be regarded as evidence of a limited impact of dissemination and perhaps be used to frame arguments for more resources being allocated to dissemination plans which emphasise developer intentions in future curriculum projects. A second response would be to suggest that the results represent the diversity in our classrooms when curriculum autonomy is accepted by schools and teachers.

Here, Northfield raises the dilemma for educational planners and developers as to the extent to which innovations should be implemented with uniformity (or high fidelity) or adapted by teachers and schools as they see fit.

Owen (1976) provided evidence showing that the rate of adoption of ASEP materials varied from one State to another. He explained the relatively low usage of these materials in Western Australia in terms of the perceived advantages of the Department's Lower Secondary Science curriculum materials, which were more structured, as well as the higher compatibility of these materials and the fact that they were freely available to all Government schools. In a later publication Owen (1977) discussed the use of ASEP materials in three schools and concluded that

teacher-related factors were important to implementation.

The results suggest that for the ASEP materials to be used successfully in a Science programme, there is a need for the Science staff to be willing to try new curriculum materials, to be 'professionally' oriented in their attitude to teaching and to be willing to work together in the planning of courses based on the use of the units.

He also emphasised the important leadership role of heads of science departments.

In another study of teaching in classes using ASEP materials, Tisher and Power (1975) distinguished three different categories of teachers. One group had values which were dissonant with those underlying the ASEP project, while another had values congruent with the project. The third group (mixed mode) had mixed values in this regard. Their research showed that there were differences in the ways teachers from each category implemented the curriculum. This indicated the importance of teacher values in the implementation process.

These studies emphasize the importance of dissemination strategies which seek to develop teacher commitment to the values inherent in the innovation if effective implementation is to occur. A more recent study, presently being completed by the author, shows how change agent strategies using collaborative approaches involving schools and teachers contributed to a high level of value congruence and commitment to the new Physical Science course in Western Australia. Findings from this study (see Dynan, 1984a) suggest that a collaborative strategy for implementation combining inservice development, resource support, effective communication linkage and innovation protection is likely to be effective in facilitating implementation and subsequent continuation of an innovation.

In relation to science at primary school level, the existence of serious problems in the adoption of innovatory approaches in Victorian schools was shown by Symington (1974) who found "very limited adoption" in many schools. He suggested three major causes, namely, teacher resistance to change, lack of background knowledge and inadequate facilities for teaching science. In Western Australia, there has been significant progress in the area of primary science, due to a consistent effort on the part of science education personnel

in the Education Department and tertiary institutions, through intensive inservice development. The author developed a model of inservice, in co-operation with other personnel, which was aimed at improving the implementation outcomes in primary school settings. This model involved close collaboration with schools, leading to school-based curriculum development, and the use of training models to facilitate the acquisition of appropriate teaching strategies (see Dynan, 1984b).

One way of perceiving the tasks of dissemination and implementation is that of overcoming 'barriers' to implementation. Such barriers have been categorised by Watson (1969) and the CERI (1973), with both sources emphasising that institutional structures and norms are designed to maintain procedures efficiently rather than to change them. To overcome this structural barrier, some compensatory action must be taken to reduce the maintenance resistance so as to enable the innovation to be introduced. Though Watson stresses personal barriers to change, the CERI report indicates that teachers are not psychologically opposed to innovations, providing that the incentives for change are sufficient to overcome the disincentives. Evidence supporting the view that factors other than teacher disinterest are more likely to lead to failure emerged from a study by Swain and Fairbrother (1971) relating to the failure of the Nuffield Advanced Level Physical Science course in Britain. Among the factors inhibiting adoption, they listed

- . lack of incentives
- . timetabling and organization problems
- . problems inherent in the course materials
- . relative costs of the materials
- . staffing problems
- . lack of appropriate student enrolments

At a system-wide level, barriers to effective innovation can change with time. In his review of twenty years of science curriculum developments in the U.S.A. Welch (1979) pointed out that in addition, to the known challenges facing the curriculum reformers of the 1960's, new problems arose later.

... in the second decade were added the unforeseen problems of declining enrollments at the secondary level, inflation, student unrest, a fading public image of science, environmental concerns, competing demands such as integration, the back-to-basics movement, social concerns and school reform movements.

This should serve as a timely warning to all of those involved in curriculum innovation of the effects of political and social changes over the medium term.

LESSONS FROM THE PAST

Given the confused history of attempts to bring about change in school curricula in the past 28 years, it may seem foolhardy to attempt to prescribe guidelines for future action. However, I believe that it is possible to learn some lessons from the past, both in respect of pitfalls to avoid and of procedures which might facilitate more effective implementation of desired innovations. While the following comments may be somewhat oversimplified, they reflect a fairly consistent pattern of findings from research in this area. They are classified under six headings.

1. Management Responsibilities

- (a) It is primarily the responsibility of management, at school and system levels to provide the appropriate environment, strategies and resources for effecting desired changes in the curriculum.
- (b) Managers of change have to decide whether to follow 'top-down' strategies for change or school-based development models. The choice depends on the nature of the particular innovation. For instance it may well be necessary to mandate some changes in curriculum content, objectives or time-allocations uniformly throughout the school system. In other cases, it may be more appropriate to allow schools to take the initiative in putting innovative ideas into practice. The important point is that there be careful consideration of which approach to adopt and a realisation of the problems associated with both kinds of decision-making procedure.
- (c) In circumstances where more than one innovation is being disseminated, management must consider the likely problems of schools and teachers coping with multiple innovations.

2. Characteristics of the Innovation

- (a) Curriculum innovations are often more complex than the developers or change agents perceive. Indeed some are comprised of a number

of distinct innovations in a bundle. Implementation involves teachers in changing roles, learning new behaviours knowledge and skills and often requires significant change in value-positions.

- (b) Consideration must be given to the attributes of an innovation which are likely to encourage or inhibit adoption and implementation. Factors such as the advantages over existing curricula, feasibility of implementation and compatibility with the school context have been identified as important for successful implementation.

3. Implementation Modes

- (a) Change agents need to clarify for themselves and their clients what degree of fidelity is desired in the implementation process. Where a high level of fidelity is required, this should be made clear to teachers and assistance given, through inservice training and other means, to enable teachers to achieve the appropriate mode of implementation. In many cases, there is likely to be considerable scope for legitimate adaptations by teachers; again this should be clarified. The notion of innovation configurations proposed by Hall (1979) may be useful in defining the acceptable range of adaptations.
- (b) It is important not to confuse adoption of an innovation with effective implementation. The Rand Study findings showed that in many instances, implementation was superficial or even subverted. In this regard, the strategies for dissemination and implementation may be crucial in ensuring that successful implementation occurs.

4. Strategies

- (a) There is considerable evidence to suggest that power-coercive strategies have limited value in achieving effective implementation. Instead, strategies which maximise teacher involvement in decision-making from the earliest possible stage in the life of an innovation appear to be more successful in gaining commitment to the innovation and consequently more effective implementation. School-based curriculum development has much to commend it in this respect, although

there are limits to the extent of effort which teachers can be expected to give to this process. Zaltman et. al. (1977) have proposed a number of alternative strategies which may be appropriate for different kinds of innovation. Arising from a case-study of the implementation of the Physical Science course in Western Australia, Dynan (1984a) suggests that a collaborative strategy involving key personnel, change agents and teachers is likely to lead to successful implementation.

5. Teacher Development

- (a) Many researchers have identified the lack of adequate inservice development of teachers as a major cause of failure of implementation. Clearly, therefore, more attention and resources should be allocated to this aspect in any strategy for implementation.
- (b) 'One-shot' inservice courses, provided away from the context, are unlikely to be of much value. Instead, prolonged inservice development specifically geared to implementation tasks and problems are more likely to be effective. This should include opportunities for on-the-job training or coaching, where new strategies of teaching or role-changes are needed.
- (c) The importance of social interaction amongst teachers and other relevant personnel should not be underestimated both in respect of encouraging adoption and also as an important part of the re-education process amongst teachers. Teachers are likely to have many unspoken concerns which may be eased by the supportive group processes occurring in meetings with other teachers.

6. Environmental Support

- (a) Clearly, innovations are not implemented in vacuo, but are subject to environmental influences within the system. These include levels of support from senior personnel and peers, resources and political influences. Any strategy for change must seek to provide an environment which encourages the innovation's adoption, implementation and continuation.
- (b) Given the normal 'maintenance' function of educational systems,

temporary support structures and protective measures are needed during the early years of implementation.

- (c) The provision of resources requires heavy investment of energy, time and finance, particularly where the innovation is a major one. It is important that the commitment to such provision be made in advance of any decision to proceed.

Concluding Comments

Two major points may be made in conclusion. Firstly, curriculum innovation is a complex process which requires enthusiasm, patience and careful planning. Recent history warns us that real change in classrooms is unlikely to occur as a result of rhetoric or policy statements emanating from on high. Schools and teachers are willing to bring about change but are rightly suspicious of 'band-wagons' which may prove to be impracticable or which may simply be replaced. Real changes can occur only if teachers are willing and able to implement them in the classroom. In this context, it is worth quoting Welch's (1979) comment in respect of the usage or lack of usage of many curriculum materials in schools in the U.S.A.

While there may be new books on the shelves and clever gadgets in the storage cabinets, the day-to-day operation of the class remains largely unchanged. A teacher tells his or her students what is important to learn and so the class progresses.

Secondly, in Western Australia, the school system is faced with the possibility of enormous changes in the structure and content of curricula over the next few years. If those responsible for managing those changes are too impatient for quick results (and political pressures may well fuel that impatience) then it is likely that the mistakes of the past will be repeated. Curriculum products will be substituted for process, teachers will be chided for their "failure" to be innovative and, once again, rhetoric will become a substitute for reality.

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DIAGNOSTIC TESTS TO EVALUATE STUDENT MISCONCEPTIONS IN SCIENCE.

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INTRODUCTION

For the past decade there has been considerable interest in misconceptions held by students. Research dealing with misconceptions in science subject areas has been conducted with primary, secondary and tertiary students in anglophone countries such as England, Australia, New Zealand, South Africa and the USA. Some examples of researchers in these countries are Gilbert (1983), Driver (1981), Solomon (1983), Brumby (1982), Hackling & Treagust (1984), Osborne (1980), Happs (1983), Champagne, Kolpfer & Anderson (1980) and Helm (1978). Similar interests in students' misconceptions in science have been conducted in non-English speaking countries such as West Germany (Duit, 1983 and Rhoneck, 1981), Czechoslovakia (Zieleniecova, 1984). To provide a broader perspective on student misconceptions Driver (1981) and later others have referred to "alternative frameworks" to better describe the reasoning processes and understanding of students with misconceptions in science subject areas.

In all the above research the usual means for obtaining information about students' misconceptions has been through individual student interviews on specific science topics. Gilbert and Osborne (1980) and Watts (1981) have described a variety of formats or procedures for conducting these interviews. The two most commonly used procedures by researchers are interviews - about - instances and interviews - about - events.

A pertinent criticism of these research procedures to identify students' misconceptions in science is that applied to all interview techniques in that it is consuming in terms of the researchers' time and difficult for a non-trained person to administer. For a classroom teacher to interview each student to obtain information on their misconceptions prior to commencing a new science topic or following the teaching of a topic is impracticable and virtually impossible. Subsequently, as interesting as this area of misconceptions may be, the lack of usability may render the area without direct application to the classroom teacher.

One way for a teacher to more easily identify misconceptions held by a group of students would be to administer a pencil and paper multiple choice test which has items specifically designed to identify misconceptions and misunderstandings. Such a test could be used as a diagnostic tool and help the teacher to begin to remedy the misconceptions that exist prior to commencing the topic or have occurred following teaching of the topic. It is, however, well documented that such a task will not be easy, since misconceptions have often been incorporated securely into cognitive structure (Gunstone, Champagne & Klopfer, 1981). Nevertheless, a teacher needs a starting place for addressing known misconceptions and a multiple choice diagnostic test would appear to provide a simple method.

DEVELOPMENT OF TESTS TO DIAGNOSE MISCONCEPTIONS

This paper describes a methodology used by the author for developing diagnostic tests to examine and identify students' misconceptions. Specifically the development of two such tests will be described, one on covalent bonding, a year 11 chemistry topic, and a second on photosynthesis and respiration, a biology topic taught in both lower and upper high school.

Broadly, the development of the diagnostic test may be broken into nine stages:

1. Propositional Knowledge statements

Propositional knowledge statements pertinent to the topic under investigation are identified. This technique has been used and described by Hackling (1981), Hackling & Treagust (1984) and Hackling & Garnett (1983) who wished to identify the content and concepts in specific topic areas.

2. Concept Map

A concept map of the concepts which all relate to the topic under investigation is developed. Creation of concept maps as described by Novak (1980) is preferred by this author and recommended, though other methods of relating concepts can be equally suitable.

3. Relating propositional statements to the concept map

The propositional knowledge statements are related directly to the concept map. In other words it is necessary to tie the propositional statements to the concept map to ensure that the content being examined is internally consistent. This is essentially a reliability check that the underlying concepts and propositional statements are indeed examining the same topic area.

4. Content Validation

The propositional statements and the concept map are content validated by competent tertiary academics, secondary science teachers and science educators. Any discrepancies or irregularities need to be removed and the list of propositional statements and the concept maps corrected and modified.

5. Unstructured Student Interviews

The test developer has discussions (unstructured interviews) with a small number of students who have just completed a given topic in order to identify any misunderstanding and misconceptions. These unstructured interviews give rise to the development of ideas for further probes by a written diagnostic test.

6. Multiple choice content tests

Questions of a multiple choice nature are written based on the topic being taught. Each question is based on one or a limited number of propositional statements. Each multiple choice question is provided with a space for the student to complete the reason why they choose the particular option of the multiple choice. After a series of questions have been developed which are representative of the topic, a test is given to a class of students. Misconceptions as well as true conceptions become evident in the free response answers.

7. Two-tier diagnostic tests

A two-tier diagnostic test is developed from the multiple choice items. This test is developed from the students' responses on the reasons given to each question as well as information gathered from the interviews. The design of the test is comparable to that used by Tobin & Capie (1981). The first part of an item on the test is a multiple choice content question. The second part of each question involves choosing the reason for the answer, this choice may be the correct answer, the wrong answer or identify misconceptions.

8. Specification Grid

A specification grid is designed to ensure that the diagnostic test

fairly covers the propositional knowledge statements underlying the topic.

9. Refinements

Successive refinements of the two-tier multiple choice tests ensures that the test can be used for diagnosing student misconceptions in the topic under examination.

EXAMPLES OF TESTS TO DIAGNOSE MISCONCEPTIONS

The examples described in this section are based on research conducted at the Science & Mathematics Education Centre. Current developments are concerned with students' conceptions and misconceptions in covalent bonding for Year 11 chemistry (Peterson, 1984), photosynthesis and respiration in plants (Haslam, 1984) and the first and second laws of thermodynamics (Treagust & Deacon, 1984). Examples to illustrate the methodology described above are taken from the work being conducted by Peterson (1984) and Haslam (1984).

1. Propositional Knowledge Statements

Examples of some of the propositional knowledge statements developed for photosynthesis and covalent bonding are shown in Figure 1. Both topics are taught in Year 11 and the statements pertain to knowledge required of students at that level of study.

2. Concept map

Part of the concept map showing the major concepts and linking statements for covalent bonding are shown in Figure 2. In developing a concept map, the attributes described by Novak (1980) are presented here.

3. Relating Propositional knowledge to the map

The number of the propositions which relate to the concepts in the concept map are shown in circles on Figure 2. It is essential that there is a representative covering of concepts and propositional statements for the topic under investigation.

4. Content Validation

In research of this type, it is essential that the content and concepts to be investigated are scientifically sound for the particular level of study being pursued. Consequently, both the covalent bonding and photosynthesis and respiration developments used experienced teachers, science educators and tertiary specialists to content validate both the propositional list and the concept map. The final list of propositions and the concept map reflect the input from the content validators.

5. Unstructured Student Interviews

In order to gain a broad perspective of students' understanding of a topic, unstructured interviews took place with students who had recently completed the topic. The discussion related to open ended questions such as "How does a plant obtain food?" or "Explain what happens when plants respire". Student responses were recorded and any misconceptions were identified. This part of the methodology could easily be conducted with interviews-about-events or interviews-about-instances cards as described by Gilbert & Osborne (1980) and Watts (1981). However, in this case a more open-ended approach was taken and some of the students responses are illustrated in Figure 3.

6. Multiple choice content test

Multiple choice tests are developed based on one or a limited number of

propositions. Examples of these questions are shown in Figure 4, together with the propositions to which they relate. A most important aspect of this stage in the methodology is to have students provide a reason for their chosen response key to each item. The reasons given, together with the student's comments from the unstructured interviews, help provide the ideas and information for writing a test to identify misconception of a particular set of propositions upon which the question is based.

7. Two-tier diagnostic tests

The diagnostic test contains items having two parts. The first part, as described above in stage 6, is the multiple choice question. The second part to each item consists of a multiple choice set of reasons for the answer given in part one. This test design is similar in format to the Test of Logical Thinking developed by Tobin & Capie (1981). The second part of each test item contains responses which are correct and wrong, together with misconceptions earlier identified in stages 5 and 6. If more than one misconception has been given by students earlier, more than one misconception should be included in the alternative reason responses. Examples of these two-tier diagnostic test items are shown in Figure 5.

8. Specification Grid

To ensure that the test covers the propositional knowledge statements and the concepts in the concept map, a specification grid is drawn up.

9. Refinements

The development of these tests to date has shown that each item can be successfully refined to improve its diagnostic nature to identify misconceptions. In this regard, there is no short cut to obtain

initial information on student responses other than talking to students in unstructured interviews. Subsequently, we have spoken to other students about their understanding of an item in order to gain a better idea of the misconceptions held about the underlying concepts and propositional statements.

CONCLUDING REMARKS

This paper has described the development of two-tier test items to help diagnose student misconceptions on a topic area. Topic area chose for illustration involved covalent bonding and photosynthesis and respiration in plants. The methodology so described is being used in current research projects and is being shown as a fruitful way for classroom teachers to help identify their students' misconceptions. There are of course limitations to this methodology. First, it is frequently difficult to write a non-trivial test item on a limited number of propositional statements. Second, it is not as easy as expected to identify misconceptions which relate to the question under discussion. The current work is progressing well and the diagnostic tests will be available in the near future for teacher use.

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Covalent Bonding

7. Equal sharing of the bonding electron pair occurs between atoms with the same electronegativity.
8. Equal sharing results in the electron pair being centrally located between the non-metal atoms.
9. Equal sharing of the electron pair results in a non-polar covalent bond.
10. Unequal sharing of the electron pair results in a polar covalent bond.
11. Polar covalent bonds
12. The shared electron pair in a polar covalent bond is located closer to the atom with the higher electronegativity.

Photosynthesis

1. Chloroplasts are parts of a plant all containing chlorophyll.
2. Chlorophyll is found in certain plant cells.
3. Chlorophyll gives the green colour to the leaves and to the stems.
4. Photosynthesis is the process by which green plants containing chlorophyll, are able to use sunlight energy, carbon dioxide and water to make simple sugar (plant food) called glucose.
5. Photo means light and synthesis means to make.
6. Photosynthesis takes place mainly in the green leaves (but green stems make food too).

Figure 1

Examples of propositional knowledge statements
for covalent bonding and photosynthesis:

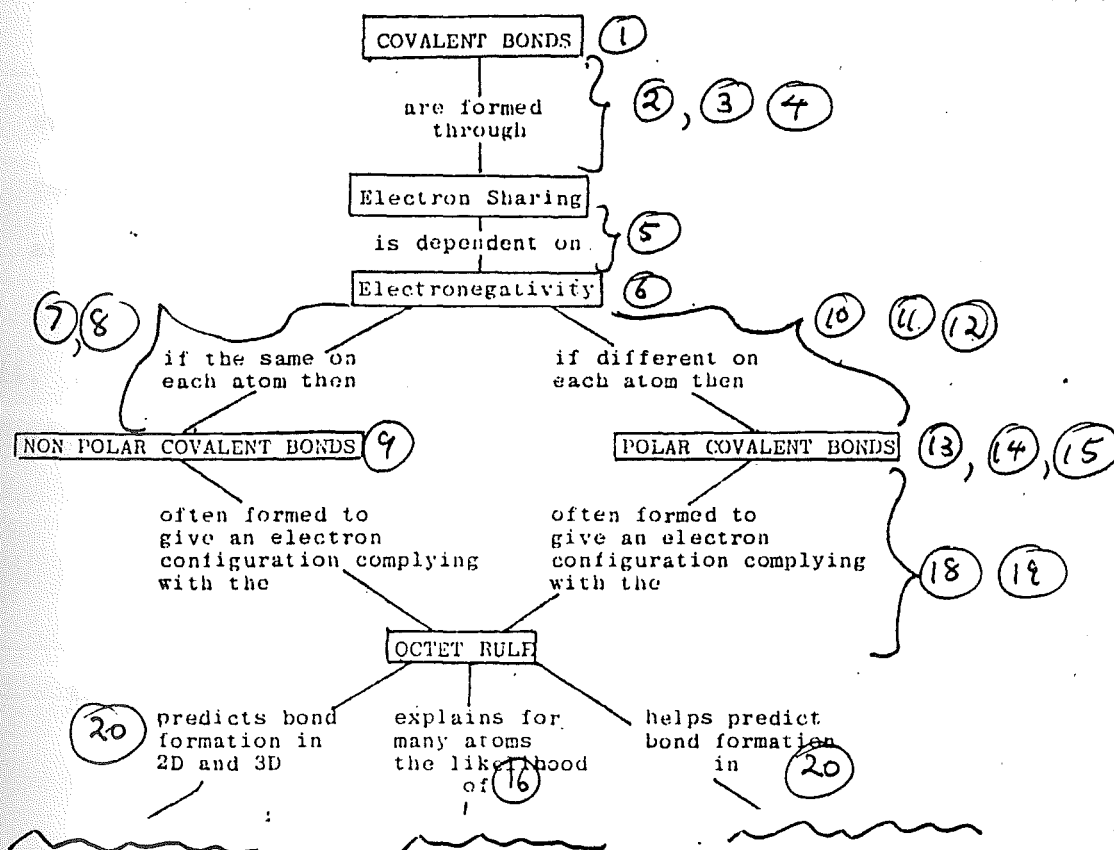


Figure 2

Part of the concept map for covalent bonding as expected of Year 11 students.

Note: Numbers in circles refer to propositional statements.

QUESTION: Explain what happens when plants respire? (How do plants respire? What happens when plants respire? What does respiration in plants mean to you?)

EXAMPLES OF STUDENTS' RESPONSES:

1. Plants respire when they breathe at night.
3. Always plants respire by breathing in sugar and oxygen and give out water and carbon dioxide.
6. When a plant gives off oxygen and takes in carbon dioxide.
7. In CO - out O same as photosynthesis
8. Plants respire by taking CO and blowing out oxygen.
9. Plants respire by breathing like we do but without a nose, they use cells or pores on the surface of leaves and branches, etc. They breathe carbon dioxide in and convert it into oxygen. Their waste is our breathing substance, our waste is their breathing substance.

Figure 3

Example of an open ended question and student responses

9. The substance Chlorine Trifluoride (ClF_3) is often described as a planar, T-shaped molecule. Based on this information ClF_3 is most likely to be a

- (i) polar molecule.
(ii) non-polar molecule.

Reason

(27) (28)

10. Naphthalene (C_{10}H_8) has a melting point of 80°C and a boiling point of 218°C . The melting point and boiling point values suggest that the intermolecular forces in Naphthalene are

- (i) weak
(ii) strong

Reason

(29) (31)

11. Water (H_2O) and Hydrogen Sulphide (H_2S) have similar chemical formulae and have v-shaped structures. At room temperature, water is a liquid and Hydrogen Sulphide a gas. The variation in state for water and hydrogen sulphide is due to the presence of strong intermolecular forces between.

- (i) H_2O molecules
(ii) H_2S molecules

Reason

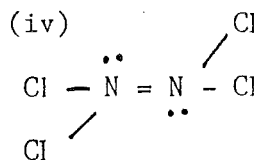
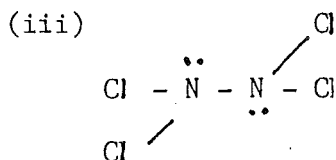
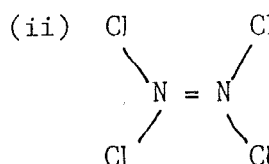
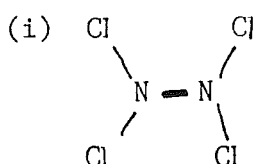
(28) (29) (30)

Figure 4

Examples of multiple choice questions with reason required together with the propositional statements being assessed.

Note: Numbers in circles refer to the propositional statements addressed by the questions

22. Which of the following best represents the structure of N_2Cl_4 ?



Reason

- (1) The high electronegativity value for Nitrogen requires that a double or triple bond is always found.
- (2) Nitrogen atoms can have a maximum of 5 electron pairs (including bonding and non-bonding pairs) in the outer shell.
- (3) Nitrogen atoms can have a maximum of 4 electron pairs (including the bonding and non-bonding pairs) in the outer shell.
- (4) The structure is due to the repulsion between bonds in the molecule.

(18) (19)

Figure 5

An example of a two-tier diagnostic test item for covalent bonding.

Note: Numbers in circles refer to the propositional statements addressed by the questions

A MODEL OF THE STRATEGIES USED BY EXPERTS
TO SOLVE GENETIC PEDIGREE PROBLEMS

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Abstract

The analysis of genetic pedigrees occurs as a problem solving task for upper secondary students of biology and human biology, tertiary genetics students, and for genetic counsellors. None of the standard texts or teachers' guides describe a procedure for pedigree analysis. This investigation set out to establish the strategies used by experts to solve these problems, and to identify procedures that might be taught to secondary students.

Introduction

High school science teachers rate genetics as one of the most important, and one of the most difficult biology topics for their students to learn (Finley, Stewart and Yarroch, 1982). Indeed studies of students' understanding of the mechanisms of inheritance after instruction, have revealed several common misconceptions (Hackling, 1981; Hackling and Treagust, 1984). Stewart (1982) developed and validated models of the conceptual and procedural knowledge necessary for the meaningful solution of monohybrid and dihybrid cross genetics problems. A subsequent study of the strategies used by secondary biology students to solve these problems revealed that many successful students followed routine algorithms to solve the problems yet had a poor understanding of the underlying conceptual knowledge (Stewart, 1983).

None of the studies of problem solving in genetics, that have been reported in the science education literature, have attempted to identify the strategies used to solve genetic pedigree problems. Furthermore none of the commonly used genetics texts or teachers' guides recommend a strategy for solving these problems. Pedigrees are a diagrammatic display of the pattern of inheritance of a particular trait within an extended family. Such pedigrees can be analysed to determine the most likely mode of inheritance of the trait, i.e. whether the trait is dominant, recessive or sex-linked.

The purpose of this study was to develop a model of the strategies used by experienced biology teachers and lecturers to solve pedigree problems, from which recommendations might be developed for instruction at the secondary level.

Method

A range of pedigree problems was collected from lower secondary, upper secondary and tertiary level instructional materials. Analysis of the problems revealed that the problem solver is required to determine the most likely mode of inheritance from four possible alternatives - autosomal recessive, autosomal dominant, sex(x)-linked recessive and sex(x)-linked dominant. Each of the possibilities (hypotheses) can be tested by assigning genotypes, based on that particular mode of inheritance, to individuals in the pedigree. If it is possible to assign a genotype to all individuals in the pedigree the hypothesis is shown to be tenable. As there are alternative modes of inheritance, problems can only be solved with certainty by falsifying the alternative hypotheses.

Many of the problems analysed contained key features which were indicative of the most likely mode of inheritance. These features could be used to identify the most plausible hypotheses for testing. The three problems developed for this study contained the following four, most common key features.

Key 1 Both parents are affected and one or more offspring are not affected with the trait. This indicates that the trait is inherited as a dominant feature.

- Key 2 Neither parent is affected yet one or more offspring are affected with the trait. This indicates that the trait is inherited as a recessive feature.
- Key 3 A higher proportion of the male offspring than female offspring is affected with a recessive trait. This indicates that the trait is likely to be inherited as a sex(x)-linked recessive feature.
- Key 4 Neither parent is affected yet a female offspring is affected. This indicates that the trait is inherited as an autosomal recessive, and cannot be inherited as a sex(x)-linked recessive feature.

Table 1 shows the salient features of the three problems used in this study. In the first problem the subjects were only required to determine if the trait was autosomal dominant or recessive. Problems two and three required the subjects to determine if the trait was autosomal dominant or recessive, or sex(x)-linked dominant or recessive.

Table 1
Salient Features of the Three Pedigree Problems

Problem	Trait	Mode of Inheritance	Keys Present
1	Long eyelashes	Autosomal dominant	1
2	Bone disease	Autosomal recessive or sex(x)-linked recessive ^a	2 and 3
3	Nerve disorder	Autosomal recessive	2 and 4

Note: a There was insufficient data provided in this pedigree to distinguish between these two possible modes of inheritance with certainty.

Three experienced biology teachers and two biology lecturers were tape recorded as they worked through the problems. The subjects were encouraged to think-aloud as they worked through the problems with minimal interruption by the investigator as recommended by Larkin and Rainard (1984). To ensure the quality of the data gathered, recordings were limited to concurrent verbalization (Ericsson and Simon, 1980).

The tape recordings, transcripts and the subjects' written answers were analysed in terms of the keys that were recognised and used to hypothesise the most likely mode of inheritance, the extent to which hypotheses were tested by assigning genotypes to individuals in the pedigrees, and with problem two, the evidence used to determine which of the two possible modes of inheritance was most likely.

Results

The results for each problem are presented in separate tables.

Table 2a
Subjects' Responses to Problem One

Subject	Keys used (1)	Hypotheses tested		Answer (AD)
		AR	AD	
Lecturer 1	1	-	-	AD
Lecturer 2	-	2.K	1.C	AD
Teacher 1	M1	2.K	1.C	AD
Teacher 2	1	-	1.K	AD
Teacher 3	-	1.P	2.C	AD

Table 2b
Subjects' Responses to Problem Two

Subject	Keys used (2,3)	Hypotheses tested				Answer (AR or SLR)
		AR	AD	SLR	SLD	
Lecturer 1	2,3	1.P	-	2.P	-	AR or SLR
Lecturer 2	2,3	1.K	-	-	-	AR or SLR
Teacher 1	2,-	-	-	1.K	-	AR or SLR
Teacher 2	2,3	1.P	-	2.P	-	AR or SLR
Teacher 3	-,3	3.C	-	1.C	2.P	AR or SLR

Table 2c
Subjects Responses to Problem Three

Subject	Keys used (2,4)	Hypotheses tested				Answer (AR)
		AR	AD	SLR	SLD	
Lecturer 1	2,M2	-	-	-	-	AR
Lecturer 2	2,4	-	-	-	-	AR
Teacher 1	2,-	-	-	-	-	AR
Teacher 2	2,-	1.K	-	2.K	-	AR
Teacher 3	-, -	1.C	-	2.P	-	AR

Note:

- M1. Misconception 1 - if a high proportion of individuals are affected, the trait is/is likely to be inherited as a dominant feature.
- M2. Misconception 2 - if a trait affects both male and female offspring it cannot be sex(x)-linked.
- 1.C The hypothesis was tested first and was completely tested, i.e. genotypes were assigned to all individuals in the pedigree.
- 2.P This was the second hypothesis to be tested, and was only partially tested, i.e. genotypes were assigned to many but not all individuals in the pedigree.
- 3.K This was the third hypothesis to be tested; it was tested by assigning genotypes to only those individuals that constituted the key feature.

Discussion

All of the subjects obtained correct answers for the three problems which was to be expected as they were routine rather than novel problems. Some subjects recognised and used more of the key features than other subjects, and some of the key features were more frequently recognised than others. Keys 2 and 3 were recognised and used in 80% of cases whereas keys 1 and 4 were only recognised in 40% and 20% of cases respectively.

The keys were used by the subjects to identify the most plausible of the hypotheses for testing. In the case of lecturer 2 solving problem 3 the identification of keys 2 (the trait must be recessive) and 4 (the trait cannot be sex(x)-linked recessive) enabled him to conclude that the trait was inherited as an autosomal recessive feature without having to test any hypothesis; a most efficient solution! By contrast teacher 3 failed to identify key 2 in problem 2, resulting in the sequential testing of three of the four possible hypotheses. The identification and use of the available keys tends to minimise the testing of the less likely hypotheses. If none of the keys are recognised then it is necessary to adopt a less efficient focussing strategy of sequentially testing the four possible hypotheses.

When testing hypotheses subjects tended to test the most plausible hypothesis first and test it to completion by assigning a genotype to every individual in the pedigree. The more efficient subjects then falsified the alternative hypothesis/es by attempting to assign genotypes to only those individuals that comprised the key. These experienced subjects recognised the key as the part of the pedigree where falsification of the alternative hypothesis was not likely to be achieved.

When assigning genotypes to individuals in the pedigree the subjects appeared to follow a standard routine that proved highly efficient. In the cases of autosomal inheritance the first genotypes to be assigned were those for offspring and parents exhibiting the recessive phenotype. Each of these individuals was assigned the homozygous recessive genotype. Next, the parents exhibiting the dominant phenotype had their genotypes deduced from the genotypes of their offspring, and finally the offspring with the dominant phenotype had their genotypes deduced from the genotypes of their parents.

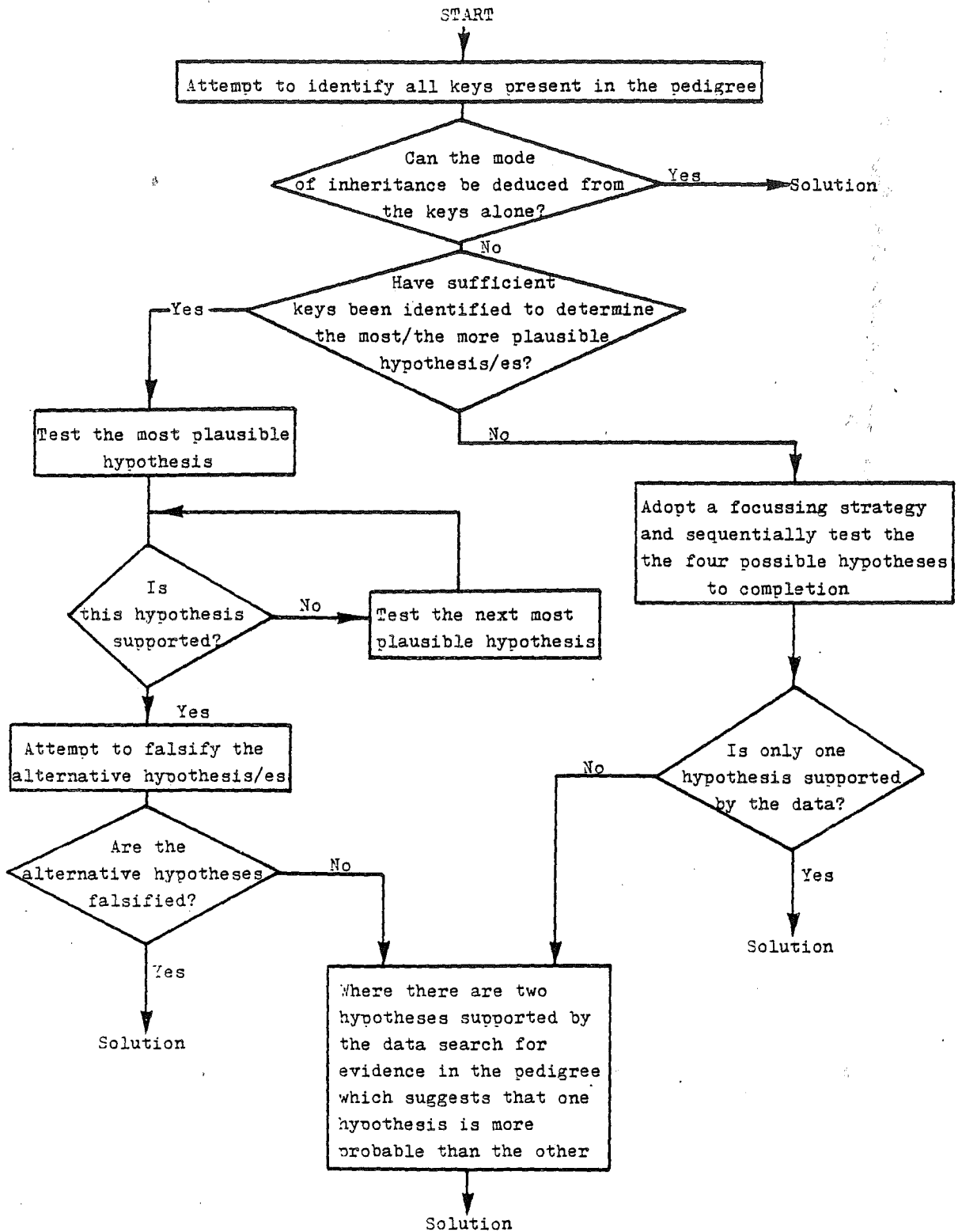
A similar routine was followed for testing sex(x)-linked recessive hypotheses. Genotypes were assigned first to males with the recessive or dominant phenotype and then secondly to females with the recessive phenotype. The genotype of mothers with the dominant phenotype was then deduced from the genotypes of their offspring. Finally the genotype of daughters with the dominant phenotype was deduced from the genotypes of their parents. Both of these routines followed the simple strategem of assigning all those genotypes that could be determined directly from the individuals phenotypes first and then deducing other genotypes from the known information provided in the previous step.

Problem 2 did not provide sufficient information in the pedigree to distinguish between autosomal recessive and sex(x)-linked recessive inheritance with certainty; the data provided in the pedigree supported both of these hypotheses. All of the subjects determined that there were two possible modes of inheritance, autosomal recessive and sex(x)-linked recessive, and then proceeded to provide evidence from the pedigree to show that sex(x)-linked recessive was the most probable of the two possible modes of inheritance. Two of the teachers referred to the presence of Key 3 as an indicator that sex-linkage was the most likely mode of inheritance. One teacher compared the actual phenotypic ratios with that expected for autosomal and sex-linked inheritance and thus concluded sex-linkage was the most likely mode of inheritance. One lecturer noted that the autosomal recessive option would require all three parents to be carriers of the recessive gene for bone disease. This was considered a highly remote possibility making the sex-linkage hypothesis the most likely.

An analysis of the strategies adopted by the five experts reveals a branching solution process as illustrated in Figure 1. This model of the strategies used by experts to solve genetic pedigree problems allows for the different solution paths used by subjects of different levels of expertise, and alternative solution paths appropriate to pedigree problems with one or two modes of inheritance supported by the data in the pedigree.

Figure 1

A Model of the Strategies used by Experts to Solve Genetic Pedigree Problems



Conclusions and Implications

The problem solving behaviour of these expert subjects in solving routine genetic pedigree problems can be represented by four sequential steps.

- 1 An initial perusal of the pedigree to identify key features indicative of the most likely mode of inheritance.
- 2 Secondly, the most plausible hypothesis was tested to completion by assigning genotypes to all the individuals represented in the pedigree to ensure the hypothesis is tenable.
- 3 Thirdly, the alternative hypotheses were tested to a limited extent, in an attempt to disprove the alternative hypotheses and confirm the initial hypothesis thus solving the problem.
- 4 If the data provided in the pedigree was insufficient to distinguish between two alternative hypotheses with certainty, the experts searched for any evidence that could be used to determine which of the two hypotheses was most probable.

Further research needs to be conducted to identify the strategies used by upper secondary students in solving these problems. It will then be possible to identify the instructional procedures that could be used to close the gap between novice and expert performance.

Recommendations for instruction at the secondary level can only be very tentative at this stage but the following instructional sequence would be worth consideration.

- 1 Ensure the students comprehend the genetic concepts underlying pedigree problems and they understand the symbols used to represent the pedigree.
- 2 Teach the focussing strategy of sequentially testing the four possible hypotheses, and ensure that students comprehend the necessity for falsification of alternative hypotheses.
- 3 Once hypothesis testing becomes a familiar routine direct students attention to the most common key features and their use in selecting the most plausible hypotheses for testing.

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THE FOUR PHASE MODEL - PERSPECTIVES OF A NOVICE

John D Rowe

My initial impressions of the model were that it was rather complicated and difficult. It also appeared to be somewhat rigid and inflexible. Despite this it appeared to very neatly crystallize many ideas and practices that had been around for quite a while. Obviously a lot of people had put considerable effort into developing the model, and it was therefore well worth careful study.

Isolated comments from a few students around the college suggested that they found the model difficult and were not convinced that it was very useful. I was rather suspicious of such comments because the same students seemed to have rather negative attitudes about almost anything, and I had already seen some very confident and effective student use of the model.

For a long time now it has been evident that science educators in Western Australia are very successful in communicating to students the need for children's science to be based on material centred activities. We also succeed in developing positive attitudes towards children assuming a central role in enquiring into science. Where we are often less successful is in giving our students a real capacity to help children develop science process skills and to conduct efficient investigations. Our students also tend to conclude periods of practical activity with rather brief and inadequate treatment of data collected by the children, despite the fact that extended discussion and manipulation of data may often be a necessary part of any concept development. The four phase model is designed to deal specifically with these problems.

I first used the model with first year students, doing little more than a verbal description of it, followed by some discussion. I doubt that this achieved anything. Later with second year students I used a fair approximation of the usual methods for teaching the model. That is, students viewed videotape demonstrations done by college staff and by ordinary teachers. The tapes were explained and discussed. The students then did peer teaching with the model and used videotapes of these lessons for strategy analysis in the usual manner. They later had an opportunity to practice the model with

children, but did not do adequate analysis of the practice lessons. Unfortunately no hard data on student reaction to this was collected.

Perhaps because it was difficult to explain tapes prepared by others, and because some of our students appeared to have difficulty in recognizing components of the model we decided to present the model in a different way. That is, we had the lecturer use the model to teach some science to the students. The model was used to introduce a topic, plan an investigation, and to analyze data provided by the lecturer. While teaching with the model the lecturer periodically commented on and explained what was being done. After each phase the students each used the phase in peer teaching and prepared videotapes for later analysis. Following this students then did approximately four hours of work with a small group of children practising the model. This practice was spread over a 4 week period. Most students used the full cycle of the model more than once, and prepared some audio tape for analysis of at least 2 phases.

In preparing the model in this way considerable stress was laid upon the following.

1. The model is used not because it is the only way to teach science, but because it is a very successful way.
2. The normal problems we have in planning investigations and analysing data are best solved by using the model.
3. The technical language of the model should be introduced to children gradually and when appropriate.

Some students displayed considerable ability to forget these points.

The purpose of this paper is not to compare our use of the model with others, but to give some basic description of student reaction to our use.

When the whole process was complete, taking some two hours per week for seven or eight weeks our observations suggested that it was fairly successful. At least our students were doing some excellent work with children. In order to learn more some 80 of the students from 4 different college groups were

given a brief questionnaire to answer. The questionnaire and scores are given as an appendix to the paper. The results are summarized below. The first group of results deals with how difficult the students found the model.

1. Students found it easy to understand our explanations of the phases.
 - Phase One 77%
 - Phase Two 67%
 - Phase Four 74%

2. Remembering the components of the phases and their order was fairly difficult, particularly for Phase Two.
 - Phase One 49%
 - Phase Two 74%
 - Phase Four 58%

3. Preparation of lesson segments for peer teaching was moderately difficult for Phases One and Two.
 - Phase One 45%
 - Phase Two 54%
 - Phase Four 37%

4. Analysis of the videotapes of the peer teaching was difficult for less than half of students.
 - Phase One 32%
 - Phase Two 48%
 - Phase Four 46%

5. About half the students, 49%, found it difficult to get audio tapes of the work with the children.

6. Many of the students, 69%, found it difficult to analyse their audio tapes.

7. A majority of the students, 67%, could stay fairly close to the model when working with children.

Student impressions on how they felt about using the model are given below.

8. 95% of students claimed that they enjoyed using the video equipment.
9. 65% of students enjoyed teaching lesson segments in front of the camera.
10. 65% of students enjoyed presenting lessons to the children in the required form.
11. 75% of students claimed to enjoy work with the four phase model in general.

Student evaluations of the professional value of their experiences with the four phase model and strategy analysis are given below.

12. 79% of students claimed to have learnt a lot from observing the video records of their teaching.
13. 71% of students claimed that the analysis of the phases was a useful exercise.
14. Only about half of the students, 56%, found the analysis of their audio tapes to be useful.
15. 92% of the students considered that their lessons with the children were successful.
16. 88% of students claimed that the work on the model helped a lot in planning lessons for the children.
74% made the same claims for planning investigations and 66% for analysing data with the children.
17. Some 83% of students considered the four phase model to be a valuable basis from which to develop skills in teaching science to children.
18. 92% of students felt that it is important to have a basic model for the teaching of any subject.

Very few of the students gave significant narrative comments. Such comments tended to be more frequent from those students with less favourable

attitudes towards the model, and were mainly concerned with the difficulties of using the model and with the time we spent on the model.

SUMMARY

In general students found learning to use the four phase model and applying strategy analysis to it fairly difficult. They also enjoyed the work and considered it to be professionally useful. The impressions gained of the whole process tended to be more favourable than those gained about particular aspects. A minority of students were not favourably disposed towards the work.

APPENDIX

QUESTIONNAIRE

4 PHASE TEACHING MODEL AND STRATEGY ANALYSIS

This questionnaire is designed to produce information about the 4 phase model that will enable us to compare different ways of presenting and learning the model. Our objective is to make it easier to learn and use the model effectively.

Instructions

Draw a line through the symbol that best fits your reaction to the statement made below.

SA = strongly agree
A = agree
D = disagree
SD = strongly disagree

There are no right or wrong choices.

1.	I found it easy to understand the lecturers explanation of:				
		SA	A	D	SD
(a)	Phase One	9	50	18	-
		73%		23%	
(b)	Phase Two	8	43	23	2
		67%		33%	
(c)	Phase Four	14	42	19	1
		74%		26%	
2.	It was difficult to remember the components and their order in:				
(a)	Phase One	8	31	35	5
		49%		51%	
(b)	Phase Two	14	42	19	1
		74%		26%	
(c)	Phase Four	11	35	27	7
		58%		42%	
3.	For the peer teaching it was difficult to prepare the lesson segments for:				
(a)	Phase One	7	28	35	8
		45%		55%	
(b)	Phase Two	9	34	32	5
		54%		46%	
(c)	Phase Four	7	22	40	10
		37%		63%	
4.	I enjoyed using the video equipment.	42	32	4	-
		95%		5%	

- | | | | | | |
|-----|--|----|-----|----|-----|
| 5. | I enjoyed teaching the lesson segments in front of the camera. | 7 | 47 | 16 | 8 |
| | | | 69% | | 31% |
| 6. | I learnt a lot from observing the video record of my teaching. | 27 | 37 | 15 | 1 |
| | | | 80% | | 20% |
| 7. | I found it difficult to do the analysis of the video records of my lesson segments. | | | | |
| (a) | Phase One | 5 | 20 | 42 | 12 |
| | | | 32% | | 68% |
| (b) | Phase Two | 10 | 28 | 29 | 12 |
| | | | 48% | | 52% |
| (c) | Phase Four | 7 | 29 | 31 | 12 |
| | | | 46% | | 54% |
| 8. | The analysis of the phases was a useful exercise. | 4 | 52 | 20 | 3 |
| | | | 71% | | 29% |
| 9. | The four phase model helped me a lot in planning the lessons that I taught to children. | 21 | 47 | 8 | 1 |
| | | | 88% | | 12% |
| 10. | My lessons with the children were generally successful. | 10 | 62 | 6 | - |
| | | | 92% | | 8% |
| 11. | I did not enjoy presenting the lessons in the required form. | 3 | 24 | 42 | 9 |
| | | | 35% | | 65% |
| 12. | I could not stay fairly close to the model when working with children. | 3 | 23 | 46 | 7 |
| | | | 33% | | 67% |
| 13. | The model really helped me in planning investigations. | 16 | 41 | 19 | 1 |
| | | | 74% | | 26% |
| 14. | The model did not really help in analysing data with the children. | 3 | 23 | 46 | 5 |
| | | | 34% | | 66% |
| 15. | I found it difficult to get audio-tapes of my work with the children. | 14 | 30 | 27 | 8 |
| | | | 49% | | 51% |
| 16. | It was easy to analyse my audio-tapes. | 3 | 21 | 37 | 16 |
| | | | 31% | | 69% |
| 17. | The analysis of the audio-tapes did not tell me a lot about my teaching with the children. | 9 | 33 | 35 | 5 |
| | | | 44% | | 56% |

18. In general I did not enjoy the work with the 4 phase mode.
- | | | | |
|---|-----|----|-----|
| 3 | 16 | 42 | 15 |
| | 25% | | 75% |
19. The four phase model is a valuable basis from which to develop skills in teaching science to children.
- | | | | |
|----|-----|----|-----|
| 14 | 46 | 11 | 1 |
| | 83% | | 17% |
20. It is important to have a basic model for the teaching of any subject.
- | | | | |
|----|-----|---|----|
| 20 | 51 | 6 | + |
| | 92% | | 8% |

In the space below make any comment about the Four Phase Model and Strategy Analysis that you think is relevant.

A NEW DIRECTION TO TEACHING PROBLEM SOLVING IN PHYSICS

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INTRODUCTION

In any Physics course the teaching and learning of problem solving is one of the main aims. If attention is directed to virtually any Physics text book, the format for teaching problem solving follows a rigid pattern with little or no variation.

Generally a principle is given, then the principle is discussed. This is followed by examples of the principle together with worked problems. At the back of the chapter a set of numerical problems on the principle is given to the student for practice.

Such problems are not without their critics. According to Mann (1981) they test two things, simple drill in numerical calculations and recall of laws and experiments. Many are on level one (knowledge) of Bloom's (1956) taxonomy scale. Lawson and Wollman (1975) are just as harsh and say typical problems require students to apply an equation or sometimes two or three equations to obtain an answer. Students soon learn that discovering the correct equation is the way to success. This sort of high order matching process often involves little thought.

Of course one can argue that such problems are useful for the following reasons.

1. The student is made familiar with scientific terminology, units and magnitudes of these units.

2. The student is exposed to practice in the manipulation of the relevant formulae for physical principles and sees where they can be used.
3. The student is given a feeling of satisfaction that he/she understands the principle because the correct numerical answer to a problem has been calculated.

In general, problem solving follows this format.

1. One or more sentences containing numerical quantities and explanation set the physical situation and pose the problem.
2. The student selects and uses one or more equations and substitutes values into these equations.
3. Solving the equations usually leads to a unique or single valued numerical answer.

The direction of the problem solving as shown previously is from steps 1 to 2 to 3.

A MODEL FOR VARYING THE PROBLEM SOLVING DIRECTION

The Education Department of South Australia (1977) have devised a model for varying the approach to teaching problem solving in laboratory work.

This model has been adapted here for use with numerical problems. The model may be described as follows.

Let P stand for the problem or question,

M stand for the method of solution,

A stand for the answer.

A table can now be drawn to show the variations.

P = problem given

\bar{P} = problem not given

M = method given

\bar{M} = method not given

A = answer given

\bar{A} = answer not given

These letters are used with reference to the student.

	Variation	Example
1.	P M A	The problem, method of solution and answer are given.
2.	P M \bar{A}	The problem, method of solution but not the answer are given.
3.	P \bar{M} A	The problem and answer are given but not the method of solution.
4.	\bar{P} M A	The method of solution and answer are given but not the problem.
5.	P \bar{M} \bar{A}	The problem is given but not the method of solution or answer.
6.	\bar{P} \bar{M} A	The answer is given but neither the method of solution nor the problem is given. Such a variation may not exist.
7.	\bar{P} M \bar{A}	A theory or technique exist but no problem or answer is given.
8.	\bar{P} \bar{M} \bar{A}	The problem, method of solution and answer are not given. This may be interpreted as encouraging student questions.

Problem Examples

Examination of the table shows that variations P M A and P M \bar{A} are normally used in classroom teaching.

Variation P \bar{M} A is exemplified by Lawson and Wollman (1975) in their

problem set.

P M A Two thin identical convex lenses each of focal length 20cm are placed together. The effective focal length is now 10cm. Write an equation that gives the focal length of a lens combination that consists of two lenses having identical focal lengths.

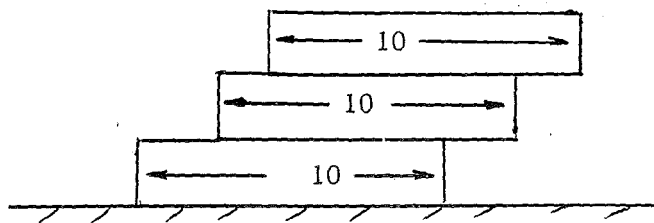
One of the 20cm focal length lenses is replaced by one having a focal length of 5.0cm. The focal length of the resulting combination is measured to be 4.0cm. Write an equation that can be used to calculate the focal length of a lens combination that consists of two lenses of unequal focal lengths.

Now check your two equations. If you believe they should be the same, try to reduce the two situations to one equation.

P M A The answer to a problem is 4.56N. Write out the question and show your method of solution.

As a rider the student may be directed to gravitational, electrostatic, frictional forces etc...

P M A For the three bricks shown determine the toppling behaviour.



P M A If $F = ilB$ pose a problem and determine the answer. Discuss the limitations of this equation.

Conclusion

Many Physics problems involve not much more thought than the selection and manipulation of equations. There are three parts to such problem solving namely the posed problem, the method or technique of solution and the numerical answer. Generally a student is posed the problem, is familiar with the technique of solution and uses this to find an answer.

There is no need to follow this direction always. Other directions should be tried e.g. if the solution method is known, then supply the numerical answer and ask for the problem to be posed.

Such direction variations may develop a better understanding of the principles of physics, the limitations of equations and the problem solving technique.

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ULTRAVIOLET LIGHT, THE EXCITING DETECTIVE

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ABSTRACT

Ultraviolet light causes inherent or reagent induced fluorescence in many substances and this property can be exploited in a variety of ways in the science classroom. For the lower school science teacher or geology teacher U V-light offers a quick method of mineral identification and can be used to introduce the concepts of atomic, molecular and crystal structure. The physical science teacher can use U V-light to demonstrate fluorescence and phosphorescence and to catalyse some photochemical reactions. However a U V - lamp finds its greatest application in the biology classroom where it can be used to demonstrate gene dosage effects, banding patterns on chromosomes, photosynthetic pigments, the capture-recapture technique, the mutagenic effect of short-wave U V - light, the effects of mutations on biochemical pathways and the structural arrangement of base pairs along the long axis of the DNA helix. Demonstrations of all the above applications will be presented.

INTRODUCTION

The study of the interaction of electromagnetic radiation with matter has been an inexhaustible mine of information throughout this century. The portions of the spectrum most useful in studying molecular structure are the ultraviolet, visible and infrared regions although recent improvements in measurement of the energies of electrons excited by either X-rays or micro-waves has also started to yield information about the electronic structure of atoms and molecules. Figure 1 shows the electromagnetic spectrum.

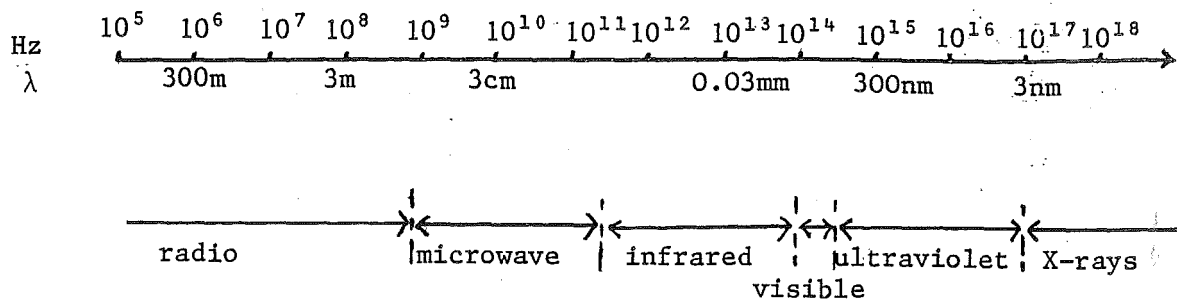


Figure 1. The electromagnetic spectrum.

Visible light and ultraviolet light cause the excitation of outer electrons in atoms and molecules which results in measurable changes to the atoms or molecules. For example the absorption spectrum of chlorophyll in the visible spectrum shows that chlorophyll absorbs light with wavelengths corresponding to the colours red and blue. Thus we can assume that chlorophyll extracts from sunlight the photons corresponding to these colours. Photons of light carry a lot of energy (about 260 kJ mol^{-1} for blue light photons) however they do not pack as big a wallop as the U.V. photon whose energy is of the order of $10,000 \text{ kJ mol}^{-1}$. As a result U.V. light can cause some dramatic changes to atoms and molecules and these can be used in the science classroom to demonstrate a wide range of physical, chemical and biological phenomena. In practice, the wave lengths of U.V. light most useful are 254 nm (short wave length) and 366 nm (long wave length). Commercially available lamps are either dual wave length models or whole range emitters with the majority of photons emitted at the long wave length. More expensive models with camera attachments and special viewing boxes are also available.

METHOD

When using an ultraviolet light source it is important not to expose eyes to direct U.V. emissions. Long wave length is not nearly as hazardous as short wave length ultraviolet light which can cause eye irritation and retina damage in cases of severe over-exposure. Viewing through ordinary household glass completely eliminates the risk of eye damage and is therefore a sensible precaution. In this display eight uses of ultraviolet light are presented. A brief explanation and the methods used to prepare each item are detailed below.

FLUORESCENCE AND PHOSPHORESCENCE

U.V. photons excite the outer electrons of some atoms and molecules to higher energy levels. Fluorescence occurs if these electrons immediately return to their original energy levels by emitting the absorbed energy as light. When a substance continues to emit light after exposure to radiation has ceased it is said to phosphoresce.

Phosphorescence is due to a delay in the atomic lattice energy levels returning to normal. Many substances fluoresce, particularly if they are placed under both short and longwave U.V. radiation. Examples include Hi-lite pens, burn cream, washing powder, some paints and plastics, many common chemicals and, of course, fluorescein. Fluorescein is a good substance with which to demonstrate the process of fluorescence because it fluoresces so dramatically, however washing powder is perhaps a more interesting example because it deliberately uses the principle of fluorescence to make white garments look "whiter than white". Contained in many washing powders are U.V. absorber/white light emitter chemicals to such an extent that some blue washing powders look brilliant white under U.V. This is why white cotton looks so white under U.V. light.

Phosphorescence is less common than fluorescence but can be demonstrated with a "Moonlighter Frisbee". Aragonite is a phosphorescent mineral which can also be used to demonstrate this process. We have tried unsuccessfully to make two phosphorescent plastics, perspex (polymethyl methacrylate) doped with the phosphorescent compounds triphenylene or naphthalene. In both cases we had trouble achieving polymerisation and suggest that the methyl methacrylate monomer should be distilled at 101°C (no flames) to get rid of polymerisation inhibitors before either naphthalene or triphenylene are added. 10 mg of triphenylene or naphthalene should be added to 20 ml distilled methyl methacrylate and incubated at 60°C for two days and then at 80°C for a further two days.

MODEL MAKING

U.V. models can be made as interesting teaching aids or as a means of demonstrating some U.V. phenomena/application which normally requires expensive equipment. The model of sodium chloride was made by painting polystyrene spheres with fluorescent paints (available in hobby shops) and then by gluing them together to represent the crystal structure of salt. The visual impact of U.V. crystal models helps students understand stereo-chemical arrangements. The second model, depicting human chromosomes, not only has visual impact but also demonstrates an important principle of microscopy which revolutionised the science of cytogenetics. When a self luminous object is viewed under a microscope the resolving power of that microscope is doubled, thus the clarity and magnifications achieved are considerably improved. Biologists interested in chromosomes developed the ultra-violet microscope and fluorescent stains to exploit this principle and have subsequently greatly developed the science cytogenetics. The model presented here is made from computer card soaked in quinacrine dihydrochloride which is the most commonly used fluorescent chromosome stain. The clarity of chromosome bands under U.V. light can be seen by viewing the model under normal and U.V. light.

MINERAL IDENTIFICATION

A kit of fifteen fluorescent minerals can be obtained from Selbys Scientific Ltd. These should be viewed under both short and long wave length U.V. light to confirm their identity. A list of fluorescence colours is given on the inside of the lid of the kit.

PHOTOSYNTHETIC PIGMENTS

Photosynthetic pigments can be extracted from the photosynthetic parts of plants by grinding these parts up in a mortar and pestle with some acetone. In practice it is best to work with soft dark green tissues such as the leaves of nettle or lantana. The extract obtained in this way will appear very green in ordinary light but appears blood red in U.V. light. This occurs because the extracted photosynthetic pigments still absorb photons but can no longer channel this absorbed energy into the photosynthetic process. As a consequence some of the absorbed energy is released by means of red fluorescence.

For further investigation of photosynthetic pigments a thin layer chromatogram

(T.L.C.) can be prepared by spotting the acetone extract on to the bottom of a T.L.C. plate, and developing with a 4:1 acetone/petroleum ether solvent. When a developed plate is viewed under U.V. light it is possible to identify up to six photosynthetic pigments. Although it is just possible to make out most of these pigments in ordinary light, U.V. viewing makes calculating their Rf values much easier.

BIOCHEMICAL PATHWAYS AND GENE DOSAGE EFFECTS.

The fruit fly Drosophila sp. normally has brick red eyes due to the presence of brown and red pigments in its ommatidia. The red colour is caused by a family of fluorescent pigments called the pteridines. Their identity and close biochemical relationship has been established by combining thin layer chromatography with U.V. examination. Although this sounds complicated the process is simple and involves only three steps, the first of which is to decapitate 10 thoroughly etherised Drosophila. Once these have been ground up in 0.01 M NaOH with the aid of a pin head, a spot of this suspension is placed on to the bottom of a thin layer chromatography plate and developed with 2:1 propal-1-ol/1% NaOH solvent. When viewed under U.V. light this chromatogram appears similar to the line diagram in Figure 2(a). This shows that there are at least 8 pteridines synthesised in the fly's eye.

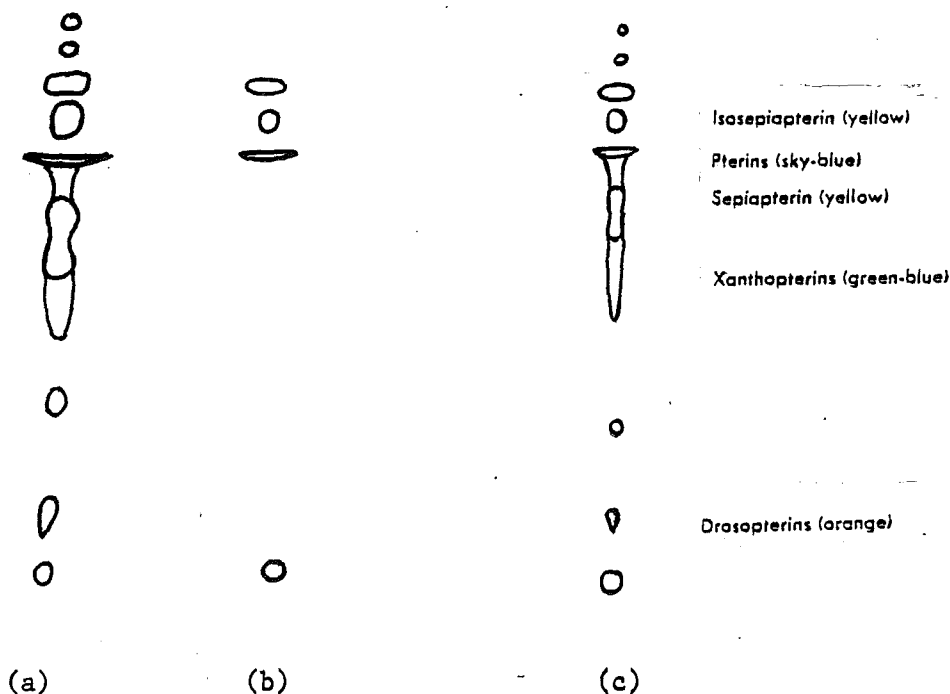


Figure 2. (a) Fluorescent pteridines in the eye of a wild type fly (bw+/bw+) (b) pteridines in the eye of a brown eyed mutant fly (bw/bw) (c) pteridines present in the eye of a fly heterozygous for pteridine synthesis (bw+/bw)

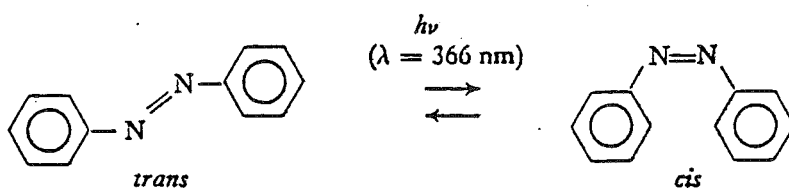
Figure 2 b shows the pteridine pigments present in a mutant fly which has brown eyes (bw/bw). It is quite obvious that this fly has a block in its pteridine synthesis pathway and is only able to synthesise 3 or 4 pteridines. Since it is unable to convert these pigments into related pteridines it has no red pigment in its eyes and therefore they appear brown. Figure 2c shows the TLC chromatogram of the eyes of the progeny of a cross between normal red eyed wild type flies (bw+/bw+) and brown eyed flies (bw/bw). These progeny are all heterozygous (bw+/bw) and since they have only half the number of genes for red pigment production as the wild type, fly they produce approximately half the amount of pteridines as the wild type. It is impossible to tell the difference between wild type (bw+/bw+) flies and heterozygous flies (bw+/bw) by simply looking at them however a comparison of Figures 2a and 2c shows that heterozygous flies produce only half the amount of pteridines of the wild type. Thus U.V. light in conjunction with TLC can be used to demonstrate the effect of gene dosage at the biochemical level.

MUTAGENIC EFFECTS OF SHORT WAVE LENGTH RADIATION U.V.

High energy short wave-length U.V. photons cause pyrimidine dimers to form in DNA. Since normal base pairing in DNA involves a purine and a pyrimidine the net result of short wave length U.V. radiation is to induce mutations. Bacteria are particularly sensitive to the mutagenic effects of U.V. radiation and can be used to demonstrate the phenomena and to isolate a wide range of mutants. The demonstration plates show E. coli growing on eosin methylene blue (EMB) plates which contain lactose as the only fermentable source of carbon. Plate 1 shows wild type E. coli growing on EMB plates and it can be seen that the colonies have a dark maroon appearance. This is due to a reaction between the waste product of lactose fermentation, lactic acid, and the indicator in the plate eosin methylene blue. On plate 2 there are fewer colonies because these bacteria have been exposed to short wave-length U.V. radiation for 1 minute and some of them have sustained lethal damages. However you will note that there is one pink colony on the plate which cannot ferment lactose but can grow on other non fermentable carbon sources available. Its gene (operon) for lactose fermentation has been damaged by exposure to U.V. radiation. A large number of bacterial mutants can be generated in this way and by performing genetic crosses between different mutant strains it has been possible to map the bacterial chromosome.

PHOTOCHEMICAL CATALYSIS

Trans-azobenzene can be induced to partially isomerise to the cis form when irradiated with ultraviolet light.



To achieve this isomerisation dissolve 100 mg of trans-azobenzene in 10 ml of petroleum ether and spot this onto the bottom of two TLC plates. Expose one plate to a U.V. source for 30 minutes while the other is kept in the dark. Develop both plates in the dark with petroleum ether and view in ordinary daylight. The plate exposed to U.V. radiation will show two spots, one corresponding to trans-azobenzene and one corresponding to cis - azobenzene. The other plate has only one spot corresponding to trans - azobenzene.

DNA VISUALISATION

Gene Link Australia Ltd, South Melbourne market a DNA kit (\$28) which permits the isolation and visualisation of DNA. To see the DNA more clearly it is stained with a fluorescent stain propidium iodide. This is a flat intercalative dye which fits between the flat base pairs of the DNA helix so that when it is viewed under U.V. light it glows like "a ladder of fire". We have had limited success with this demonstration.

CAPTURE-RECAPTURE TECHNIQUE

The capture-recapture technique of population size estimation is based on the principle that number of previous captured organisms expressed as a fraction of the total number of organisms caught in any sample can be used to estimate total population size. However, problems of sampling bias can reduce the accuracy of the technique if the mark to indicate previous capture is visible to the experimenter. They do not know whether to avoid or collect marked organisms and often juggle the number of marked organisms to what they think is about right. Problems of sampling bias can be overcome by marking organisms on their dorsal surface with a fluorescent paint or ink which is undetectable in ordinary daylight.

CONCLUSION

Ultraviolet light sources are valuable teaching aids for science teachers. Apart from the uses listed here there are numerous other applications which range from visualising immuno-precipitation reactions to distinguishing between a free range egg and a battery egg. Whatever its application the visual impact of a U.V. demonstration guarantees student interest and attention.

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SECONDARY SCIENCE LABORATORY INVESTIGATIONS

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There is no doubt that the laboratory activity has been a distinctive feature of science courses for many years. This has certainly been so in Western Australian schools and laboratory activities are likely to be viewed by science educators as an integral part of secondary science in the foreseeable future. Tamir and Lunetta (1981) stated that the new science curricula of the 1960's were united in the view that the main purpose of the laboratory was to "convey the method and spirit of scientific inquiry, to provide students with opportunities to investigate, to inquire and to find out things for themselves." They noted that this emphasis was in marked contrast to using the laboratory primarily as a place to illustrate, demonstrate, and verify known concepts and laws. A similar emphasis was incorporated into guidelines for science teachers in Western Australia. The Science Teachers' Handbook stated that "... laboratory problems arise from accidentally or deliberately engineered situations in the classroom ... [that allow students] ... to recognize and state a problem, to design and carry out controlled experiments, to organize information and identify regularities, to formulate theories and to evaluate evidence and draw conclusions." (p B5.1). If implemented in an appropriate manner that coordinates laboratory activities with the development of science content, the laboratory appeals as an ideal means of actively involving students in the learning process. According to Hofstein and Lunetta (1982), appropriate laboratory activities could be effective in promoting intellectual development and developing some inquiry and problem solving skills. Further, they claimed that laboratory activities could assist in the development of some observational and manipulative skills and in understanding science concepts.

Evidence from the USA and Israel suggests that, with respect to laboratory investigations, the implemented curriculum was not a reflection of the intended curriculum. For example, Hurd (1969) commented that "from the fragmentary data available it appears that the importance of enquiry-oriented laboratory investigations described in the literature is not extensively reflected in teaching practices." Tamir and Lunetta suggested that the discrepancy between stated objectives and classroom practice could be attributable to a teacher preference to run smooth demonstration and verification type laboratories. They suggested that another reason could be related to the nature of the laboratory exercises presented in teacher guides and student manuals. This latter view received some support in an investigation of inquiry related tasks in laboratory handbooks. Tamir and Lunetta (1981) noted that seldom, if ever, were students asked to formulate a question to be investigated; formulate an hypothesis to be tested; predict experimental results; work according to their own design; formulate new questions based on investigations; and apply an experimental technique based on investigations just completed. There is no doubt that text materials do have an influence on the implemented curriculum, however, local school variables are also likely to have an important influence on the manner in which the curriculum is implemented. Science laboratories are among the most demanding of science activities since the organization of equipment and students provides a real challenge to the most experienced science teachers and implementation presents the teacher with numerous instructional and managerial challenges.

PURPOSE

The purpose of this study was to investigate the nature of laboratories in grades 8 to 11 in Western Australian schools. The focus for the study was on the instructional and managerial behaviours of the teacher and on the task involvement of learners in laboratory oriented

science activities.

METHOD

Sample

The sample consisted of 15 science teachers and students in science classes in years 8 to 11 in two co-educational high schools in the metropolitan area of Perth, Western Australia. The students were from homes of low-medium socio-economic level families.

Design

Two trained observers visited five year 8 classes during a three week period. The observers were scheduled to observe each class for approximately the same number of lessons with each class being observed for a total of approximately eight to twelve lessons. Narrative records were taken during each lesson to provide a descriptive summary and time log of the activities and the nature of the interactions that occurred. Efforts were directed toward identifying the students who participated in the interactions and categorizing the cognitive level of the interactions. The study was then replicated with students and teachers of: year 9 and 10 science; and of year 11 physics, chemistry, biology and human biology. The study extended for approximately ten weeks during second term of 1984. At the end of this time the study was extended to a second school. Two additional trained observers were involved in data collection and interpretation.

Following each lesson the observers formulated hypotheses that were consistent with data collected to that point in time. These hypotheses provided a focus for observation in subsequent lessons and were retained, refined or discarded on the basis of further observations. Two hundred lessons comprised the database for this investigation.

RESULTS AND DISCUSSION

Group Structure

At all year levels teachers tended to implement science activities in a way that resulted in the academic work being completed. The predominant group structure involved the teacher interacting with the class as a whole. In this setting teachers were able to involve students while retaining a high level of control over the pacing of the lesson. Less frequently, the teacher lectured or demonstrated to the whole class in a non-interactive style. This usually occurred as the teacher introduced new content and attempted to clarify certain concepts. This procedure was also adopted when the teacher was short of time and needed to take control in order to get the work done.

Individualized activities were common in all classes, particularly seatwork activities in which students copied notes from the board, summarized material from the textbook and completed worksheets and textbook exercises.

Small group activities tended to occur when data were collected during laboratory investigations in years 8 to 10. Less frequently small group discussion activities were scheduled.

Scheduling of Laboratory Activities

The amount of time allocated to laboratory investigations is obviously topic dependent. For example, a year 10 class studying introductory chemistry has more scope for laboratory investigations than a year 10 class studying astronomy. As an example of the manner in which teachers distributed time to laboratory activities the following details are provided for Ken Joseph, one of the participating teachers. Mr Joseph was observed in four classes: A year 9 advanced class working on Introductory Chemistry and Insects topics; a year 9 basic class working on the Astronomy and Insects topics; a year 8 heterogeneous group working on the topic Mechanics; and a year 11 Biology class. During every observed

lesson the year 9 advanced students were provided with opportunities to participate in laboratory activities. The total time allocation for laboratory activities was 42%. In the case of a heterogeneous year 8 class 42% of the time was also allocated to laboratory activities. In contrast, no time was allocated to laboratory investigations in the year 9 basic class. Similarly, no time was allocated to laboratory activities in year 11 Biology. In an interview with Ken Joseph he commented that there was much more work in laboratory classes nowadays. He tried to involve students in some laboratory work each day and estimated that up to 25% of the science time was allocated to laboratory activities. He also stated that there was more scope for laboratory work with advanced level students because of their superior independent study skills compared to basic level students. These views were representative of the interview data obtained from all teachers. Another factor that possibly contributed to the failure to schedule laboratory activities for the basic level class was the difficulty experienced in controlling the behaviour of many students in the class.

Analysis of the teacher interviews suggested that laboratory activities were viewed as an optional extra rather than an integral part of the course. The perceived need to have more time to complete the theoretical parts of courses resulted in less time being available for laboratory work. This was particularly the case in year 11 physics and chemistry courses where demands of the Tertiary Admissions Examination provide greater incentive for teachers to cover the course content. This finding tends to highlight the gulf between the content and laboratory components and stands in stark contrast to the recommendation that laboratory activities "should be closely correlated with classroom activity (Education Department of Western Australia, 1974).

The teacher interview data provided insights into other deterrents to

laboratory work. Science was often timetabled into regular classrooms and in some instances into the library. In most cases these alternative rooms were not conducive to laboratory activities. This was so for several reasons. The first and possibly the most important reason was the lack of a suitable surface on which to manipulate equipment with safety. Because of the lack of water, gas and other facilities that are usually standard fare in a science laboratory, practical difficulties were faced by teachers timetabled to teach science in a non-science specific room. An additional obstacle was the relative distance of some of these rooms from the equipment store and the laboratory assistant. Thus the provision of materials and the return of used materials was more difficult than is the case in most science laboratories.

Purpose of Laboratory Work

The purpose of laboratory work was difficult to infer from the observational data. The major problem with laboratory activities was that they did not appear to be a part of the ongoing science programme. Rather they seemed to be an appendage to the programme; a frill that was necessary, but did not contribute to the knowledge to be learned. Laboratory activities were perceived as a required part of the work to be completed and were treated accordingly. In several classes laboratory work appeared to be a privilege. For example, in one class, two students were required to complete textbook exercises while the remainder of the class conducted the laboratory exercises. Towards the end of the double period the teacher approached a boy in the class and instructed him to allow the two boys to copy his laboratory notes because they had not done today's experiment. In this class it appeared that the important thing was to complete the write up. This did not always appear to be the case. One teacher was obviously interested in students participating in laboratory exercises. Students were given long periods of time to participate and were encouraged to stay on task. In other classes the

teacher tended to move about the laboratory from group to group assisting students who were trying to complete the work and motivating others who were more inclined to off task behaviour.

The laboratory activities observed in this study tended to make low demands on the students in terms of cognitive effort and the pacing was usually left entirely to the students. Students could decide whether to work at a quick pace, a slow pace, or not to work at all. A consequence of such an organizational pattern was that the pace of the activity was determined by the slowest students in the class. Few attempts by the teacher to hasten task completion were observed. The activities themselves tended to be entirely based on a recipe. The planning and interpretation parts of the activity left little room for student thinking or diversity. Usually the activity was implemented in a manner that provided students with a set of procedures to follow and the headings under which to complete the write up. Of course there were some variants on the theme. In one class selected students were invited to provide the procedures. For most students, however, the result was just the same; they followed a recipe that was provided by someone else.

In all classes students had laboratory books that were required to be completed and were marked as a part of the science assessment. There was no doubt in any of the classes that the experiments were to be written up in the prescribed manner. The important component of the task seems to be the completion of the writing up of the experiment. The interpretation of results was dealt with in a somewhat different manner in each of the classes. However, several points appeared to be common across the observed classes. Students could get assistance from others in the class. In some cases the teacher actually wrote the correct interpretation on the blackboard, on other occasions the correct interpretation was dictated, in some cases target students provided the correct interpretation that was

vetted by the teacher and then copied into student notebooks. Only in one class was the task left entirely to the students. In this class a student was heard to ask the teacher: How much room should I leave for the results? The teacher replied: "In my class we always leave four lines for the results and three lines for the conclusion."

Another interesting example involved a year 10 advanced class that had collected data on the speed of sound on the school oval. On their return to the classroom the teacher endeavoured to discuss the results of the investigation. However, the students did not cooperate at all. The usually cooperative class were unruly and hindered the teachers efforts to conduct a useful discussion. Accordingly, the teacher cut short the discussion and commenced another field based activity. Immediately the students became cooperative. It seemed that the interpretation activity, which was cognitively demanding, was not what the students were interested in doing. As a consequence, they did not assist the teacher to extend the activity. When the teacher introduced another activity enthusiasm returned and student behaviour returned to normal.

Management of Time

Another paradox was evident in the pacing of many laboratory sessions. Whereas seatwork and whole class activities were usually paced by the teacher, laboratories were usually paced by the students. Students appeared to know that the entire period of time was set aside for laboratory activities and they worked at a pace that allowed the work to be completed in the allocated time. As a consequence, most laboratory sessions were usually characterised by a leisurely pace with students off task for extended periods of time.

Two extremes were commonly observed in laboratory activities. The first and most common involved teachers allocating an entire double period of time each week for practical work. The students knew that this amount of time had been allocated and made no attempt to complete the work inside

the allocated time. In fact the time appeared to be used almost exclusively for collecting and recording data. Often the interpretation was left until the next period, at which time it was completed in a whole class interactive mode. The second extreme involved teachers who spent almost an entire period reviewing the procedures that students should follow, leaving very little time for students to actually implement the activity. Perhaps the worst example of this involved a year 10 class on an excursion into the school grounds to collect insects. Eight minutes were allocated for the field trip. During this time students socialized to a marked extent and collected a number of animals, very few of which were insects. A short discussion about the characteristics of insects followed their return to the classroom.

A distinction needs to be made between self paced activities where the student paces his own engagement, teacher paced activities in which the teacher controls the rate at which students engage in the learning tasks and off task behaviour. In the latter case the student elects not to engage in the learning tasks. Many examples of the latter category were observed in this study. Students simply opted to be off task for extended periods of time. As a consequence, many students took a long time to complete most of the laboratory activities. However, when they were engaged the students tended to complete the assigned tasks relatively quickly.

Rule Structure

The rule structure for laboratory activities tended to be different to that in operation in other classroom settings. Whereas seatwork and whole class activities had clearly defined rules, the laboratories were conducted in groups that appeared to have a set of rules that was considerably different and not as clearly defined or understood by the students. In seatwork and whole class activities students were not

allowed to move about the room or speak loudly to others. Obvious inattention was not permitted. In contrast, in laboratory sessions students frequently moved about the room, called out to others on the other side of the room and engaged in off task activities for lengthy periods of time. The style of off task activity was often disruptive.

It was evident from the observations that students had at least two agendas that governed their behaviour during laboratory activities. The first of these was an agenda to complete the assigned work within the rule structure that governed academic work and task involvement and the second was a social agenda that resulted in almost constant interaction with others about a wide range of matters that were not related to the laboratory investigation. In most instances the cognitive demands of the laboratory activities were such that it was possible to complete the work and socially relate to peers. In some instances, however, off task behaviour was disruptive and prevented students from engaging in the learning tasks. The incidence of such behaviours resulted in many students engaging in an intermittent manner that contributed to a slow pace of laboratory activities. Disruptive off task behaviours were often related to misuse of equipment or to students physically interacting with others as they moved about the classroom. Differences in participation were observed for males and females in laboratory exercises in years 8 to 10. Males tended to be more involved with the equipment. This seemed to be true whether the classes utilized single sex groups or mixed sex groups. It was not uncommon to observe females standing back from the activity while the males manipulated the materials.

IMPLICATIONS

Teachers have a lot on their mind as they implement a laboratory activity. As they move from group to group it is necessary to monitor the engagement of students within the group in a diagnostic sense and at the same time to monitor the behaviour of the class as a whole in a managerial

sense. In addition, there are concerns that relate to the use of equipment in each of the groups. It is not surprising that teachers should find laboratory activities challenging and it is not surprising that some student-student interactions should pass unnoticed. For most teachers the task of self diagnosing strengths and weaknesses evident in laboratory activities would be too demanding. In order to improve the quality of laboratory activities it is probably necessary to alert teachers to the results of these research findings and to provide them with feedback on their own instructional and managerial performance in laboratory activities. The best way to obtain the data to provide feedback to teachers is probably to invite a colleague to make observations of the type used in this study. In this way teachers could assist one another to improve the quality of teaching and learning in laboratory activities. Some thought could be given to the instructional leadership role of the senior master in assisting teachers in science departments to analyze one another's lessons and to provide coaching in order to effect change.

The results of this study indicated that there is a clear need for science curriculum personnel to review the science curriculum materials provided and recommended for use in secondary schools. The recipe approach to laboratory activities has been well documented and is a continuing problem that is in conflict with the guidelines provided in the Science Teachers' Handbook and the objectives of most contemporary secondary science curricula. Curriculum reform is essential if laboratory activities are to be substantially improved in a system that seems so reliant on texts and resource materials.

Science educators associated with preservice personnel need to ensure that their students are familiarised with the outcomes of this research and that they develop the skills needed to plan and implement appropriate

laboratory activities. Particular attention should also be directed to the selection of supervisory teachers for field experience programmes. Care should be taken to ensure that effective role models are provided and that students are given opportunities to practice the skills developed in their preservice course.

There are also implications for further research. This study has involved two schools and 15 teachers. Follow up studies to be conducted in order to learn more about teacher and student behaviour in laboratory activities. The power of the methodology used in this study is in the number and variety of hypotheses that evolve as the study progresses. Replication and extension studies are needed to increase the generalizability of the findings.

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WHY DOES THE POINT OF EDUCATIONAL RESEARCH

FAIL TO PENETRATE THE HIDE OF CLASSROOM PRACTICE?

John C. Happs

INTRODUCTION

I clearly remember being addressed (along with several other first year teachers) by the Deputy Principal of a large comprehensive school in England, at the start of my teaching career in the late 1960's. Strategically inserted between the many pearls of wisdom, anecdotes and good wishes was a sincerely delivered piece of advice which struck me as being most controversial at the time. He said:

"Forget all of that theoretical stuff that they taught you at teachers' college because now you are about to face the realities of the classroom where most of those theoretical ideas just don't work".

As a person currently involved with classroom-based research and teacher education, I would now like to think the above statement to be somewhat exaggerated and perhaps more than a little out of date. Many educators hope that a significant amount of present-day educational research will find some application in our schools yet, according to a number of observers, this is indeed a moot point. Medley points to the lack of substance behind available research findings:

"The teacher educator who examines the research is likely to conclude that there is less there than meets the eye".

(Medley, 1979, p. 16)

Approximately two decades ago, both Gage (1964) and Ausubel (1967) considered that there was widespread agreement amongst educators, learning theorists and educational psychologists, that the relevance of learning theory for classroom teaching was highly questionable.

There is little doubt today that professions such as medicine, engineering and dentistry, along with the worlds of business and communications, are rapidly affected and improved by the results of related research, yet educators such as Bolster, reflect that:

"Classroom teachers wish to improve their craft and educational researchers want to generate useful knowledge, yet educational research seldom influences classroom teaching".

(Bolster, 1983, p. 294)

Herron has noted that teachers in particular have tended to be unimpressed with research data:

"What does not look trivial or downright inane seems to be impractical and out of touch with the realities of the classroom".

(Herron, 1979, p. 87)

This lack of confidence in the application of educational research, does not appear to be confined to classroom teachers. White makes the point:

"Many teachers and administrators are socialised into the belief that research is an esoteric pursuit, harmless, but of little import to practical people."

(White, 1984, p.4)

A number of experiences may have served to reinforce this kind of attitude toward the value of educational research and, one example which readily springs to mind, stems from Bruner's (1961) argument that a 'discovery' approach in the classroom provides the learner with motivation and the ability to better organise his/her knowledge frameworks. Bruner also proposed that the 'discovery' of information is likely to offer the learner a 'real possession' of knowledge whilst fostering long-term retention.

Teachers realise from experience (and frequently cite) that although the discovery approach to learning does offer certain advantages, under certain conditions, it is a time-consuming strategy which is not likely to prove useful as a central technique for teaching in the typical classroom and/or laboratory situation which demands the coverage of an ever-expanding syllabus, with large numbers of students. Other innovative strategies such as the use of conflict situations (Berlyne, 1965, Stavy and Berkovitz, 1980) and peer-group interaction (Johnson and Howe, 1978; Happs, 1983) certainly appear to pay dividends when executed under specific conditions yet, again, teachers are quick to point out that researchers (or interpreters of their work) have tended to transfer research findings from 'simplified' experiments into the more complex and less controlled arena that is the 'average' school classroom.

Specific difficulties appear to exist which prevent the transfer of useful information from researcher to teacher and the notion of different agendas between the two groups has been raised by Smyth:

"It is only when the agendas of the researchers match the intuitions of teachers that dialogue becomes possible. Without this discourse it is not possible to develop a connection between concept and practice".

(Smyth, 1984, p. 69)

It may be that 'learning for understanding' is not a goal that is compatible with 'learning for examinations', this latter aim being frequently promoted by school administrators and employers. Thus researchers and practitioners usually have clearly defined (and different) roles in curriculum analysis and/or implementation.

Practitioners have a direct responsibility for the 'quality' of school-teaching and this may be seen to include curriculum development, examination successes, and general classroom climate. In contrast to this, researchers are more concerned with factors leading to student retention and understanding of subject-matter, along with associated aspects such as cognitive structures, theoretical models and methodologies for probing these.

Van Aalst comments:

"We can say therefore that researchers and practitioners differ completely because of their respective tasks, aims and approaches to their work. Can one imagine a greater gap?"

(Van Aalst, 1980, p. 400)

Whereas the researcher is likely to approach a learning/teaching problem from a specific theoretical viewpoint, the classroom teacher is more often concerned with 'reality' and the logistics of the classroom/laboratory situation.

Let me relate another personal anecdote which perhaps highlights this difficulty which, in turn, may contribute to the research-practice chasm:

I was recently supervising a teacher-trainee who was preparing to teach a chemistry module to an 'average' fourth form [14 year-old] co-educational group in New Zealand. He had clearly demonstrated to me that he was conversant with many of the Learning in Science Project investigations (see Osborne et al., 1980) and that he appreciated the significance

behind exposing the learner's prior knowledge in an area, prior to teaching. Yet when the time came for the delivery of that series of lessons on acids and bases, I witnessed no consideration of the learner's prior knowledge in that area, nor did any innovative teaching approach emerge. Instead I saw only the teacher-dominated techniques of traditional pedagogy.

The eight-period introduction to acids and bases was filled with blackboard information, diagrams from text-books and several 'experiments'. Students filled their note-books; They appeared to be interested and the ensuing end-of-topic test revealed a 'normal' distribution of grades which indicated (to someone I'm sure) the 'success' of the teaching episodes. An encouraging start for a teacher-trainee, no doubt, yet my later discussions with the more able members of that particular class left me with no doubts that their understanding was superficial and often distorted. Comments such as "I've forgotten when he said about that", indicated the temporary nature of some learning.

It appears to me that many teachers, whether or not they are relatively experienced, tend to emulate the kind of teaching approach through which they received their subject knowledge at the tertiary level, i.e. essentially via teacher-controlled activities, heavily flavoured with expository methods. It also appears that once a teacher becomes entrenched in a particular teaching mode (s)he may find it extremely difficult to change those habits which have been developed and 'found to work' in the classroom situation. After all, teaching techniques are useful only when they are seen to 'work.' Thus teachers are likely to put to one side those theoretical and/or new perspectives encountered outside the classroom, whilst they remember the pragmatic time-tested strategies required to gain control over thirty active children.

This pessimistic view assumes then that one or more of the following conditions may contribute to this dilemma:

- (i) It is difficult for the teacher to identify any significant changes in classroom instruction techniques that have stemmed from educational theory and research. This affects how they view any theories or ideas.
- (ii) Research into teaching has never led to valid, useable theories of learning.
- (iii) Practitioners do not trust theoretical information that is expressed in specialised language.
- (iv) The teaching-learning situation is so pressurised, because of examinations, class sizes, etc., that there is little opportunity for teachers to 'try out' new approaches.
- (v) There is a breakdown in communication between the researcher and the practitioner, such that potentially useful (to the teacher) information rarely becomes available, outside research journals.
- (vi) The researcher is too concerned with matters which are fundamentally different to those aspects of the classroom which are important to the teacher.

- (vii) Teachers feel that they should be acting as researchers themselves since they are always in the classroom. They understand the students in their charge; they appreciate the kinds of problem areas which require more research. After all, it may be argued, teachers have to ultimately implement any research findings that are relevant to the improvement of classroom teaching:

"Innovations need to be recognised or approved by those who will have to put them into practice".

(Van Aalst, 1980, p. 402)

- (viii) Schools are made up of systems which have acquired enormous inertia to the extent that changes, which are desired by both researcher and practitioner, may prove extremely difficult to initiate:

"Schools have had such a long run in their present form that we tend to assume that they are permanent, stable, easily able to resist attempts to change them".

(White, 1984, p. 3)

- (ix) Whereas the development of future strategies and the implementation of research findings is largely left to experts in the fields of medicine, engineering and communications, members of the community (with little or no expertise in education) often play a significant role in formulating school curricula and their implementation.

Important decisions about science content (for instance) and the level at which it is taught in schools can be made by personnel who have no expertise in science educational research.

Gallagher (1984) has recently demonstrated how curriculum planning (in Michigan) can be controlled by administrators who lack the specific skills, needed for decision-making in this area.

Non-professional input may be a major reason for the lack of impact of educational research. Examples are frequently seen whereby the media and community groups call for schools to move back to an emphasis on examinations and rigour in 'the basics'. This kind of advice, which may originate from well-meaning people (again lacking expertise in educational research and/or practice) tends to have a disproportionate influence on the direction of future educational trends. The public demand for more 'rigour' in our school system is often cited by the media yet White has indicated how the presence of an even more stringent examination apparatus than ours, as in Britain and France, does not remove the problem:

"Syllabuses fill up with facts for the same reasons that schools are organised the way they are: because of a simplistic, Nineteenth Century view of learning, that the mind is a bucket which can be filled by dropping facts into it".

(White, 1984, p. 12)

Additionally, White stresses that even if we insist that students pursue a prescribed course of study, whilst passing specified examinations, there is still no guarantee that useful understanding will be acquired.

SUMMARY

Current classroom-based research (particularly in the area of science education) reflects important changes in research styles and methodologies. Such changes have been influenced by a need for information which is more relevant to classroom practice, local conditions, the responses of individual learners to instruction, and to long-term retention with understanding of material taught.

The outlook for the impact of educational research on classroom practice may be a little brighter today than it was ten years ago. Yet, unless practitioners come to realise the value of such research for classroom application, and unless conditions are provided which are conducive to the implementation of research, the gains will continue to be slight.

In brief, greater inroads may have to be made into the communication of research information to practitioners whilst school systems need to provide more opportunities for teachers to trial and evaluate new strategies and materials, without the handicap of external, uninformed influences.

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"HANDS-ON" SCIENCE: HOW OFTEN AND WHOSE HANDS?

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The *Science Syllabus K-7* for Western Australian primary schools (Education Department of Western Australia, 1983) is unequivocal in its support of active involvement by children in their science program. "Learning from hands-on activities" is the second of four essential characteristics of a primary science program listed in this syllabus. The inquiry-based, problem-solving approach to science teaching advocated in this state, and others (see, for example, Education Department of South Australia, 1983) cannot be implemented unless children spend a large part of their science lessons actually manipulating materials.

All of the tertiary institutions responsible for preservice training of primary teachers offer courses which, although differing in perspective, are materials-centred and inquiry-based. Over the last decade, hundreds of their graduates have entered Western Australian schools, and it might be assumed that much primary science is taught on inquiry lines. There is evidence that this assumption is reasonable. Rowe (1983) reported from a survey of eighty schools, including metropolitan and rural, government and non-government schools, that in 74 per cent of classes, science was taught with significant material-based activity and was inquiry-oriented. In a study involving observation of 12 classrooms at each year level of schooling, Hacker (1984) found that the general mode of teaching science in primary school is problem-solving or inquiry-based. Hacker and Rogers (1983) report that the class experiment was the single most common teaching activity across all levels of primary school. On average, 41 per cent of time was spent with the class working on teacher-directed experiments, and seven per cent for each individualised experiments and teacher demonstrations. Another nine per cent of class time was spent on project work or field trips.

While these results paint a positive picture of science in the primary school, both Rennie (1983) and Rowe (1983) report that the time devoted to science averages barely 60 minutes each week. It is most important, therefore, that those 60 minutes represent high quality science experiences

which maximise each child's opportunity to participate in the science activities in a meaningful way. This paper reports observational data from primary science classrooms and focusses on the nature and extent of children's participation during group work in science activities. There are clear implications to be drawn from the results for teachers wishing to optimise the effectiveness of the "hands-on" part of their science lessons.

The Research

The research reported here is part of a major project entitled *The Effect of Inservice Training on Teacher Attitudes and Primary School Classroom Climates*, funded by the Commonwealth Schools Commission and carried out in 1983. The general aim of the project was to devise, implement, and monitor the effects of an inservice program devoted to the teaching of a primary school science topic in a non-sexist manner.

The research was implemented in a field study using two matched groups of ten teachers (five male and five female) and their classes. All teachers of straight Year 5 classes in one region of the Perth metropolitan area were contacted. Teachers were matched on the basis of their responses to a questionnaire designed to measure their attitudes and teaching methods in science, and certain biographical data. Once selected, teachers from each of the ten matched pairs were randomly assigned to an experimental or control group. The experimental group received two days of inservice work, one week apart, comprising half of a day about teaching a physical science topic (electricity), and one and a half days designed to raise teacher awareness of reported differences in attitudes and achievements of boys and girls in science, the need for all children to develop skills in, and positive attitudes towards, physical science, and techniques to help achieve this goal. The control group received half of a day inservice on the teaching of the electricity topic. The inservice programme is described fully in Parker, Rennie and Hutchinson (1984).

After inservice, and before teaching electricity, teachers gave their classes a questionnaire to establish a baseline for children's attitudes and interests in science in general, and electricity in particular. During the teaching of electricity, the researchers visited each classroom to record observational data of the children and teacher at work. On completion of this topic, both teachers and children completed a second questionnaire about attitudes and interest in the electricity topic. The effectiveness of the inservice was judged on the basis of classroom observational data and

responses to the teachers' and children's post questionnaires. The present paper reports some data from classroom observations. A discussion of findings from the children's questionnaires is presented in Parker and Rennie (1984).

Method of Classroom Observation

Observational data measuring children's participation in science were structured by focussing on the nature of the children's activities for the duration of the lesson, and the nature of the teacher's interactions with the children. The collection of data was facilitated by recognising two instructional contexts. *Whole-class instruction* occurs when the teacher works with the class as a unit. Typical teaching activities include giving information, explanation, conducting a question-answer session, and class discussion. *Group work* occurs when children interact in small groups with or without equipment and materials. In this context, teachers interact with groups or individual children. Children may work alone for short periods within either context, and in this study individual work was coded as part of group work because it usually involved recording of group activities.

During whole class instruction, both teacher-student interactions and the participation of children were recorded, but are not reported here. During group work, observations were recorded using the *Group Work Schedule* which included a section to record the nature and extent of children's participation in the lesson, and a teacher-student interaction section to code the nature and circumstances of the interactions between the teacher and groups of students. The *Group Work Schedule* is shown in Figure 1, and its development and use, together with the observation schedules developed for whole-class instruction are described in Rennie, Parker and Hutchinson (1984).¹

For the purpose of this research, teachers were asked to teach their science lessons in a certain way. Classes were expected to do a sequence of activities with a typical lesson consisting of children working in groups with equipment, with perhaps a teacher-led whole-class presentation at the beginning and end of the lesson. This common format reduced the number of

1. For the purpose of this research, instruments measuring only overt behaviour were prepared. Measurement of covert time-on-task requires interview and/or questionnaire methods and the collection of data by these means would be more time-consuming than the constraints of the project would allow. More importantly however, the research focussed on Year 5 classrooms engaged in activity-based science lessons in which nearly all participatory behaviour may be expected to be overt.

GROUP WORK SCHEDULE

(Groups formed by teacher/children/usual seating)

School _____ Teacher _____ Room _____ Date _____ Sheet No. _____

Group	No. in Gp.	STUDENT ACTIVITIES						TEACHER-STUDENT INTERACTION					NOTES
		Watching Listening	Reading Writing	Manipulating Equipment	Planning Discussing	Other On Task	Off Task	Initiator S or T	Tell or Discuss	Uses Equipment	Evaluates work +/o/-	Evaluates Behaviour +/o/-	
1	B G												
2	B G												
3	B G												
4	B G												
5	B G												
6	B G												
7	B G												
8	B G												
9	B G												
10	B G												

Figure 1. The Group Work Schedule

instructional variables operating in the research, and in terms of organisational variables, data were collected only on the the size and composition of the groups.

Each of the eighteen classrooms in the research study was observed for one science lesson of about one hour in length.² Classes averaged 31 children present at the time of observation. The topic in most cases was making a switch. Data for group work were collected by two observers each observing one half of the class. One sweep of each half-class was made every 90 seconds and teacher-student interactions were recorded when they occurred. These data were combined to give average results in each class for boys and girls in same sex or mixed groups. The process of data combination took account of different numbers of children in groups, and different combinations of the types of groups coded by each observer.

Observation of one hour in each of a number of classrooms may be described as "thin" description (Brophy, 1979), but a number of variables necessitating longer periods of observation for stable measurement have been controlled in this reasearch. Most importantly, context variables relating to subject matter, instructional objectives, and general variables relating to teacher background, attitudes and perceptions about teaching the topic have been incorporated into the research design of the larger study.

Children's Activities during Group Work

Children worked in pairs or threes using the electrical materials for an average of 64 per cent of class time. Children's activities during group work were coded in six categories: watching or listening to other group members; reading or writing; manipulating equipment, planning/discussing their work; other-on-task behaviour, such as finding equipment, borrowing a pencil, talking with the teacher; off-task behaviour. The activities of each boy and girl were recorded within their group, so that patterns of activity could be examined for children in same-sex and in mixed groups.

The results are presented in Table 1 separately for the experimental and control groups. Children were on-task for an average of 94 per cent of the time, and most of this time was spent actually working with and manipulating

2. One male and one female teacher from the control group elected not to teach the electricity topic, leaving a total of eighteen teachers.

the electrical equipment. Analysis of time spent by boys and girls on the various activities reveals some interesting comparisons. Table 1 shows first, that there is little difference between the pattern of time spent on each activity by boys whether in same-sex or mixed groups, and this pattern is similar between the experimental and control groups of teachers. Second, the pattern of time spent on activities by girls in same-sex groups matches the pattern for boys in same-sex groups, and these patterns are similar between the two teacher groups. Third, in mixed groups taught by the experimental group of teachers, boys and girls spent about the same amount of time on each activity, except that girls spent a little more time watching/listening. Compared to girls in all-girl groups, girls in mixed groups spent less time reading/writing and more time watching/listening. Almost the same amount of time was spent manipulating equipment. Fourth, in mixed groups taught by teachers in the control group, girls spent nearly 25 per cent less of their time manipulating equipment than did boys. The corresponding comparison for the experimental group is three per cent. Girls spent nearly one quarter of their time watching/listening, while boys spent only six per cent of their time in this passive involvement.

Table 1
Percentage of Time Spent on Activities by Children
in Same-sex and Mixed Groups.

Composition of Group	Activities					
	Watching/ Listening	Reading/ Writing	Manipulating Equipment	Planning/ Discussing	Other on-task	Off task
Experimental Group						
Boys						
same sex	10.0	15.5	58.6	3.9	7.1	4.9
mixed	10.8	10.7	58.8	7.0	7.4	5.3
Girls						
same sex	9.4	20.7	54.4	3.8	6.1	5.6
mixed	18.3	11.6	55.8	6.0	4.6	3.7
Control Group						
Boys						
same sex	6.9	17.9	57.4	4.1	6.8	6.9
mixed	5.9	15.0	62.1	4.3	6.0	6.7
Girls						
same sex	10.1	22.0	49.5	5.1	7.5	5.8
mixed	24.0	22.4	37.6	4.9	3.9	7.2

Note Results are averaged using class as the unit of analysis

Participation by the experimental group of teachers in the inservice course is associated here with more active involvement of girls in the activities of group work. In classes taught by control-group teachers girls in mixed groups were more likely than boys to watch or listen while the boys spent more of their time manipulating equipment. Compared to girls in all-girl groups, girls in mixed groups spent 14 per cent more time watching/listening, about the same time reading/writing and 12 per cent less time experimenting. The corresponding comparisons in the experimental group show that girls in mixed groups spent nine per cent more time watching/listening than girls in all-girl groups, nine per cent less time reading/writing and one per cent more time experimenting.

Table 2
Mean Time Spent Manipulating Equipment
by Children in Different Groups

Group	Usual or Child-selected Partner		Teacher-selected Partner	
	n (classes)	Time (%)	n (classes)	Time (%)
Experimental Teachers				
Boys				
same-sex	9	60.0	1	47.5
mixed	5	60.2	1	51.9
Girls				
same-sex	7	54.4	-	-
mixed	5	59.8	1	35.8
Control Teachers				
Boys				
same-sex	5	59.0	3	54.6
mixed	3	55.3	3	68.8
Girls				
same-sex	5	53.4	3	42.9
mixed	3	38.6	3	36.5

Note Results are averaged using class as the unit of analysis.

During the collection of group work data, the observers took note of how the groups were formed. In most cases children worked with their usual seating partner, in other cases children selected their own partner, usually of the same sex. Other times the teacher moved children into groups which were sometimes same-sex, and sometimes mixed groups. The observers noticed

that children in teacher-made groups did not work as well together as did children-choice groups or usual-partner groups. As the time spent manipulating equipment is the activity requiring the most sharing and working together, an *ex post facto* analysis of this data was made and the results appear in Table 2.

The figures in Table 2 suggest that nearly all children spend more time with the equipment when they are working with their friends or their usual seating partner, than when in groups selected for that lesson by the teacher. A possible explanation, based on this analysis and classroom observation, is that children more readily share tasks in a cooperative way when they are working with someone they know well. This results in higher average time manipulating the equipment than if there is indecision about who does what. The only exception is for boys in mixed groups formed by the control teachers. These boys spent most of their time using the equipment, and the difference between boys and girls is greatest in this group. The pattern of results for mixed-sex groups is similar to that shown in Table 1 - girls use the equipment less than boys. Only in usual-partner or child-selected groups in classes taught by experimental teachers did boys and girls have an equal share of hands-on experiences.

Teacher-student Interaction during Group Work

Teacher-student interactions during group work took place as a result of the group calling for the teacher's assistance, or the teacher supervising the group. If the group was progressing satisfactorily, the teacher often moved past without comment. Other times, the teacher offered help and/or gave an evaluation of work or progress. Such evaluation was coded as positive or negative. Negative evaluation was usually corrective rather than critical. The two or three critical evaluations of behaviour noted are not analysed.

Teacher interactions with groups were described and analysed separately for same-sex and mixed groups. Statistical analysis took account of the different numbers of groups of each composition in the class to arrive at a per group figure which was comparable between classes. Class results were then averaged over the two groups of teachers and are reported in Table 3.

The first column in Table 3 is a measure of the degree of supervision of groups in each class. The figure gives the percentage probability that each group was observed by, or interacted with, the teacher at least once during the lesson. For example, in classes taught by teachers in the experimental

research group, 88 per cent of all boy groups could be expected to be involved in at least one interaction with the teacher. On average, teachers interacted with about 90 per cent of the groups in their classes during the lessons. The number of interactions varied within each class, and the second and third columns of Table 3 report the average number of interactions per group which occurred during the lessons. There are likely to be more interactions when more lesson time is spent on group work, and when teachers move quickly between groups rather than stay for long interactions with a few groups. Nevertheless, the results show that teachers tended to initiate the interactions with all-boy groups, and girls tended to initiate the interactions with all-girl groups. Teachers in the experimental group supervised the mixed-sex groups closely, initiating the highest number of interactions with these groups.

Table 3
Mean Teacher-Student Interactions per Group during Group Work

Teacher Group	Groups interacted with (%)	Number of interactions initiated by		Teacher uses equipment (%)	Teacher evaluates	
		Teacher	Child		Positive (%)	Negative (%)
All Boy Groups						
Experimental	88	1.28	.71	24	16	3
Control	83	1.23	1.05	29	12	3
Mixed Sex Groups						
Experimental	93	1.81	.73	11	14	1
Control	93	.82	.98	11	13	6
All Girl Groups						
Experimental	87	1.13	1.33	35	7	0
Control	83	.92	1.26	42	18	2

During some interactions, teachers handled the electrical equipment either by helping children "get it right", or by actually completing the work for them. The percentage of interactions where this occurred is recorded in the fourth column of Table 3. In general, teachers seem most likely to help all-girl groups in this way, and least likely to help mixed groups. This pattern is probably associated with the high number of student-initiated interactions with all girl groups - girls ask for help more often.

The last two columns in Table 3 report the nature of evaluations teachers made for progress or work completed. These evaluations occurred in less than one quarter of the interactions and were usually positive involving praise. In a number of cases, children were asked to display completed work to the class, or to show "how they did it". Teachers usually chose equal numbers of boys and girls when calling on individuals for this purpose.

Discussion

These results show that when children work in groups on science activities, they do so with a very high level of time-on-task. However, there can be a good deal of variation in what different members of the group are doing. In particular, girls in mixed-sex groups may miss out on their share of the "hands-on" experiences. This is less likely to happen when the girls in mixed groups are working with their chosen friends or their usual desk partners. The observers noted a frequent pattern of events in teacher-formed mixed groups. Boys tended to take the equipment and work on the task until they had finished. When the boys put the equipment down, the girls picked it up and began the task for themselves. The results in Tables 1 and 3 show that in classes taught by experimental teachers, girls got an equal share of using the equipment and that mixed groups were closely supervised. Several teachers in the experimental group reported that, initially, girls lacked confidence and familiarity with the materials compared with the boys. However, by half-way through the topic girls had settled in and become more confident in working with the equipment and in solving their own problems. Overall these results suggest that when teachers are made aware that girls might be missing out, they can help to prevent this from happening.

In a review of research about "hands-on" science programs, Shymansky, Kyle and Alport (1982) found that children achieved more, liked these programs more, and improved their skills more, than did children in traditional text-book based science classrooms. Their findings uphold the "hands-on" approach to science adopted by the Education Department in Western Australia. The classroom observation in this research revealed several factors which teachers might consider to ensure that all children participate equally and effectively in science activities. Some are common sense. First, those teachers who had equipment organised on desks, or ready to give out, saved considerable lesson time which in other classes was wasted because both teachers and children spent time chasing equipment. Second, in a topic such as electricity, groups larger than two do not work well. Six hands are too many to share in

manipulating the equipment, and someone misses out. If insufficient equipment was available, teachers successfully rotated activities. Third, teachers should be aware of the difficulties some girls experience when using equipment unfamiliar to them. A little extra time and encouragement early on will help their confidence so they can cope easily. Fourth, some children do not work well in mixed groups. Teachers must ensure that groups are formed in which all children work cooperatively. Mixed groups can be very effective, but children need to get used to working with each other, otherwise some group members, often the girls, are likely to miss out on their share of the "hands-on" science activities.

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MEASURING SCIENCE TEACHERS' PERCEPTIONS OF THEIR SCHOOL ENVIRONMENT

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The concept of school environment or climate has appeared with increasing frequency in the educational literature during the last decade. Tye (1974, p.20) has described this concept as a set of factors which "give each school a personality, a spirit, a culture." The school environment is clearly important since an understanding of it could lead to improvement of the school's functioning and affect satisfaction and productivity within a school.

An important distinction can be drawn between school-level and classroom-level environment. For example, whereas classroom climate might involve relationships between teachers and their students or among students, school climate might involve a teacher's relationships with other teachers, senior staff and the school principal. Student perceptions are used frequently to measure classroom environment, but they are seldom used in measuring school climate because it is felt that students would be unaware of many aspects of the school-level environment. The school environment also can be considered more global than the classroom environment. Furthermore, classroom-level environment research has been based on different theoretical and conceptual foundations from school-level environment research. The theoretical underpinnings of classroom environment research are described in recent reviews (e.g., Moos, 1979; Walberg, 1979; Fraser, 1981a, 1985), whereas school environment research has tended to be associated with the field of educational administration and rests on the assumption that schools can be viewed as formal organizations (Thomas, 1976).

Science education researchers internationally have paid substantial attention to studies involving students' perceptions of classroom-level environment. In fact, sufficient classroom environment work has been completed to enable the writing of a comprehensive review of research specifically in science classrooms (Fraser and Walberg, 1981).

In contrast, research on teachers' perceptions of school-level environment has received scant attention from science education researchers.

Consequently, in order to provide a basis for the beginnings of a tradition of school environment research in science education, the present paper has as one of its major aims the provision of a general overview of existing instruments measuring school environment. A second major aim of this article is to report the first use of an instrument called the Work Environment Scale (WES) specifically for the purpose of measuring science teachers' perceptions of their school environment.

Measuring human environments

There are three characteristic methods for conceptualizing and measuring human environments. These have been delineated by Moos (Insel and Moos, 1974 and Moos, 1974a) as dimensions of organizational structure (in which behaviour in an environment is influenced by structural dimensions such as size of school, staffing ratios, etc.), personal characteristics of milieu inhabitants (in which the characteristics of the environment are assumed to depend on the nature of its members' personalities, intelligence levels, etc.), and psychosocial characteristics and organizational climate (which involves both psychological and social dimensions of an environment, as perceived by insiders or outsiders, in a framework of person-milieu interaction). It is this third approach to measuring environments that is made use of in the WES.

Moos (1974a) has found that the same three general categories can be used in conceptualizing the individual dimensions characterizing diverse psychosocial environments. This finding has emerged from Moos' work in a variety of environments including hospital wards, school classrooms, prisons, military companies, university residences and work milieus. The three basic types of dimensions are:

Relationship Dimensions (e.g., support, involvement) which identify the nature and intensity of personal relationships within the environment. They assess the extent to which people are involved in the environment and the extent to which they support and help each other.

Personal Development Dimensions (e.g., autonomy, competition) which assess the basic directions along which personal growth and self-enhancement tend to occur.

System Maintenance and System Change Dimensions (e.g., innovation, clarity, work pressure) which involve the extent to which the environment is orderly, clear in expectations, maintains control and is responsive to change.

An important conclusion reached by Moos (1974a) is that, at minimum, all three dimensions must be assessed to provide an adequate and reasonably complete picture of any environment; this was taken cognizance of in the initial development of the WES. In the following review of existing instruments measuring perceptions of psychosocial characteristics of school environments, an attempt is made to show how the scales contained in several of the instruments can be classified according to Moos' scheme.

Instruments for measuring school environment

Coughlan (1966, 1969) has developed a 120-item instrument called the School Survey to measure teachers' perceptions of or attitudes to 14 important dimensions of school environment. These dimensions are Administrative Practices, Professional Work Load, Nonprofessional Work Load, Materials and Equipment, Buildings and Facilities, Educational Effectiveness, Evaluation of Students, Special Services, School-Community Relations, Supervisory Relations, Colleague Relations, Voice in Educational Program, Performance and Development, and Financial Incentives. KR-20 reliability estimates for the different scales, which vary in length from six to 10 items, range from 0.44 to 0.80 with a median of 0.67. Some examples of recent studies which made use of the School Survey to measure school environment are Ellett, Masters and Pool (1978) and Perkins (1978).

Hoyle (1976) has developed the Learning Climate Inventory (LCI) to measure teachers' perceptions of five dimensions of school environment at the primary or secondary school level. The LCI's five factor analytic scales, which are called Leadership, Freedom, Evaluation, Compliance and Cooperation, measure dimensions that are especially salient in open schools. Based on six samples of U.S. teachers and varying in size from 34 to 100, alpha reliabilities of LCI scales were found to range from 0.50 to 0.72 and test-retest reliabilities were found to range from 0.75 to 0.92. Furthermore, the use of the LCI in a study comparing the environment of open-space and traditional schools revealed significant differences between teachers' perceptions in the two types of schools (Hoyle, 1973).

Pace and Stern (1958) developed the College Characteristics Index (CCI) to measure student or staff perceptions of 30 environment characteristics of college or universities. Each of these 30 variables (e.g., Affiliation, Aggression, Deference, Impulsiveness, Order) was based on Murray's (1938) taxonomy and paralleled a needs scale in Stern, Stein and Bloom's (1956)

Activities Index. That is, each Activities Index scale corresponded to behavioural manifestations of a needs variable, while the parallel CCI scale corresponded to environmental press conditions likely to facilitate or impede their expression. Stern (1970) reported that CCI scale reliabilities (KR-20 coefficients) ranged from 0.40 to 0.78 with a mean of 0.65 for a sample of 4,196 students and staff in 51 institutions in the U.S.

The original CCI has been adapted by Stern (1961) to form the High School Characteristics Index (HSCI), which is suitable for use at the Grade 9 to 12 levels. When the HSCI was administered to 947 high school students from 12 widely scattered schools in the U.S., Stern (1970) found that scale reliabilities (KR-20 estimates) ranged from 0.28 to 0.77 and that each scale differentiated significantly ($p < .001$) between the perceptions of students in different classrooms. Also factor analysis of the 30 HSCI scales for the same sample revealed that the following seven factors accounted for 59 per cent of the variance: Intellectual Climate, Expressiveness, Group Life, Personal Dignity, Achievement Standards, Orderliness, and Practicalness. An example of a study employing the HSCI in science education research is Gardner (1976).

McDill, Rigsby and Meyers (1969) have employed scales derived from a factor analysis of items based in part on the CCI and HSCI in exploring environment-achievement relationships. The large sample which provided their perceptions of school environment consisted of 20,345 students and 1,029 teachers in a national U.S. sample of 20 high schools. Factor analysis revealed that 80 per cent of the variance could be explained by the following six factors: Academic Emulation, Student Perception of Intellectualism-Estheticism, Cohesive and Egalitarian Estheticism, Scientism, Humanistic Excellence, and Academically Oriented Student Status System. Multiple regression analyses revealed that, with father's education, student academic values and student ability held constant, each of the six environment scales was significantly related to mathematics achievement, and five of the climate scales (with the exception of Scientism) was significantly related to college plans.

Two further instruments measure learning environment perceptions at the whole college level (as distinct from the college class level); however, these have not yet been adapted for school use. These are Pace's (1969) College and University Environment Scales (CUES) and Peterson, Centra, Hartnett and Linn's (1970) Institutional Functioning Inventory (IFI). The CUES measures

the variables of Community, Campus Morale, Faculty-student Relationship, (Relationship Dimensions in Moos' scheme), Awareness, Scholarship (Personal Development Dimensions), Practicality, and Propriety (System Maintenance and System Change Dimensions). The scales contained in the IFI are Institutional Esprit (Relationship Dimension), Intellectual-aesthetic Extracurriculum, Concern for Improvement of Society, Concern for Undergraduate Learning, Concern for Advancing Knowledge, Concern for Meeting Local Needs (Personal Development Dimensions), Freedom, Democratic Governance, Self-study and Planning, Concern for Innovation, and Human Diversity (System Maintenance and System Change Dimensions).

Brookover has reported a study in which perceptions of school environment have been related to student achievement (Brookover and Schweitzer, 1975; Brookover et al, 1978). The sample consisted of 8,078 fourth and fifth grade students, 327 teachers and 68 principals in a random sample of schools in Michigan. Brookover's instrument measures student perceptions of five dimensions (Sense of Academic Futility, Future Evaluations and Expectations, Present Evaluations and Expectations, Teacher Push and Teacher Norms, Academic Norms), teacher perceptions of five dimensions (Ability, Evaluations, Expectations and Quality of Education/College, Present Evaluations and Expectations for High School Completion, Teacher-Student Commitment to Improve, Principal's Expectations, Academic Futility) and principal perceptions of four dimensions (Parent Concern and Expectations for Quality Education, Efforts to Improve, Principal and Parent Evaluation of Present School Quality, Present Evaluations and Expectations of Students). Simple correlational analysis with the school mean as the unit of analysis revealed that the magnitude of the simple correlation between achievement and an environment scale ranged from 0.01 to 0.77. In particular, student sense of Academic Futility was found to have the largest correlation with achievement. Multiple regression analyses with the school as the unit of analysis revealed that the amount of achievement variance accounted for by the set of 14 school environment variables before and after socioeconomic status and the ratio of white to black students were controlled was 73 and four per cent, respectively.

Probably the most widely used instrument measuring school environment is Halpin and Croft's (1963) Organizational Climate Description Questionnaire (OCDQ). In fact, Thomas (1976) has noted that the OCDQ has been used in over 200 studies in at least eight different countries and that the instrument achieved something of bandwagon status in research in the field of educational

administration. The final version of the OCDQ contains 64 items of four-point response format which measure teacher perceptions of eight factor-analytically derived dimensions. Four of these dimensions pertain to teachers' behaviour and are called Disengagement, Hindrance, Esprit (i.e., morale) and Intimacy, while the other four dimensions pertain to the principal's behaviour and are called Aloofness, Production Emphasis, Thrust, and Consideration. Furthermore, Halpin and Croft have suggested a method by which profiles of OCDQ scores can be used to classify schools into six climate types: open, autonomous, controlled, familiar, paternal and closed. Also, in terms of Moos' three general categories, the Disengagement, Esprit, Intimacy and Consideration scales are classifiable as Personal Development Dimensions, the Hindrance and Thrust scales are classifiable as Personal Development Dimensions, and the Aloofness and Production Emphasis scales are classifiable as System Maintenance and System Change Dimensions. Although the OCDQ was designed initially for use in elementary schools, it has been used in numerous studies at the secondary school level.

The OCDQ formed the basis for the development of some new factor-analytic school environment scales by Finlayson (1973) in England and by Deer (1980) in Australia for use in secondary schools. For example, Deer's instrument has two scales measuring student perception of teachers and other students (Teacher and Peer Concern for Students, Teacher and Peer Control of Students), four scales measuring teacher perceptions of the teacher group (Job Orientation, School Organization, Personal Relations, Communication), three scales measuring teacher perceptions of head of department behaviour (Participatory Management, Awareness, Professional Concern for Staff) and four scales measuring teacher perceptions of the school principal's behaviour (Participatory Management, Sensitivity, Professional Consideration for Staff, Personal Consideration for Staff). Administration of these scales to a sample of 1,457 ninth grade students and 359 teachers in 10 coeducational government secondary schools in New South Wales revealed that alpha reliability coefficients for the 13 scales ranged from 0.71 to 0.92.

Description of WES

The WES (Moos, 1974b) was designed for use in any work milieu, but its 10 dimensions of work environment seem quite well suited to describing salient features of the science teacher's school environment. The 10 scales in the WES consist of three measuring Relationship Dimensions (Involvement,

Peer Cohesion, Staff Support), two measuring Personal Development Dimensions (Autonomy, Task Orientation) and five measuring System Maintenance and System Change Dimensions (Work Pressure, Clarity, Control, Innovation, Physical Comfort). The WES consists of 90 items of True/False response format, with an equal number of items in each of the 10 scales. The instrument is described in more detail in Table 1 which provides a scale description and sample item for each scale and shows each scale's classification according to Moos' scheme. Furthermore, although the WES has been used in a variety of work milieus, it appears that prior to this study no use has been made of it in measuring teachers' perceptions of school environment.

In the initial development of WES scales, Moos (1974b) used several methods to gain a naturalistic understanding of the social environments of work groups and to obtain an initial pool of questionnaire items. For example, individuals were interviewed with regard to the characteristics of their work groups. Also, a wide variety of different people was involved in drafting initial versions of items.

Since the environment described in the original form of the WES is that of any work milieu, there was scope in the present study to improve the instrument's face validity for use specifically in measuring science teachers' perceptions of their school environment. For this reason, the present investigation made use of a version of the WES in which the word "people" was changed to "teachers", the word "supervisor" was changed to "senior master" and the word "employee" was changed to "teacher".

Validation of WES

Moos (1974b) has reported validation data for the original form of the WES based on its administration to a sample of 624 employees and supervisors in a broad range of work groups (e.g., salesmen, nurses, drivers, maintenance workers) in the U.S. In particular, it was found that the internal consistency reliability (alpha coefficients) for various scales ranged from 0.70 to 0.91 and that the magnitude of the scale intercorrelations (which can be used as an index of discriminant validity) ranged from 0.05 to 0.59. Table 2 summarizes Moos' (1974b) results by reporting the values obtained with the sample of 624 people for each scale's internal consistency (alpha reliability coefficient) and the discriminant validity (using the convenient index of the mean correlation of a scale with the other nine scales).

Table 1. Description of scales in the WES and their classification according to Moos' scheme

Scale name	Description of scale	Sample item	Moos' General Category
Involvement	The extent to which teachers are concerned and committed to their jobs	Teachers put quite a lot of effort into what they do. (+)	Relationship
Peer Cohesion	The extent to which teachers are friendly and supportive of each other	Teachers go out of their way to help a new teacher feel comfortable. (+)	Relationship
Staff Support	The extent to which the senior staff is supportive of teachers and encourages teachers to be supportive of each other	Senior masters often criticize teachers over minor things. (-)	Relationship
Autonomy	The extent to which teachers are encouraged to be self-sufficient and to make their own decisions	Teachers can use their own initiative to do things. (+)	Personal Development
Task Orientation	The extent of emphasis on planning and efficiency	There is a lot of time wasted because of inefficiencies. (-)	Personal Development
Work Pressure	The extent to which the press of work dominates the job milieu	It is very hard to keep up with your work load. (-)	System Maintenance
Clarity	The extent to which teachers know what to expect in their daily routines and how explicitly school rules and policies are communicated	Teachers are often confused about exactly what they are supposed to do. (-)	System Maintenance
Control	The extent to which the school administration uses rules and pressures to keep teachers under control	Teachers are expected to conform rather strictly to the rules and customs. (+)	System Maintenance
Innovation	The extent to which variety, change, and new approaches are emphasized in the school	This place would be one of the first to try out a new idea. (+)	System Maintenance
Physical Comfort	The extent to which the physical surroundings contribute to a pleasant work environment	The colours and decorations make the place warm and cheerful to work in. (+)	System Maintenance

Table 2. Internal consistency (alpha reliability) and discriminant validity (mean correlation of scale with other nine scales) for WES for two samples

Scale	Alpha reliability		Mean correlation with other nine scales	
	Moos sample (N=624)	Science teachers (N=114)	Moos sample (N=624)	Science teachers (N=114)
Involvement	0.85	0.85	0.40	0.41
Peer Cohesion	0.70	0.60	0.37	0.33
Staff Support	0.78	0.66	0.25	0.29
Autonomy	0.76	0.61	0.35	0.27
Task Orientation	0.78	0.78	0.31	0.34
Work Pressure	0.84	0.74	0.21	0.16
Clarity	0.82	0.73	0.57	0.33
Control	0.77	0.64	0.18	0.18
Innovation	0.91	0.84	0.34	0.29
Physical Comfort	0.83	0.70	0.24	0.26

The present study involved administration of the slightly modified version of the WES to a sample of 114 science teachers in 35 secondary schools in Tasmania, Australia. This sample provided representative coverage of male and female teachers, of teachers with varying amounts of teaching experience, of teachers in state government schools and independent schools, and of schools in city and country areas. Data from this sample science teachers were analysed to provide estimates of each scale's internal consistency (alpha coefficients) and discriminant validity (mean correlations of a scale with the other nine scales). Table 2 shows that the KR-20 coefficients for the different WES scales ranged from 0.60 to 0.85 for the science teacher sample. These figures are generally only a little lower than Moos' estimates shown in the same table. The magnitudes of the mean correlation of a scale with the other nine scales shown in Table 2 range from 0.16 to 0.41 for the sample of science teachers. These values are a little lower than those (namely, 0.18 to 0.57) obtained by Moos, and therefore suggest better discriminant validity. Overall the data in Table 2 indicate that the WES scales display satisfactory internal consistency and measure distinct, although somewhat overlapping, aspects of school environment.

Uses of WES

The WES does appear to have possibilities as an instrument which can be used by science teachers and science education researchers to measure and describe school environments. Such assessments could form the basis of studies of the effects of the school environment on such outcomes as teacher job satisfaction or student achievement or morale. Also investigations might be made of links between school-level and classroom-level environment (see Fraser and Rentoul, 1982). Furthermore, it is conceivable that science teachers might use assessments of their perceptions of actual and preferred school environment as a basis for discussion of improvements in their school environments which would reduce actual-preferred discrepancies (see Moos, 1974b; Fraser, 1981b).

One use of the WES which might be considered is in describing schools prior to the appointment of new teachers. If new teachers' preferences are accurately described, it might be possible to match new teachers with the most suitable school environments. This would be consistent with Lewin's (1936) and Murray's (1938) theoretical points of view which clearly recognize both the environment and its interaction with personal characteristics.

of the individual as potent determinants of human behaviour. Stern (1970) used Murray's ideas to formulate a theory of person-environment congruence in which complementary combinations of personal needs and environmental press enhance student outcomes. More recently, Fraser and Fisher (1983) have shown the importance of person-environment fit for students in the enhancement of their learning outcomes. Consequently, it would seem likely that, if a teacher could be matched with a school in which the school environment is similar to that which the teacher prefers, then the teacher's efficiency and satisfaction and thus student learning might be improved. This aspect of the use of the WES certainly warrants further investigation.

Thomas (1976, p.441) noted that "organizational climate is an elusive and tangible concept and yet it is one which may offer the educationist a means of better understanding the operation of schools." Stewart (1979) suggests that, by attempting to regulate the school environment, it is possible for educators to improve the learning and social development of students. Such regulation of the school environment could be facilitated by using such instruments as the WES to measure and describe environments. Hopefully the information contained in this article will complement a previous paper describing an instrument called the School-Level Classroom Environment Questionnaire (Rentoul and Fraser, 1983) and will lead other science education researchers and science teachers explore further the usefulness of the WES in assessing and studying the important concept of school environment.

Conclusion

This paper has described the first use of the Work Environment Scale (WES) to measure science teachers' perceptions of 10 important psychosocial dimensions of their classroom environment. Noteworthy features of this instrument are its adequate coverage of Moos' three general categories for conceptualizing all human environments, its face validity for use in schools, and its economy (in that teachers take only 10 to 15 minutes to respond to all 10 scales). Also administration of the WES to a sample of 114 science teachers has shown that each scale possessed adequate internal consistency and discriminant validity.

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THE ARGUMENTS FOR AND AGAINST SCIENCE EDUCATION

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INTRODUCTION

With the current reviews on tertiary admission methods it becomes relevant to re-examine the arguments for and against the inclusion of various subjects in the general scheme of education provided for senior secondary students: and, by extension, students in earlier years. Such discussion get drawn towards two points: firstly, the inclusion of the subject at all: secondly, the "standards" required to "pass" each subject. This paper is confined to the first point: the second is discussed elsewhere. Apart from mathematics and science, there is no provision for a range of levels of possible intellectual achievement within a single subject area, each level of which is acceptable as part of the entrance requirements for at least one tertiary course. For all other tertiary entrance subjects the arguments about status continue.

Some improvement (to a purely academic matriculation) has been made by providing a range of subjects specifically designed to be of lower intellectual standard for students not wishing to proceed on to tertiary studies. That this approach has been misdirected, albeit because of the considerable pressure from parents and schools for students to eschew the lower grades of alternative subjects on the basis of lower academic standing, is a fact we now have to live with. The status of each subject is ranked (allegedly by the community at large, actually by the education community) according to its intellectual difficulty and academic standing for tertiary entrance requirements. These lower subjects are seen for what they are - downgraded tertiary entrance subjects.

CONTEXT

A vast improvement upon the present system would be a range of subjects developed according to the situation the students will most likely to find themselves upon leaving secondary school - anything less than this is inappropriate. Without completely specifying the future, and without even defining a manpower policy, the basic educational needs of the population can be spelled out. In the recent past it was mistakenly assumed that secondary education would be most efficient if it was essentially vocationally orientated. This conclusion followed from a rather naive underestimation of how rapid technological change has turned out to be. It is now realized that by far the largest components of senior secondary education should be based upon inter-personal skills and facts required to adequately function as a citizen in a particular range of social environments, that is, a considerable amount of general knowledge. It is within this context the arguments for and against the inclusion of science as a discipline of study in upper secondary school will be pursued. Later, the arguments shall be extended to include science in lower secondary and primary schools.

PRESENT SUBJECTS CLASSIFIED

At present there is available a range of studies in science from the purely physical, such as Physics, Chemistry and Geology, through to the largely physiological, such as Human Biology. The same subjects are also graded according to the extent of mathematical knowledge required to successfully complete the prescribed course: ranging from an above average knowledge (Physics) to hardly any mathematical knowledge (Human Biology, General Science). A third classification is based upon the alleged extent of problem-solving, as opposed to rote learning of various facts, with a high proportion of the course taken up with problems in Physics and practically no problem solving in Human Biology. Recently however, a fourth classification has emerged (at least in WA) - that of English language skills with Physical Science requiring considerable skill and Physics requiring no skills beyond elementary reading ability.

However, one cannot take any of these four categorizations and from it develop a justification for studying, or not studying, a particular scientific discipline. Firstly, within the context of this paper each of these four categorizations are irrelevant as a justification for the study of a subject. Secondly, one may not justify studying science because, say, such a study involves application of mathematical techniques until it has been shown that one aim of education is to learn mathematics. Justifying the inclusion of a subject on the basis of certain content is acceptable when the need for learning the content has been demonstrated.

BASIS OF JUSTIFICATION

For centuries there seemed to have been only a single aim used for the education of the young: this was to set the child on the right path towards the attainment of an ideal man, whether that be a warrior, a priest, a king, a nobleman, or, since the Reformation for the lowest levels of education a common man or woman. In general, education was directed towards fulfilment of a person's decreed status in life, and to a much lesser extent, a study of the surrounding world. The attaining of the aim providing the justification for the course of instruction followed. Through the past two centuries the English tradition has reserved upper secondary schooling as a preparation for university and, as a consequence, the justification of what is studied in senior school, in particular, has changed until it now hinges on the necessity of studying subjects selected from a rather small range of academic disciplines. Despite our tradition, the demands of pre-requisites for selected disciplines (at university or any other tertiary institute) are insufficient justification to impose upon courses for all students: that is, to justify the provision of intellectually weaker courses simply because many students cannot succeed in the 'proper' courses.

Both of the above justifications (attaining the ideal man and the academic tertiary entrance) have led mankind into conflict on scales ranging from the personal to the international. Philosophy teaches us that all argument and analysis ultimately start from agreed-upon axioms and in the above the axiom is that the proper study of mankind was formerly the ideal man, latterly a preparation for university.

We now rather belatedly realize that most people will not attend a tertiary institution but still require a vast range of skills and knowledge if they are to live in harmony with one another in a future which has been predicted to be depersonalized. Given this analysis the earlier assertion (of the contemporary approaches to upper secondary education largely based on preparation for tertiary studies being misdirected) is true.

There is a growing realization that the proper study of mankind is man: that is, humankind as it is. This does not mean that we return to the anthropocentric notion of the Universe as in pre-Middle Ages but it does make us view things in a particular light. Others have held what, superficially, is the same view: but the difference is that the previous proponents have held that to know thyself implies acceptance of the insignificance of man in relation to Nature, of knowledge vested in God and ignorance the lot of mankind. To accept as axiomatic the study of mankind does not require these, or any other, constraints. Surely humans, as a species, must learn what it takes to survive and this does not presuppose any knowledge of why things are thus - only the knowledge that in order to survive one needs to know that certain things are thus. If we wish to avoid anomie, all of what is taught needs to be justified, particularly in the social and ethical aspects of what we expect students to learn.

When curriculum makers grasp the difference between necessary knowledge for everyone and knowledge it would be ideal for everyone to know, then a start can be made upon producing relevant curriculae. A lack of appreciation of this distinction has been the cause of why many curriculae, whose stated aims are so idealistic, have not resulted in the success anticipated. A knowledge of the fundamental reasons as to why things are thus and not something else is only needed when we are in a position to actually determine the directions in which we want our human species to develop. The decisions as to which changes to make are essentially social and political rather than ethical and scientific although such decisions would, hopefully, be based upon accurate data and reasoning. Which gets back to the point that an understanding of (scientific) principles is unnecessary knowledge for most people.

To strengthen the conclusion that factual knowledge is the only justifiable part of universal educational consider the following. One particular aspect of current education orthodoxy is the teaching of concepts and the subsequent understanding thereby gained by the learner: but what little research that has been done clearly indicates that many of the principles taught at upper secondary levels in science are too difficult for the majority of students to understand. Given radical changes in our provision of learning situations/teaching methods, it will be possible to educate children at rates

which surpass the current rates of cognitive development. Understanding is a relative term, and we seem to get by knowing a lot without actually reasoning but rather relying on what we have memorized.

SUBJECTS JUSTIFIED

Justification starts with an axiom (that education of children ought to be centred upon the study of humans) and ends with a priority list along the continuum necessary-ideal. Within the context that students should learn firstly about themselves, a component of knowledge based firmly upon facts is now justified but facts relevant to which disciplines? Taking a modern anthropocentric view one obtains :-

firstly, the disciplines of communication, human biology (physiology, biochemistry if you wish) and psychology; which is to say, those aspects of learning in which "I" am the focal point and because you and I are alike the same information will be true for you.

Secondly, ethics, sociology, history and geography: which is to say, those aspects of knowledge in which "we", the group of you and I, are the focal point.

Thirdly, disciplines such as applied technology, industrial processes, agriculture, astronomy... which is to say, the ways in which we and our environment interact.

Always remembering that the major part of the compulsory education system will be information based. There are two equally important threads: the social and the scientific, neither of which, in the present context, can be overemphasized at the expense of the other. Recall also, that information is a communicable summary of what is observable and/or demonstrable. Thus far, in justifying an information-based curriculum no particular method of teaching is prescribed.

A recent advance is to examine curricula in terms of students learning to adapt and develop according to possible future situations. In the present context each child will be educated from the vantage point that individually they are an integral part of a species whose heritage (presumptuously?) is the universe, since to the extent that we as a species control ourselves and our environment, we control our destiny. Such control arises through individual people investigating the works of Nature in an attempt to better understand them. Curiosity is a major motivational force behind advances in knowledge in the child too. I believe that we cannot afford to stifle this curiosity lest in the adult the driving force completely degenerates to one of a desire for control or power for its own sake. Curiosity knows no bounds and it is the learning done under this motivation that will lead to 'understanding' as we know that term. Therefore one component of any set of curricula must include options for study - options selected by the child - disciplines in which the child is given all the guidance required in order to develop their skills. And it is in these optional situations that the skills are largely cognitive.

The majority of secondary students do not go on to tertiary studies yet science courses are still highly sequential especially for the final three years of secondary schooling. For students who do eventually proceed to tertiary studies such sequential programmes are essential but these programmes are optional and for those few students alone: such sequential programmes are additional to the core of information based programmes.

Justified so far are the inclusion of an information-based component of science and an intellectual study of science as two separate aspects of school curriculum. The former is necessary for the child to grow, with dignity, into a mature adult. The latter necessary for those who can master the discipline and perhaps advance the frontiers of human knowledge. Are there any sufficiently powerful arguments against the inclusion of science education as outlined above?

COUNTERARGUMENTS

Those who argue that we should teach concepts and only a minimum of mere facts are arguing from two false premisses. The first is that of the Platonic notion that a concept is something different from, and more than, the sum of the defining features; and the second is that everyone is capable of understanding these concepts. Even admitting these premisses (which I do not) the counter argument for the inclusion of the teaching of concepts still fails on the needs basis.

There are those who would argue that with the advent of the computer/calculator age there is only a need to teach mastery of these and similar devices of modern technology: all the rest can be obtained simply by pressing the correct button. Whilst it is essential that children learn to come to terms with modern technology the justification for learning such skills depends upon the extent to which they are concordant with the aims of education. Certainly it is becoming increasingly difficult to lead a meaningful life because of the move towards gigantic governmental and industrial data bases. The actual using of these systems does require only very minimal skills: and, whilst databases are very useful it is the human interactions that are fundamental and therefore it could be argued that people should know a lot about the methods of information gathering and dissemination.

Others say that if the computer-based information revolution is to permeate our entire lifestyle then, because it will be very easy to obtain information, schools should concentrate their efforts upon teaching principles. Nothing could be further from the truth at senior secondary level. Apart from the considerable time and effort on the part of the schools to teach the skills required to interact with computers for such uses (even apart from actual programming), most principles are currently beyond the intellectual skills of most students. Generalizations are sometimes confused with principles. Generalizations can be taught either in much the same way as other information or through induction via examples from experience. Some

examples to illustrate this important distinction follow.

Generalizations can be utilized by applying an implication rule - sodium salts are water soluble: therefore sodium phosphate is probably water soluble. The shape and structure of the various parts of an organism can indicate a lot about the organism - therefore fossil teeth, for example, can tell us a lot about the diet of the original animal. Generalizations usually do not require the application of mathematics more than elementary. Generalizations can be treated as isolated items and hence understood and learnt only in terms of the relevant supporting items of experience.

The applications of principles require a more involved logic: consider - Le Chatelier Principle, the Chloride Shift in gas transport in the blood, negative and positive feedback in almost any situation. Principles usually require an element of proof beyond demonstration via induction. Principles are not isolated - they are each embedded in an ever more complex network.

Lastly, the argument based on most of the people that I know are capable of thinking etc. etc. fails because most of the people I know are a biased sample: one does not associate with people who do not, in general at least share similar interests etc. How many people with whom you closely associate are unemployed most of the time? did not get past year 10 at school? at best can be said to have a skilled or semi-skilled occupation? or have a job based upon an organizational treadmill? The fact is that few actually have and/or use the intellectual skills required for serious academic work. Bear in mind too, that in any sphere of activity few have the abilities to inspire the remainder of the population.

EXTENSION TO PRIMARY SCIENCE

So much for senior secondary science: what can be concluded about the inclusion of science in earlier grades in school? In arguing for the above justifications no restriction was involved with respect to level of education except to imply that all tertiary education was essentially vocational. That is to say, all pre-tertiary education is primarily a preparation for a child to develop into a mature adult capable of leading a fulfilling life in a modern community. Thus, exactly the same justification would be used at all grades of primary and secondary education.

CONCLUSION

In conclusion, a new fad is not being offered. What has been shown is that the inclusion in the curriculum of much of what is taught (and not learnt) is upper secondary science today cannot be justified. What can be justified are curriculae which are information-based around the theme of the human species. In the foreseeable future Earth needs to be populated by people who live harmoniously together and strive for a common good. What one might like to see in the distant future as a result of a national educational system, and what the country needs in the near future, are two different goals at this point in time.

The Importance of the Darling Scarp in
Field Geology Courses

by

K.K. Sappal and S.A. Wilde

INTRODUCTION

The Darling Scarp marks the eroded western margin of the Archaean Yilgarn Block and its Tertiary weathering cap - the Darling Plateau. It parallels the north-trending Darling Fault, but occurs between 1 and 3 km inland of the present fault trace as determined by gravity and aeromagnetic measurements. The Scarp probably once marked the position of the Darling Fault, but has retreated inland due to subsequent erosion.

The Darling Fault is one of the major features on the Earth's surface, extending for almost 1000km along the western edge of the Australian continent. The zone was first active during the Archaean (c.2,600 m.y. ago), when the main sense of movement was in a lateral direction. There was periodic movement along this zone during later geological times, but it was not until the Phanerozoic (younger than 570 m.y.) that the present normal fault with west-block-down movement was generated. The west block, represented by the Perth Basin (figure 1), has a maximum downthrow of 15 km to the west. The main period of movement extended from the Late Triassic to the Middle Jurassic (200 to 170 m.y. ago) and would have led to the formation of the Darling Scarp. It was certainly in existence during the Cretaceous, when it controlled the deposition of the Donnybrook Sandstone.

The Darling Scarp is not clearly defined along the whole length of the Darling Fault. It loses expression north of Moora and south of the Donnelly River, near Pemberton. It is best developed between Gingin and Brunswick Junction, near Bunbury (figure 1), where it rises from foothills 75m above sea level to the crest of the Darling Plateau at an elevation of c.270m. The reason why the scarp is prominent here is because marine erosion during the Tertiary has stripped away the former cover of Cretaceous rocks between the Dandaragan and Blackwood Plateaux (Wilde, 1981).

THE IMPORTANCE OF THE SCARP IN GEOLOGICAL TEACHING

The Darling Scarp region is important for teaching some of the fundamentals of geology at school level for three main reasons:-

- (i) proximity to the Metropolitan Area,
- (ii) diversity of rock-types, and
- (iii) variety of specialized and applied geological uses

(i) Although this may appear obvious, the close proximity of the scarp is none the less a very important factor, since it means that both day and half-day trips can be easily scheduled. Coupled with the relative ease of access and the generally good quality of exposure of the rocks, this makes the area ideal for basic teaching purposes.

(ii) The Darling Scarp would probably be used in teaching for the above reason alone. It is fortunate, therefore, that a wide diversity of rock types are present in the area. These cover all major eons of geological time and there are representatives of the three major classes of rock - igneous, metamorphic and sedimentary.

(iii) In addition, features present in the area enable more advanced and specialized aspects of geology to be demonstrated. These include detailed examples of various rock processes, as well as more applied aspects of geology which are vital to our modern civilization.

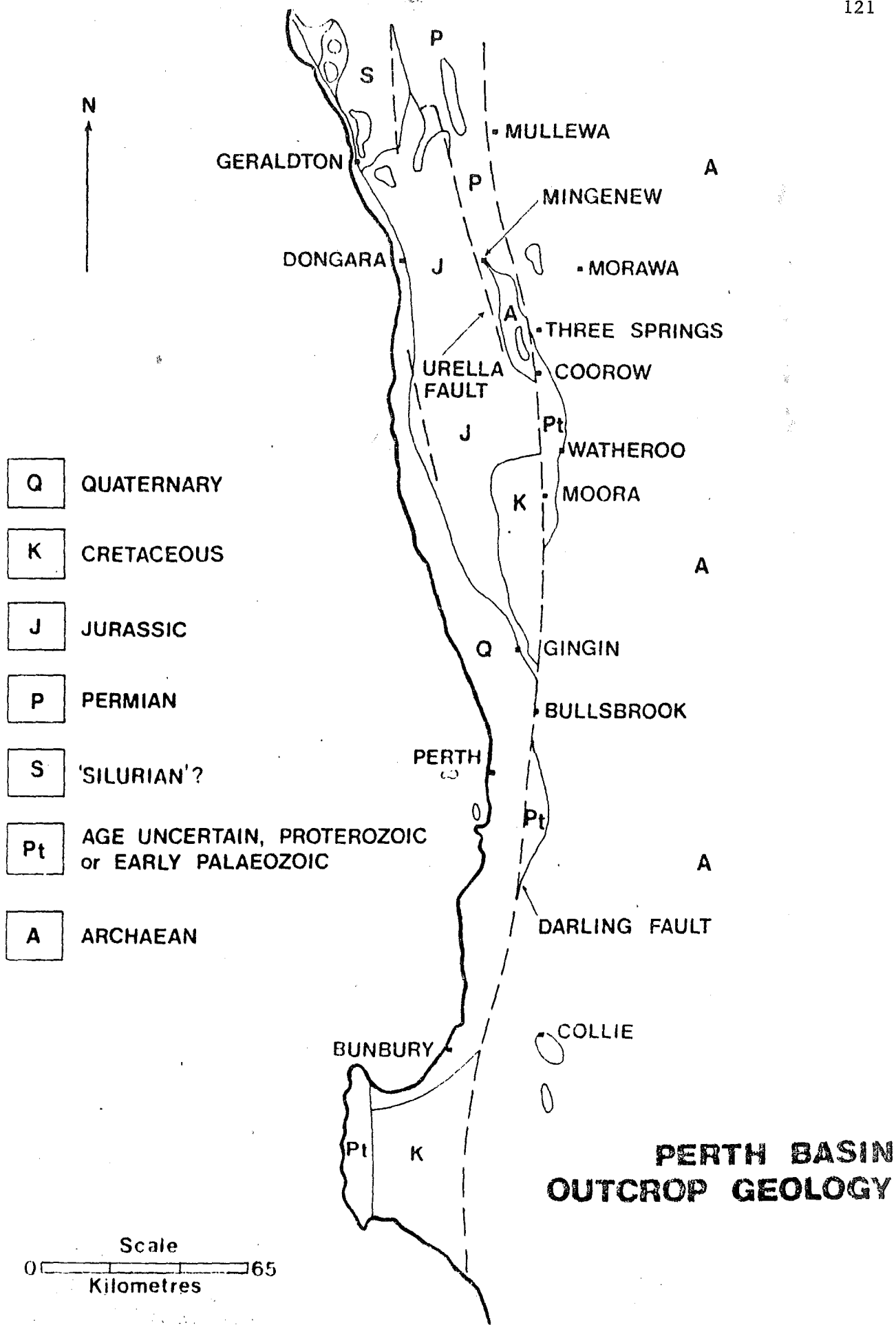


Figure 1. Darling Fault and outcrop geology of the Perth Basin.

In the following discussion, the Darling Scarp is taken to include not only the actual escarpment, but also adjacent areas to the west (Perth Basin) and the east (Yilgarn Block).

BASIC GEOLOGICAL TEACHING

Two of the fundamental aspects of geology that must be appreciated by students at an early stage are the subdivisions of geological time and the variety of rock types that can occur. The importance of the Darling Scarp area in these respects may be judged from the following summary of the main geological features of the region.

GEOLOGY AND STRATIGRAPHY

Archaean Rocks (>3,000 to 2,500 m.y. old)

The Archaean rocks of the Yilgarn Block consist of granite, gneiss, migmatite and metamorphosed volcanic and sedimentary rocks, together with some intrusive dolerite dykes. The rocks exposed in the Darling Range near Perth are mainly granites, migmatites and dolerites (figure 2). However, there are also three belts of metamorphic rocks which contain the oldest units in the area. The Chittering Metamorphic Belt extends along the Chittering Valley and consists of gneisses and schists. The Balingup Metamorphic Belt outcrops along the Darling Scarp southwards from Armadale, and consists of gneisses, schists, quartzites, banded iron formations and other thin units of metamorphosed igneous and sedimentary lithologies. The Jimperding Metamorphic Belt near Toodyay contains lithologies similar to the Balingup belt, although sedimentary rocks are more abundant. Rocks older than 3,200m.y. have been recorded from the Toodyay area (Nieuwland and Compston, 1981).

A belt of volcanic rocks occur near Boddington and have been defined as the Saddleback Group. They are about 2,700 m.y. old and are similar to the greenstones around Kalgoorlie.

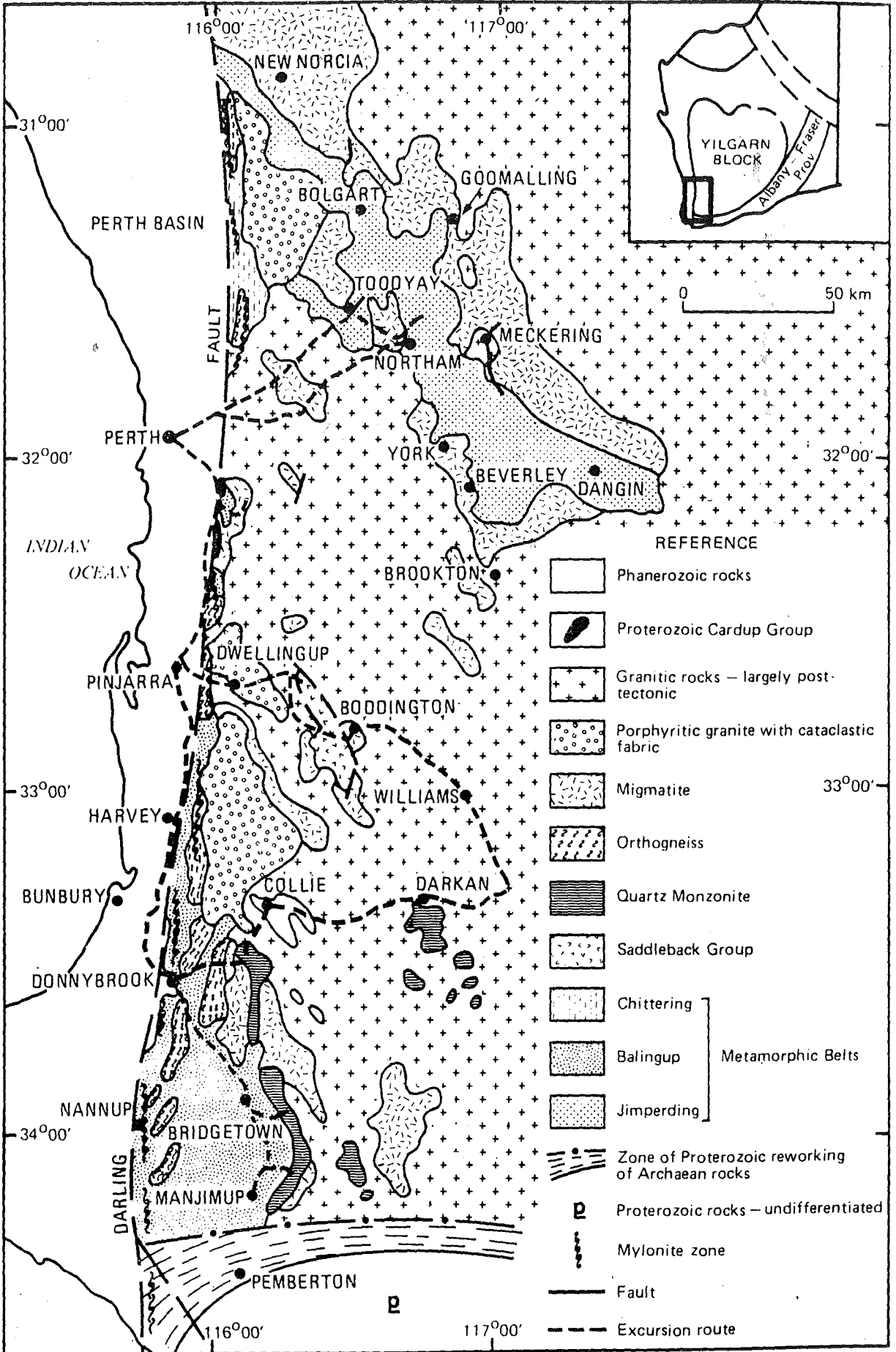


Figure 2 : Regional geology of the southwestern part of the Yilgarn Block. (from Wilde, 1980).

The whole area was invaded by granitic rocks around 2,600 m.y. ago, resulting in the formation of migmatites (mixed rocks) adjacent to the metamorphic belts and the emplacement of large granite batholiths throughout the region.

Additional minor intrusives of Archaean age include dykes and veins of pegmatite and dolerite.

Proterozoic Rocks (2,500 to 570 m.y. old)

Sedimentary rocks of Middle to Late Proterozoic age are exposed just east of the Darling Fault in a narrow belt extending from Gosnells to Serpentine. These are described as the Cardup Group and consist of conglomerate, sandstone, siltstone and shale, and were laid down as shallow marine sediments on the Continental Shelf. The contact of the Cardup Group with the underlying basement is unconformable, and dips 60° to the west.

This sequence is intruded by a Late Proterozoic suite of dolerite dykes, with an age of 560-590 m.y. (Compston and Arriens, 1968). There are also a large number of pegmatite dykes close to the Darling Scarp that yield a variety of Proterozoic ages (see Wilde, 1980).

Phanerozoic Rocks (570 m.y. to the present day).

Rocks of this age occur chiefly in the Perth Basin which developed as a rift-bounded trough (aulacogen) between the Yilgarn Block to the east and Greater India to the west.

The Phanerozoic history of the Perth Basin is summarised below:-

- i. Development of a downwarp in the Ordovician/Silurian, possibly between 500 to 395 m.y. ago, and the commencement of paralic sedimentation in the southern Perth Basin in the Early Permian (280 m.y. ago).
- ii. Formation of a deep graben in the centre of the downwarp and the maximum movement on the Darling Fault between the Late Triassic and Middle Jurassic, with the deposition of Mesozoic

sediments in the Perth Basin. During the Early Cretaceous (Neocomian), the super continent of Gondwanaland started to break up, and Western Australia separated from Greater India. The actual continental break-up occurred along a major fault near the original western margin of the Perth Basin, and not along the Darling Fault. There is no evidence to suggest that any movement has occurred on the Darling Fault since the Neocomian (125 m.y. ago).

Palaeozoic Rocks (570 to 230 m.y. old) are extensive at the base of the Perth Basin. The oldest rocks are Lower Permian in age and consist of glacial sediments overlain by extensive coal measures. During this period, prior to major vertical movement along the Darling Fault, sedimentation extended onto the adjacent Yilgarn Block. However, the only place where such rocks are still preserved is in the downfaulted basins at Collie and Wilga (Figure 2).

Mesozoic Rocks (230 to 65 m.y. old) are extensive in the Perth Basin.

Triassic and Jurassic sediments of approximately 5,000m thickness underlie the Swan Coastal Plain, and these have been encountered in a number of boreholes drilled in the Perth Basin. The only Mesozoic rocks exposed at the surface are of Cretaceous age (Figure 1) and these occur near Gingin. Lithologies include chalk and greensand (glauconite-bearing). Five km east of Muchea are the Bullsbrook Beds, consisting of conglomerate, sandstone and siltstone with plant fossils. Cretaceous rocks further south near Donnybrook (Figure 2) extend east across the Darling Fault.

Tertiary Rocks (65 to 1.8 m.y. old) occur in the sub-surface of the Perth Basin. However, the most extensive unit is laterite which caps the various lithologies in the Yilgarn Block. Laterite consists of a ferruginous/aluminous layer, generally 2m thick, that overlies a kaolinized pallid zone of variable thickness. Sand derived from ancient river courses may overlie the laterite.

Quaternary Rocks (1.8 m.y. to recent) are extensively developed in the Perth Basin. They are unconsolidated to weakly lithified and result from erosional and depositional processes related by sea level fluctuations. They are the youngest elements in the landscape and thus correspond closely to the geomorphic units (see Figure 3).

The above is just a brief outline of the geology of the Darling Scarp area, designed to show the great range in age of the rock units and their lithological variability. The interested reader is referred to some of the numerous publications on the area e.g. Bettenay et al (1960), Compston and Arriens (1968), Gee (1979), Johnstone et al (1973), Jones and Pearson (1972), McWhae et al (1958), Playford et al (1975), Sappal (1983), and Wilde (1980).

ADVANCED AND SPECIALIZED GEOLOGICAL TEACHING

The good quality of exposure along the Darling Scarp and the diversity of rock types allows the demonstration of important geological features. In addition, because of the proximity to the Perth Metropolitan Area, various aspects of applied geology can readily be studied.

The following five examples have been chosen to illustrate the variety of features that can be demonstrated; these are considered to be the main aspects, although numerous other features of specialist interest are available to the geological teacher with good local knowledge and a keen eye.

(i) Study of Rock-Forming Processes

The availability of well-exposed igneous, metamorphic and sedimentary rocks enables a variety of processes to be observed.

Igneous rocks are probably best examined in the large number of old, disused quarries present along the scarp. Fairly fresh surfaces allow the examination of igneous textures, whereas features related to dyke emplacement (such as chilled and sheared margins) are also readily observed e.g. Government and Mountain Quarries at Boya.

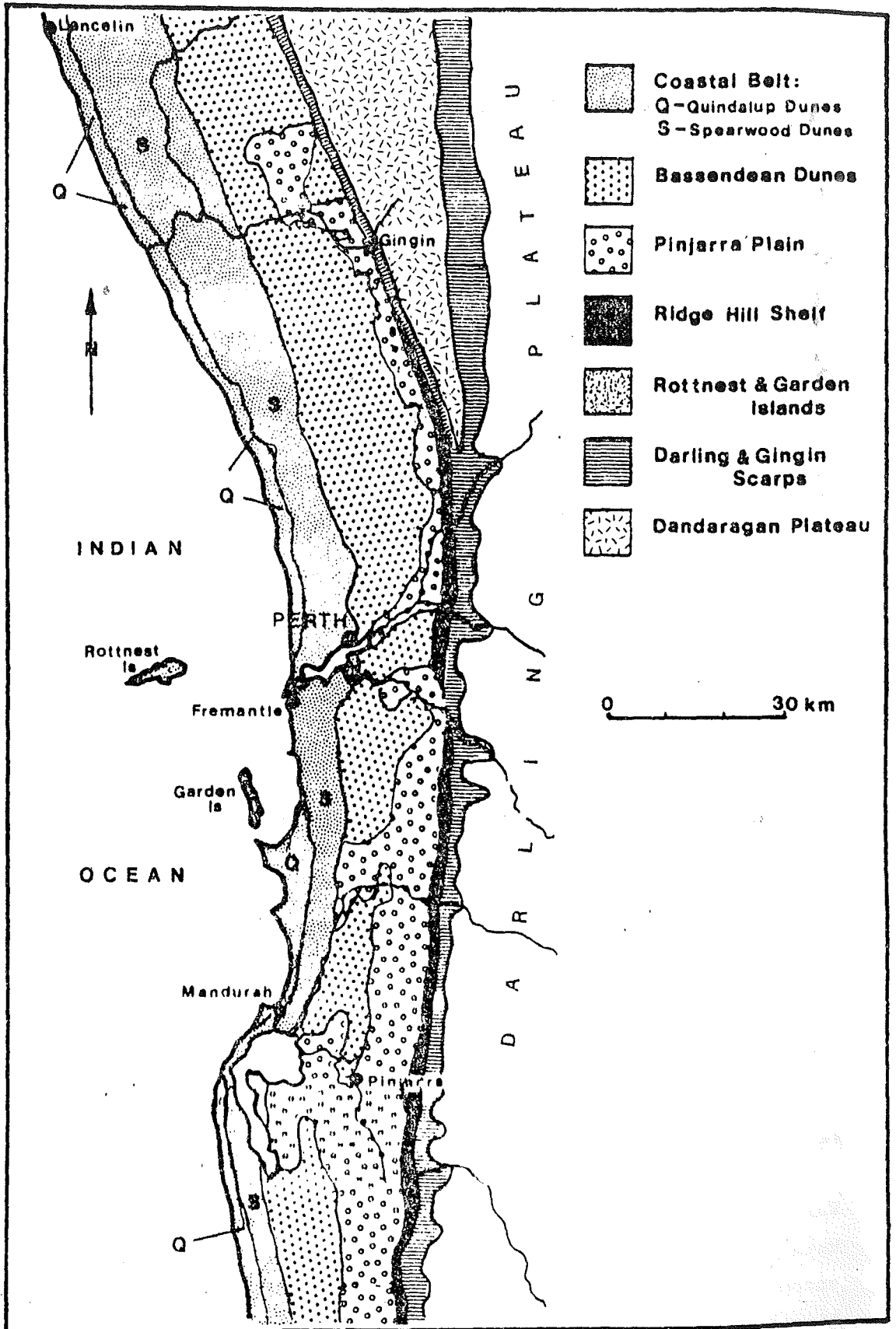


Figure 3 Geomorphic units of the Swan Coastal Plain and the Darling Plateau.

Metamorphic rocks are well-exposed around Toodyay, and along the Scarp in the Chittering Valley and south of Armadale. Various lithological and textural types are present and there is also a wide variety of well-developed metamorphic minerals e.g. kyanite, sillimanite and staurolite in the Chittering Valley.

Sedimentary rocks range from weakly lithified varieties along the coast to more indurated varieties near Gingin and Donnybrook. Permian coal measure sequences in the Collie Basin are well-exposed in operating open-cut mines and can be used to demonstrate facies interpretation and the measurement of palaeocurrent directions. Recent sediments near the coast illustrate styles of beach sedimentation, whereas sections through the laterite profile in both the Perth Basin and Yilgarn Block indicate the mechanisms of in situ formation of residual rocks.

(ii) Basic Measurement Techniques

Demonstration and practical "hands-on" experience using compasses and clinometers to measure azimuth and dip of planar surfaces is facilitated by the many good quarry exposures along the Darling Scarp. Bedding and cleavage surfaces are well-developed in weakly metamorphosed Cardup Group rocks in the Armadale and Byford districts. Joints and dyke trends are well-illustrated in the granitic quarries near Boya and Gooseberry Hill.

Once basic measurement skills have been taught, techniques in making elementary geological maps can be developed. These can be extended to more advanced exercises as skills develop.

(iii) Structural Geology

Following the establishment of the above techniques, there are several areas where important structural geological phenomena can be examined and measured.

Various fold styles are present in the Chittering and Jimperding Metamorphic Belts, and locally within the Cardup Group. Many of these are accompanied by cleavage or schistosity, together with the development of lineations.

Although the Darling Fault itself is not exposed in the region, intense shear zones of probably Archaean age (Blight et al., 1981) are well developed in the Swan Gorge at Walyunga Park and immediately east of Harvey. The rocks range from deformed granites, through augen gneisses, to mylonites.

(iv) Mining Geology and Quarrying

There is a great diversity of operations involving extraction of raw materials from the Scarp region. Historical changes in extraction methods can be reviewed by comparing disused quarries with operating ones e.g. in the aggregate operations near Perth or the preparation of sandstone facing blocks from Donnybrook.

There are also numerous limestone, sand and clay pits, and a wide variety of rock-types that are used in brick manufacture e.g. shale at Cardup, clay at Red Hill, schist in the Chittering Valley, etc.

Bauxite mining in the Darling Range and coal mining at Collie (presently the only source of coal in Western Australia) are examples of larger-scale extractive operations that may be studied.

(v) Engineering Geology

Some aspects of engineering geology can be demonstrated in past and present mining operations. In addition, the problems of slope stability and the mechanical properties of rocks are addressed in site works for the various dams that have been constructed along the Darling Scarp to supply fresh water to the Metropolitan area. Similar problems are encountered in certain road and railway constructions and a variety of engineering solutions, based upon rock-type, have been tried.

Although not comprehensive, the above examples clearly illustrate the importance of the Darling Scarp in teaching geology in the field.

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SELF PACED LEARNING MODULES FOR USE
WITH SENIOR COLLEGE PHYSICS CLASSES

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The wide range of learner attributes present in physics classes in the recently formed Senior Colleges creates a challenge for teachers who are required to cover a two-year syllabus in one year. One approach to solving the problem is to utilize self-paced learning modules that allow students to progress at a rate which is compatible with their learning needs. Since no such comprehensive learning modules existed which closely corresponded to present TAE physics syllabus topics these were designed and constructed in-house. This paper will report on the design, construction and implementation of two of these modules.

INTRODUCTION

Senior Colleges were established in Western Australia in 1982 as 'second chance' adult colleges catering mainly for students seeking Tertiary Admissions Examination (TAE) grades as specified by Tertiary Institutions for entrance purposes. These students are all post-secondary school age and come from widely different backgrounds including: overseas Government sponsored students; overseas private students; Australian students repeating TAE and Australian students attempting TAE for the first time.

All TAE subjects conducted at the Colleges follow prescribed core syllabi but condense the normal Year 11/12 programme into one year. In the physics programme as well as other difficult subjects, this places considerable strain on teaching staff in attempting to meet the needs of such widely varying student backgrounds and abilities. The use of self-paced learning materials appealed as a means of enabling students with higher aptitude to progress at an appropriate pace while allowing the teacher more time to assist less able students. Anderson and Artman (1972) reported that a self-paced individualized physics course ultimately helped all students achieve the specified level of mastery and retain competence over an extended period of time. Since the self-paced learning programmes (described herein) incorporate diagnostic tests that enable students to identify strengths and weaknesses, it is anticipated that more time will be allocated to studying weaknesses and that achievement will be higher than in traditional classes. Tuckman and Waheed (1981) indicated substantial gains in achievement using self-paced instructional techniques.

DESIGN

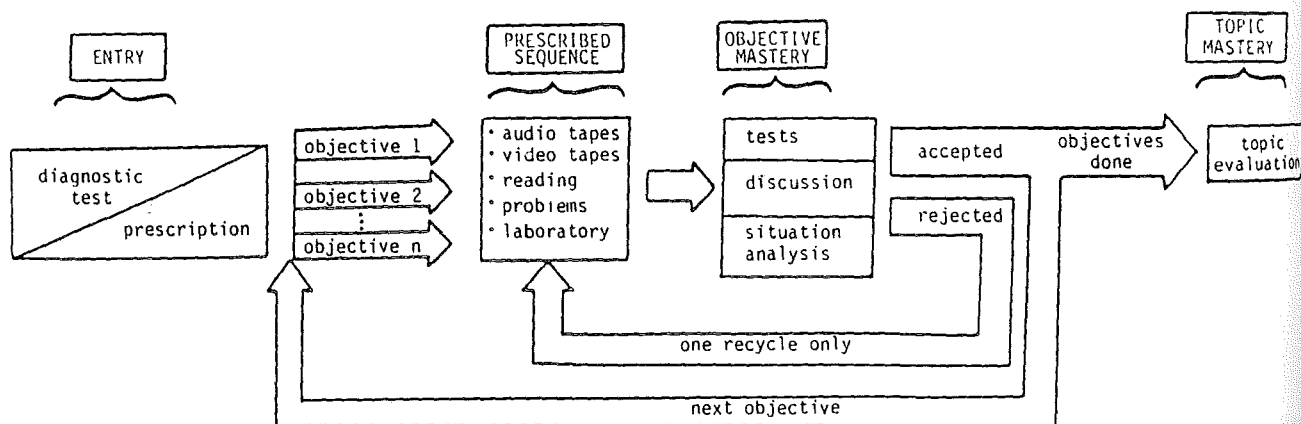
It was through extensive discussion and consultation over several months that a design for the project evolved. The main features to be incorporated included provision of

- self-diagnosis of learning needs
- complete teacher independence
- a wide range of audio-visual resources
- built-in remediation
- regular mastery testing

These features became reality through the construction of two Modules covering the topics Heat & Gas Laws and Current Electricity respectively.

Their structure is shown in Diagram I.

DIAGRAM I



The Diagnostic Tests were considered a crucial part of the programme since their accuracy in pinpointing student deficiencies would ensure that time was spent efficiently on only those sections that require attention. Considering that the Year 11/12 syllabus occupies only one year, efficiency of learning ranks as highly as effectiveness. The test for the Heat and Gas Laws Module consisted of twenty-four multiple choice items. Groups of these items, designed to test content covered in all objectives of the Module, were mixed randomly throughout the test. The Current Electricity Module

test was of similar design and consisted of sixteen items. Computer analysis of test data revealed that the internal consistency reliabilities of these two tests were found to be 0.76 and 0.86 respectively.

It was found upon inspection that the syllabus content for Heat and Gas Laws divided suitably into eight major objectives, while Current Electricity divided into four objectives. These objectives constituted the smallest units of study prescribed by the Diagnostic Tests and, as such, tended to be similar in design. A 'sequenced boxes' approach was adopted which provided references to audio listening, text and reference reading, video viewing and problem sets. Each sequence ended with an Objective Mastery Test. If a student performed above a pre-determined level on this test then progress to the next prescribed objective was automatic. A poor result on the test would channel the student back through a remedial loop of different learning activities. Although research seems to support the use of two to three remedial loops per objective, it was found that time, manpower and budget considerations precluded any further expansion of this programme. However, the modular nature of the materials produced would make future inclusion of other remedial loops possible.

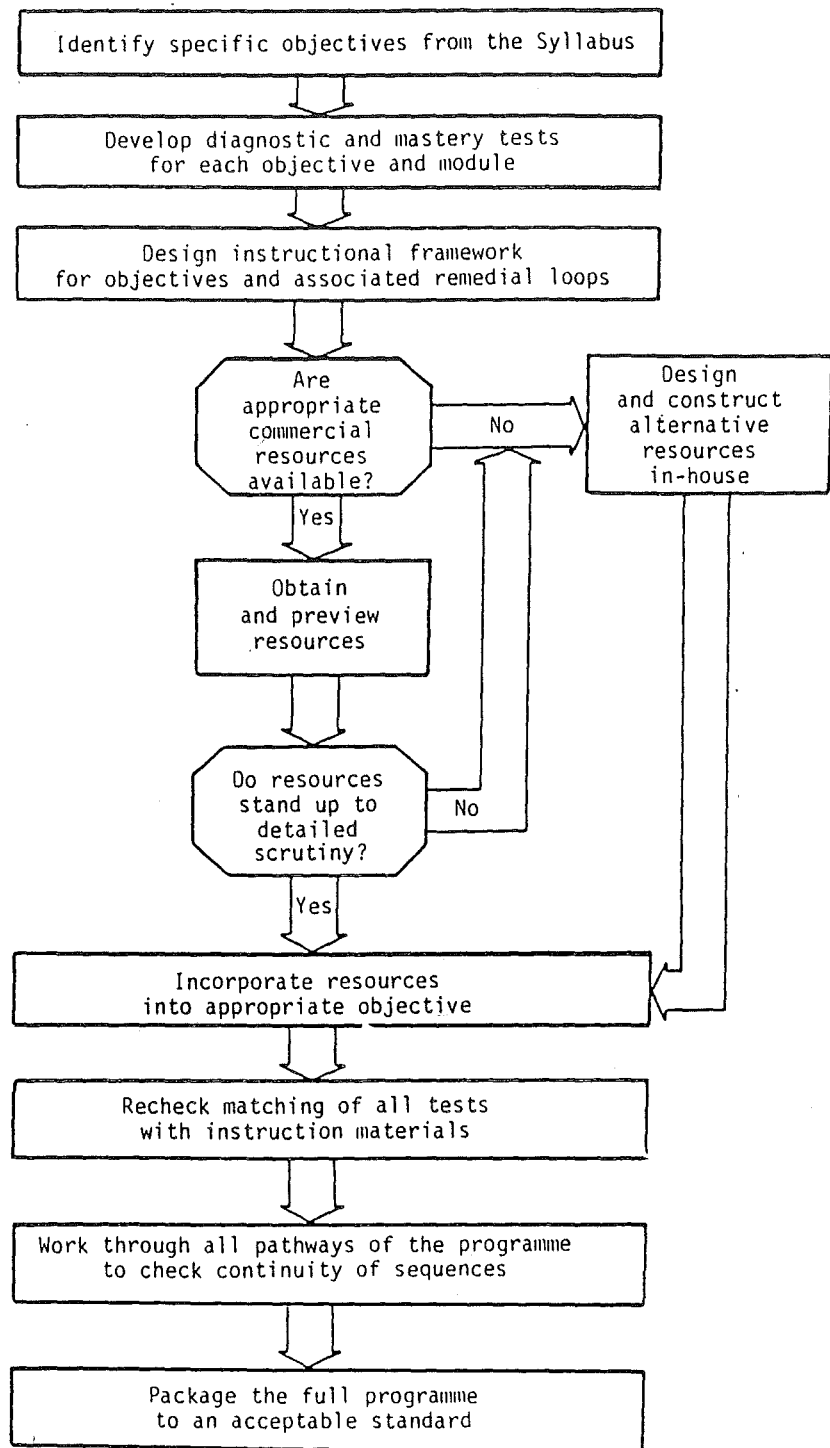
For the programme to be teacher-independent it was considered necessary to incorporate all diagnostic and mastery test solutions as well as fully-worked solutions to all prescribed problems into the Student Guides. These guides would form the instructional core of the programme and would be presented to the students in book form.

The final Module Mastery Tests for both the Heat and Gas Laws and the Current Electricity Modules were parallel forms of the corresponding Diagnostic Tests and their internal consistency reliabilities were found to be 0.82 and 0.75 respectively.

PRODUCTION

The production phase consisted of many steps and the flow-chart in Diagram II shows the sequence followed for the development of this project. The production section is included in this paper because it was felt that the finished curriculum materials may disguise the full extent of planning and development which took place. Prospective project developers may then be aware of the magnitude of their commitment should they consider undertaking a similar project. We were not so lucky.

DIAGRAM II



Production demanded considerable time and space, so it was decided to do this during the May school holidays. This allowed construction to proceed for long periods of time without interruption. Materials could also be left on work benches with minimal disturbance. The tasks to be completed were outlined on a blackboard. This made a visible display of process and progress and identified links and priorities among the requirements.

A format for the two Module Student Guides was adopted which in appearance was to be bold, friendly, and to quickly establish recognizable symbols to steer students through the various learning paths. This task was made much easier with the help of an excellent graphics book (Slater 1984). From rough scripted originals the book progressed to copy/typing composite paste-ups and finally to single pages ready for photo-copying, collation and binding. This portion of the programme construction made high demands on both time and effort. Prospective programme developers should be warned that carrying a project through to a final, good quality product involves overcoming many hidden time-consuming problems which are probably best left to a publisher. The Student Guides produced for this project ended up being in excess of one hundred pages each.

A limited amount of supporting audio visual resources for the Modules were obtained through commercial suppliers. However, there was difficulty in locating materials which specifically matched TAE physics syllabus requirements. This necessitated in-house production of twelve audio tapes and four video tapes to complement purchased resources. Study Cards were also constructed to accompany each audio tape. The main benefit of having control over the content of some of these materials was that short, 'single concept' tapes covering difficult sections could be made. Time and patience were necessary pre-requisites for this venture.

IMPLEMENTATION

Since the self-paced programme was introduced mid-year there was an opportunity to offer students some gradual exposure to the style of independent learning they would experience in the programme. Optional small-group tutorials and independent study sessions were introduced and contact with audio visual learning resources was promoted. Students were also referred more regularly to the text and reference collection which was purchased primarily to support the project. As a consequence, those classes which eventually undertook the self-paced programme adapted to it sooner than would normally have been anticipated. Despite this, some time was taken to explain the structure and philosophy of the programme when Student Guides were issued. Physical areas for application were explained and demonstrated. These areas included:

- an audio room with 10 study carrels.
- all laboratory activities set-up with instructional cards in physics laboratory.
- a section of the physics laboratory for synchronized slide/tape viewing,
- a quiet area for concentrated study and individual help - multiple copies of texts, references and journals were located here.
- an area of the lecture theatre designed as a 'study cubby' for relaxed reading and video viewing (earphone sound system).
- an audio-pack depot housing a rack for packaged audio tapes and associated study cards.
- a duplicate audio-pack depot with associated listening posts located in the Library - overnight borrowing privileges applied here.

Students were given complete freedom to plan and operate their study programme within the constraints of the diagnosed objectives. However, this did not mean students were denied individual assistance and tuition where required. Attitudinal surveys indicated that students enjoyed the freedom provided through this programme which allowed them to tailor what and when they studied to suit their individual needs.

Four class groups were involved in an experimental design to trial the materials over a six-week period. The self-paced 'treatment' classes are indicated in Table I.

TABLE I
Application of self-paced treatment

	Topic 1	Topic 2
Class 1	X_1	X_1
Class 2	X_2	X_1
Class 3	X_1	X_2
Class 4	X_2	X_2

X_1 = Traditional

X_2 = Self-paced

Extensive research data were collected using this design (Berry, 1984) and preliminary analysis has indicated favourable results on achievement testing for self-paced treatment groups (Berry and Tobin 1984).

CONCLUSION

This project proved to be of immense satisfaction and benefit to the developers and seemingly the recipients of it. It provided valuable insights into ways in which students learn and proved to be a substantial tool in promoting the College's adult ethos and autonomous learner goals. It was time and effort well spent.

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ARE THERE GENDER RELATED DIFFERENCES IN YEAR 10 STUDENTS'
ATTITUDES TOWARDS AND KNOWLEDGE OF ENERGY?

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ABSTRACT

Over the past decade there has been a growing interest in energy education amongst the adult and school-aged population. Whilst no specific energy education programmes are taught in W.A. schools, education about energy and energy related issues exist in the science and social studies curricula. Subsequently, students can become educated about energy and energy related issues through schooling.

The purpose of this study was to examine attitudes towards and knowledge of energy and energy conservation of a sample of year 10 students in Perth metropolitan high schools. The students had not been involved in a specific energy education programme. This paper focusses on the differences in performance, in respect to student gender, on instruments measuring attitude towards and knowledge of energy.

INTRODUCTION

In the past few years a ground swell has been growing concerning the position of females in society. This has resulted in the Federal government recently introducing sexual discrimination laws, the appearance of an abundance of journal articles regarding the position of girls in schools, business' advertising that they are equal opportunity employers and the appointment of an officer within the Education Department of W.A. to investigate discrimination in the curriculum.

In keeping with the concern for the performance of females in the school system, this paper presents data describing the similarities and differences between males and females in Year 10 metropolitan senior high

schools with regard to their attitude towards energy conservation and their knowledge of energy facts.

PROCEDURES

The Attitude Instrument

The Attitude Towards Energy Conservation (ATEC) instrument was based on a previous instrument developed by Koballa (1981). Students responded on a five point Likert scale from "Strongly Agree" to "Strongly Disagree". Also following the recommendation of Koballa (1981) and Shrigley (1983), the attitude instrument consisted of three subscales. Scale 1 reflected the personal nature of attitude, Egocentric items. Scale 2 reflected the consistency subconcept of personal involvement, Action-centred items. Scale 3 reflected the social influence subconcept, Sociocentric items. An example of an egocentric item is "I fail to understand why energy conservation is necessary". An example of an action-centered item is "Individuals can't do much to conserve energy". An example of a sociocentric item is "People should drive small cars in an effort to conserve energy". Cronbach-alpha reliabilities for the three scales were established at 0.82, 0.49 and 0.79 respectively (n=359). The overall reliability for the attitude instrument was 0.85 (n=359).

The Knowledge Instrument

The knowledge instrument contained a number of True/False statements. The statements were based on a USA study conducted by the National Centre for Education Statistics and were content validated by using the five most commonly used text books in WA. Due to the large number of statements on the instrument it was decided to split the instrument into two forms, each with 50 statements, of which 20 statements were common to both forms A and B. Each form of the instrument contained statements specifically dealing with conservation of energy. There were 14 such statements on form A and 15 statements on form B. Eight of these statements were common to both forms.

Cronbach alpha reliabilities of 0.77 and 0.78 were achieved for forms A and B respectively.

Student Sample

The students were from middle class socio-economic backgrounds and were drawn from 3 Perth metropolitan senior high schools. The 333, year 10 students were administered the instruments in the final weeks of third term. All year 10's in each school were sampled. Approximately half the students in each school completed form A of the knowledge instrument and the other half completed form B. All students completed the ATEC instrument.

RESULTS

The results of the analysis of the ATEC instrument data for each gender are shown in Table 1.

TABLE 1

Year Ten Student Performance on the ATEC Instrument Measuring Their Attitude Towards Energy Conservation According to Gender

Group	N	Egocentric x ± s.d.	Action-centred x ± s.d.	Sociocentric x ± s.d.	Total x ± s.d.
A Male	93	1.78 ± 0.58	2.06 ± 0.59	2.66 ± 0.76	2.00 ± 0.50
Female	84	2.01 ± 0.54	2.21 ± 0.64	2.69 ± 0.70	2.14 ± 0.48
F-ratio		7.67**	2.70	0.07	3.60
B Male	73	1.72 ± 0.56	2.19 ± 0.72	2.60 ± 0.68	2.15 ± 0.53
Female	83	1.93 ± 0.50	2.26 ± 0.50	2.68 ± 0.56	2.27 ± 0.39
F-ratio		5.81*	0.51	0.62	2.90
** p < 0.01		* p < 0.05			

Note: For the attitude instrument, lower scores on the five point scale indicate a more positive attitude

On the three subscales males showed a more positive attitude than females. However, only on the egocentric subscale was the difference statistically significant.

The results of the analysis on the knowledge of energy instrument are shown

in Table 2. Males on both forms of the instrument showed a greater knowledge of energy and energy conservation than females. These differences were all statistically significant at the 1% level of confidence.

TABLE 2
Year Ten Student Performance on the Knowledge of Energy Instrument

Group	Gender	Conservation Subscale (%)	Total Score (%)
		$x \pm s.d.$	$x \pm s.d.$
A	Male	61 \pm 17	58 \pm 13
	Female	54 \pm 17	48 \pm 12
	F-ratio	7.26**	19.96**
B	Male	58 \pm 15	56 \pm 14
	Female	52 \pm 15	48 \pm 14
	F-ratio	6.95**	14.12**

** $p < 0.01$ * $p < 0.05$

Further inspection of the data could not show a specific content area where females showed a weakness in their knowledge of energy or males showed a greater strength in their knowledge of energy. On form A of the instrument there were 20 statements where males outscored the females by more than 10%. On form B of the instrument there were 23 statements. Five of the statements in form B were also common to form A. In no cases did the females outscore the males by more than 10% on either form of the instrument. In particular, the following statements showed differences of more than 30%.

Some telephone lines in outback Australia are powered by solar cells

In one hour, a 60 watt light globe uses less energy than a 100 watt light globe

The closer a power station is to a city, the more energy that will be lost in transmission

DISCUSSION

The results of this study are supported by other researchers who have reported similar trends. The nature of the instrument causes it to fall into the province of physical science rather than biological science. Females do not perform as well in the physical sciences as they do in the biological sciences (Girls in Science and Technology). Females also perceive science, in particular physical science, as a masculine subject (Weinreich and Haste, 1981). This masculine image can be a strong deterrent for females to perform well especially when they are under pressure to be recognised as feminine (Girls and Physics, 1982; Kelly, 1981; Girls and Science, 1980). This image is not surprising considering the predominance of males in the science and engineering fields as well as male domination within school science.

CONCLUSION

To improve female student performance in science, it is likely that female attitudes towards science must be improved. However to do this societal and parental influences must change and to a large extent these influences are beyond the reach of the school. Based on these data, year ten females' attitudes towards energy conservation are less positive than males. Similarly, females are less knowledgeable about energy than males. If these data are generalizable to the school population of year ten students in WA who are completing their required formal schooling, two approaches are necessary in order to ensure that females are not disadvantaged by schooling for their later life. Specifically science lessons need to contain material that is of equal interest and as easily comprehended by females as well as males. Second, based on the egocentric scale especially, science lessons need to be presented in such a manner that all students need to closely examine their own behaviour in terms of energy and its use.

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THE ROLE OF COGNITIVE FACTORS IN
CHEMISTRY ACHIEVEMENT

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Abstract

The upper school chemistry course is generally considered to be conceptually demanding and assumes considerable knowledge in a number of concepts, facts and principles in chemistry. Controversy exists in literature regarding the contribution of cognitive variables such as the "developmental level" and "prior knowledge" in science achievement. Research evidence also indicates that other cognitive variables such as intelligence, disembedding ability and memory capacity also contribute to achievement in chemistry. The study reported in this paper outlines an investigation of the role of all these cognitive variables on achievement in three aspects of TAE chemistry, viz., laboratory application, problem solving and achievement. Standardized tests were administered to groups of year 11 chemistry students in several metropolitan high schools in Perth, Western Australia. Data analyses indicated that developmental level followed by prior knowledge predict chemistry achievement better than the other cognitive variables. Problem solving ability was found to be significantly related to laboratory application and examination performance. Implications of these findings are discussed in the concluding section of this paper.

Introduction

Chemistry as a subject option in the upper school is generally recommended for the academically able students. The aims of the TAE chemistry course (The Board of Secondary Education, 1981, p. 65) recommends that students should be able to

- . apply fundamental facts and principles,
- . use appropriate conceptual and theoretical framework,
- . perform chemical calculations using the mole concept and
- . demonstrate competence in process skills.

It is obvious that mastery of these skills require a high level of intellectual ability, memory capacity and intelligence in addition to appropriate prior knowledge. Though such applications are required, it has been observed that much of the content is rote learnt (O'Loughlin & Dekkers, 1981). Cole, Watts and Bucat (1978)

also "recommend that the bulk of the materials..... be learnt and remembered before the principles course is begun." The principles course that Cole, Watts and Bucat (1978) referred to such as concepts like bonding, heats of reaction, equilibrium are seen to be even more conceptually demanding. Ingle and Shayer (1971), who analysed the Nuffield chemistry course reported that a full comprehension of many of the concepts required the Piagetian formal operational thinking. Swartney (1969) who investigated the CHEM study found that many students who studied this course could not express many of the concepts in their own words nor could they apply them in problem solving tasks. Gillespie (1971, p. 1), writing about the CHEM study course stated that "the old uncomprehending learning of facts was replaced by the new uncomprehending learning of theories." O'Loughlin and Dekkers (1981) suggested that the conceptual level of much of the course was not compatible with the cognitive level of students. Chiappetta (1976) who reviewed a number of studies which assessed the cognitive level of a number of students found that more than 50 percent of the students of age 16 years still functioned at the concrete level.

If students are not able to understand concepts, the tendency is to memorize as many algorithms, facts and ideas as possible. In fact, Cole, Watts and Bucat (1978) have emphasized that "the ability to recall correctly a large number of facts..... is a great asset to science students." Elaborating on the role of memory learning, Kellett (1979) has advanced the concept of the "working memory capacity". Kellett (1979) advocated that it was possible to increase the "effective working memory capacity" of students even though nothing could be done about the number of "chunks" of information (Miller, 1956) or the "M" powers (Burtis & Pascual-Leone, 1974). Efficient chunking or chunking in large size should enable a subject with a lower "M" power to handle tasks with average information content. Hence memory capacity is seen to play an important role in achievement.

Ausubel's (1967) concept of "meaningful verbal learning" has gained wide currency through the successful studies by Novak (1978) who strongly advocates a shift to the Ausubelian model by all those

concerned with verbal transmission of knowledge as a key factor contributing to understanding and hence achievement. Emphasis is placed on the comprehension of concepts and the inter-relations among concepts. As successful links between prior knowledge as anchoring concepts and new knowledge are established, meaningful learning is said to occur. The implication is that students with the appropriate prior knowledge will be able to comprehend better and therefore achieve better.

Studies by Witkin et al. (1974), Saarni (1973) and others have indicated that "field independence" - the ability to disembed relevant information from an irrelevant background, contributes significantly to achievement in mathematics, the sciences, engineering and architecture domains than "field dependence". Witkin (1954) found that this cognitive style to be stable even in the face of deliberate attempts to make a change. As chemistry requires the ability to be analytical, the ability to locate and use data from problem solving tasks, tables, graphs etc., it is reasonable to expect the influence of field independence/dependence in achievement in chemistry.

Cronbach (1972) who reviewed several studies on the relationship between intelligence tests and school success found that in most cases the correlations were positive and significant. Harvey (1981) also found high correlations between IQ and achievement in science.

There is also a wealth of research evidence to suggest the relationships among the various cognitive variables themselves such as field independence and skill acquisition (Skubic, 1971), reasoning ability and intelligence (Eysenck, 1974), intelligence and Piagetian developmental level (Novak, 1978) and intelligence and mathematical ability (Eysenck, 1974). An understanding of the types and nature of such relationships should enable science teachers get a deeper insight into the nature of their roles in influencing achievement in chemistry.

Method

Students enrolled in year 11 TAE chemistry course were tested

to determine their 1) level of performance in logical thinking 2) ability to disembed relevant information from irrelevant background 3) memory capacity in "M" powers, 4) prior knowledge about lower school chemistry, and 5) IQ scores (tested by the schools and made available for this investigation). Following the assessment of these predictor variables, author developed and validated tests in three areas of chemistry, viz., problem solving, laboratory skill and achievement in chemistry were administered.

Subjects

Subjects were 370 students (220 males and 150 females) with a mean age of 15 years and 6 months, enrolled in the year 11 TAE chemistry course as full time students in high schools in the Perth metropolitan area. Eleven schools participated in the study, four independent and seven government schools.

Predictor Variables

DEVELOPMENTAL LEVEL. The Test of Logical Thinking (TOLT) developed by Tobin and Capie (1981) was administered during Term I. This is a group paper and pencil test consisting of 10 items based on five reasoning modes, viz., proportional reasoning, control of variables, correlational reasoning, probabilistic reasoning and combinatorial reasoning. For each item the subject is required to select an answer from five alternatives and a reason from five alternatives. Scores on the test were treated as a continuous distribution. As this test assessed "formal reasoning", scores above 3 were considered to represent some degree of formal reasoning ability. Reliability (Cronbach alpha) for this sample was found to be 0.85. The reliability estimates of the original test was reported as from 0.80 to 0.85.

DISEMBEDDING ABILITY. Subjects ability to disembed relevant information from irrelevant background was assessed by means of the Hidden Figures Test (ETS, 1982). This is a timed test in which the subject's task is to locate and outline simple figures concealed in complex ones. Internal consistency (Cronbach alpha)

for this sample was found to be 0.91.

MENTAL CAPACITY. FIT: The Figural Intersection Test (Burtis & Pascual-Leone, 1974) was used to measure mental capacity. The FIT is a group test consisting of 42 items. For each item, the subject must place a point marking the intersection of from two to eight overlapping figures. An item with eight overlapping figures theoretically requires a mental capacity of seven for successful completion, while an item with seven overlapping figures requires a mental capacity of six and so on. Reliability of FIT has been found to be in the 0.80's (Burtis & Pascual-Leone, 1974). A reliability coefficient was not calculated for the present sample as more than 90 per cent of the subjects performed very well.

PRIOR KNOWLEDGE. Prior knowledge in chemistry was assessed by means of a 20 multiple-choice item test. The items were selected from the Science Item Bank (ACER, 1978). When administered to a group of year 11 chemistry students twice with an interval of a week in between, the test-retest reliability was found to be 0.81 ($p < 0.05$). Internal consistency (Cronbach alpha) was found to be 0.87. Two of the test items appear below.

1. Most hydrogen atoms consist of
 - a. a neutron with an orbiting electron
 - b. a proton with an orbiting electron
 - c. a proton orbiting a neutron
 - d. an electron with an orbiting neutron
2. If one mole of oxygen atoms has 6.02×10^{23} atoms, then the number of atoms of oxygen in mole of oxygen molecules is
 - a. 3.01×10^{23}
 - b. 6.02×10^{23}
 - c. 12.04×10^{23}
 - d. 18.06×10^{23}

INTELLIGENCE. IQ scores from the ACER Intermediate D Test (ACER, 1978) were available from five schools (a sample of 129 subjects,). Some schools did not use IQ tests at the time of entry to the upper school. So, IQ scores obtained at the time of entry to the lower school (year 8 in Western Australia) were used for this study. This was considered justified due to the reported high correlations between ages of 8 years and after (Bayley & Oden in Krech, D. et al., 1969, p. 663).

Achievement Measures

To assess achievement in chemistry three tests were given during Term II; a laboratory application test, a problem solving test and an achievement test. School examination scores in chemistry were used as additional performance variable.

LABORATORY APPLICATION. This was assessed by a laboratory application test which contained 21 filling-in-the-blanks type questions. Subjects were shown a chemical reaction based on which they were asked to hypothesize, predict, reason why and write equations based on their observations. Internal consistency (Cronbach alpha) was found to be 0.92 for this sample. Two of the items appear below.

1. What is the chemical name of the solution formed when sulfuric acid reacted with the heated powder? How did you arrive at this conclusion?
2. What was the substance that was formed on the iron nail? How did you arrive at this conclusion?

PROBLEM SOLVING ABILITY. This was assessed by a test that contained two problems. Based on the course covered in the schools and consistent with the aims of the TAE chemistry syllabus (BSE, 1981, p. 55), both the problems were related to the mole concept, though the first problem involved an indirect application of this concept along with the idea of percentage composition. The second problem was more direct involving stoichiometric relationships between mass and mass, mass and volume, and mole to mole. The first problem is given below.

1. Two large iron ore deposits have been found within 20 kilometres of each. The first deposit is known to contain 40 per cent of haematite, Fe_2O_3 . What mass of the ore-body should be dug out from the earth to obtain 350 tonnes of iron?
The second ore-body is estimated to contain 400 tonnes of iron in the ore-body-mass of 1600 tonnes. Assuming all other requirements for ore treatment and transport are equal, which deposit is economically more viable?

The internal consistency (Cronbach alpha) for this test when administered to the sample in the study ($n=275$) was found to be 0.87.

ACHIEVEMENT IN CHEMISTRY. This was assessed by a 20 item multiple-choice test. Items were selected from ACER-Chemtic-YEAR 12 and ACER-Chemtic-Year 12 Supplement (ACER, 1981). Questions were based on four areas of the course; kinetic theory, laboratory processes, periodic table and the mole concept. Two example from the test are given below.

1. An oxide of a metal X is prepared by burning the metal in oxygen. It is found that 1.04 g of X yields 1.52 g of the oxide. Assuming the relative mass of the metal to be 52, the empirical formula of the oxide is

a. X_3O_2 b. XO_3 c. X_2O_3 d. X_3O

2. 5.0 L of nitrogen gas is at a temperature of -40°C and 100.0 kPa pressure. The volume of nitrogen at 0°C and 101.3 kPa pressure is

a. $5 \times \frac{101.3}{100} \times \frac{273}{(273-40)}$ L. b. $5 \times \frac{100.0}{101.3} \times \frac{273}{(273+40)}$ L.

c. $5 \times \frac{100}{101.3} \times \frac{273}{(273-40)}$ L. d. $5 \times \frac{101.3}{100.0} \times \frac{(273-40)}{273}$ L.

FIRST TERM EXAMINATION PERFORMANCE. Examination scores for chemistry were obtained from all the participating schools. Though each school administered its own test, all of them used the same basic format and approximately the same content area. For the purposes of correlation and regression analyses the scores from each school were standardized setting a mean of zero and a standard deviation of 1.

Results

On the test of logical thinking, 90 per cent of the Ss scored 3 and above out of a maximum of 10 and were deemed to have some degree of formal reasoning ability.

On the Hidden Figures Test, using the quartile procedure, the top 25 percent, who obtained a score of 25 or more out of a maximum of 32 were designated field-independent and the bottom 25 per cent who scored 7 or less were designated field-dependent and the rest field-intermediate.

Applying the scoring procedure given in Bereiter and Scardamalia (1979), 90 percent of the Ss were found to have a mental capacity

of 7 when the Figural Intersection Test was used. The remaining ten per cent showed a range of mental capacities from 1 to 6.

On the test of prior knowledge, 8 per cent of the Ss who scored less than 10 out of a maximum of 20 were considered to have a low prior knowledge, 58 per cent who obtained scores between 10 and 15 were considered to have moderate prior knowledge and 34 per cent of the Ss who scored 16 and above were considered to have a high prior knowledge.

Descriptive statistics for the predictor and performance variables are given in Table I.

Relationships with Achievement

Table II shows intercorrelations of the predictor variables, the three separate performance measures and the standardized examination scores. For all the other tests, subject raw scores were used for the purpose of this analysis and subsequent regression analyses. It could be seen that developmental level correlated moderately with laboratory application, problem solving, examination performance and achievement test performance (0.34, 0.39, 0.38 and 0.34 respectively, $p < 0.001$). Prior knowledge correlated with laboratory application, problem solving, examination performance and achievement test performance (0.33, 0.28, 0.35 and 0.23 respectively, $p < 0.001$). Field-independence is found to be mildly correlated with examination performance (0.20, $p < 0.001$). IQ is found to be negatively correlated with prior knowledge and laboratory application (-0.38, -0.33 respectively, $p < 0.001$). Memory capacity is not found to be correlated with any of the performance variables. Developmental level followed by prior knowledge appear to be the key predictor variables correlated with the performance variables.

To determine the amount of variance accounted for by the best linear prediction equation of the five predictor variables, four multiple regression analyses were performed, one for the school examination score and one each for the three performance test scores. The results of these analyses are shown in Tables III-V.

TABLE 1

Descriptive Statistics for Predictor and Performance Variables Together with
Reliability Measures

Cognitive Variables	Instrument	Sample Size	Mean \pm Standard Deviation	Maximum Score Possible	Cronbach Alpha Reliability
Prior Knowledge	Test of Prior Chemistry Knowledge	367	14.4 \pm 2.4	20	0.87
Field Independence	Hidden Figures Test	344	13.9 \pm 7.3	32	0.91
Developmental Level	Test of Logical Thinking	346	7.3 \pm 2.5	10	0.85
Memory Capacity	Figural Intersection Test	324	6.8 \pm 0.7	7	----
Laboratory Application	Laboratory Application Test	275	14.2 \pm 4.7	21	0.92
Achievement	Achievement Test	280	10.1 \pm 3.3	20	0.89
Achievement	School Examination	360	59.5 \pm 17.8	100	----
Intelligence	IQ Scores	129	118 \pm 5.5	---	----
Problem Solving Ability	Problem Solving Test	275	5.1 \pm 3.1	12	0.87

TABLE 2

CORRELATIONS BETWEEN VARIABLES

	Prior Knowledge	Field Independence	Developmental Level	Memory Capacity	Laboratory Application	Problem Solving	IQ	Exam Score	Achievement
Prior Knowledge	1.00	0.07	0.30 ^a	0.08 ^a	0.33 ^a	0.28 ^a	-0.38 ^a	0.35 ^a	0.23 ^a
Field Independence		1.00	0.36 ^a	0.16 ^b	0.04	0.06	-0.01	0.20 ^a	0.16 ^a
Developmental Level			1.00	0.19 ^a	0.34 ^a	0.39 ^a	-0.11	0.38 ^a	0.34 ^a
Memory Capacity				1.00	0.07	0.04	0.07	0.07	0.08
Laboratory Application					1.00	0.33 ^a	-0.33 ^a	0.40 ^a	0.30 ^a
Problem Solving						1.00	-0.07	0.44 ^a	0.40 ^a
IQ							1.00	0.15 ^b	-0.17
Exam Score								1.00	0.43 ^a
Achievement									1.00

a = $p < 0.001$, b = $p < 0.05$

TABLE III
Multiple Regression Summary Table for Prediction
of Performance in Laboratory Application

Predictor Variable	Multiple R	R Square	% of Variance Explained (cumulative)
Prior Knowledge	0.38	0.15	15%
IQ	0.45	0.20	20%
Field Independence	0.50	0.25	25%
Developmental Level	0.51	0.26	26%
Memory Capacity	0.52	0.27	27%

Table III shows a multiple R of 0.52 among the predictor variables and the laboratory application test score accounting for 27% of the laboratory score variance. Prior knowledge, IQ and field-independence appeared to be the best predictors accounting for 15%, 5% and 5% of the variances respectively.

TABLE IV
Multiple Regression Summary Table for Prediction
of Performance in Problem Solving Ability

Predictor Variable	Multiple R	R Square	% of Variance Explained (cumulative)
Developmental Level	0.50	0.25	25%
IQ	0.52	0.27	27%
Prior Knowledge	0.53	0.28	28%
Memory Capacity	0.53	0.28	28%

Table IV shows a significant multiple R of 0.53 among the predictor variables and the problem solving ability.

Table IV shows a significant multiple R of 0.53 among the predictor variables and the problem solving ability accounting for 28% of the variance in problem solving ability. Developmental level emerged as the best predictor accounting for 25% of the variance followed by IQ, prior knowledge, and memory capacity accounting for 2%, 1% and 0.4% respectively. The field-independence variable was not entered into the regression equation due to an insufficient tolerance level.

TABLE V
Multiple Regression Summary Table for Prediction
of Performance in Multiple-Choice Achievement Test

Predictor Variable	Multiple R	R Square	% of Variance Explained (cumulative)
Developmental Level	0.44	0.19	19%
IQ	0.46	0.21	21%
Field Independence	0.47	0.22	22%
Prior Knowledge	0.47	0.22	22%
Memory Capacity	0.47	0.22	22%

Table V shows a multiple R of 0.47 among the predictor variables and the multiple-choice item test score accounting for 22% of the variance. Developmental level proved to be the best predictor accounting for 19% of the variance followed by IQ and field-independence, respectively for 2% and 1% of the variance.

Standardized examination scores were also regressed on the predictor variables which showed that 24% of the variance in the examination scores could be accounted for by developmental level, IQ, prior knowledge and field-independence.

Tables III-V provide support for the hypothesis that developmental level is the best predictor of performance in multiple-choice achievement and problem solving ability. This appears to be consistent with the findings of Ingle and Shayer (1971), Kavannaugh and Moomaw (1981), Shayer and Adey (1982) and Lawson and Renner (1983). The finding that prior knowledge is a good predictor of performance in laboratory application where knowledge about past experience in identification, familiarity of methodology are essential is consistent with the Ausubelian theory (1963; Novak, 1978). The finding that IQ is the second best predictor in each of the performance variable is also consistent with the research findings of Cronbach (1970), Eysenck (1974) and Harvey (1981).

The finding that memory capacity did not account for any unique variance in any of the performance tests could perhaps be due to the fact that 90 per cent of the sample tested received the maximum score possible in the Figural Intersection Test. If it is true, as Burtis and Pascual-Leone (1974) have proposed, that mental capacity is maximum by the age of 15-16 years of age, then clearly a majority of the sample in this study had already reached the maximum, restricting the range of scores to only 10% of the sample. It is interesting to note that Lawson (1983) used this test for the first year college students with a mean age of 22.8 years and found that memory capacity is a predictor of performance in essay items.

Disembedding ability contributes in a small way to performance in achievement test, examination performance and laboratory application. It can be said that field-independence is an asset to any chemistry student as far as general achievement is concerned.

Discussion

The present results are of sufficient magnitude to suggest that these cognitive variables investigated here are of sufficient importance to warrant the attention of teachers and science educators.

It is now possible to attempt a causal explanation of the relationships using the path analysis which is primarily a method of working out logical consequences of a variable that is changed which effects a change in another variable. Path analysis, originally used by Sewell Wright (in Nie et al., 1975) is widely used in social

sciences. Though path analysis does not generate any new statistics, it enables using, displaying and interpreting data from standard regression equations.

The path analysis model developed here is based on selecting a set of variables consisting of variables selected on the basis of research, time ordering, and theoretical considerations. Additionally a residual variable is associated with some variables in the model to account for external influence. While the directed paths are often referred to as "causal paths" their inclusion in the model should not be interpreted as true causality. This is the researcher's best guess as to how variables might fit together.

The path model shown in figure 1 is based on the following set of criteria.

- . The paths are indicated by arrows from cause to effect.
- . Standardized regression coefficients or Beta estimates indicate the strength of these paths.
- . Beta estimates greater than twice the standard error and with a significant F ratio are only included as paths.
- . Where Beta estimates are not significant, correlation coefficients are used to indicate the relationships
- . External influences or unanalysed causes are shown by arrows from outside the model.

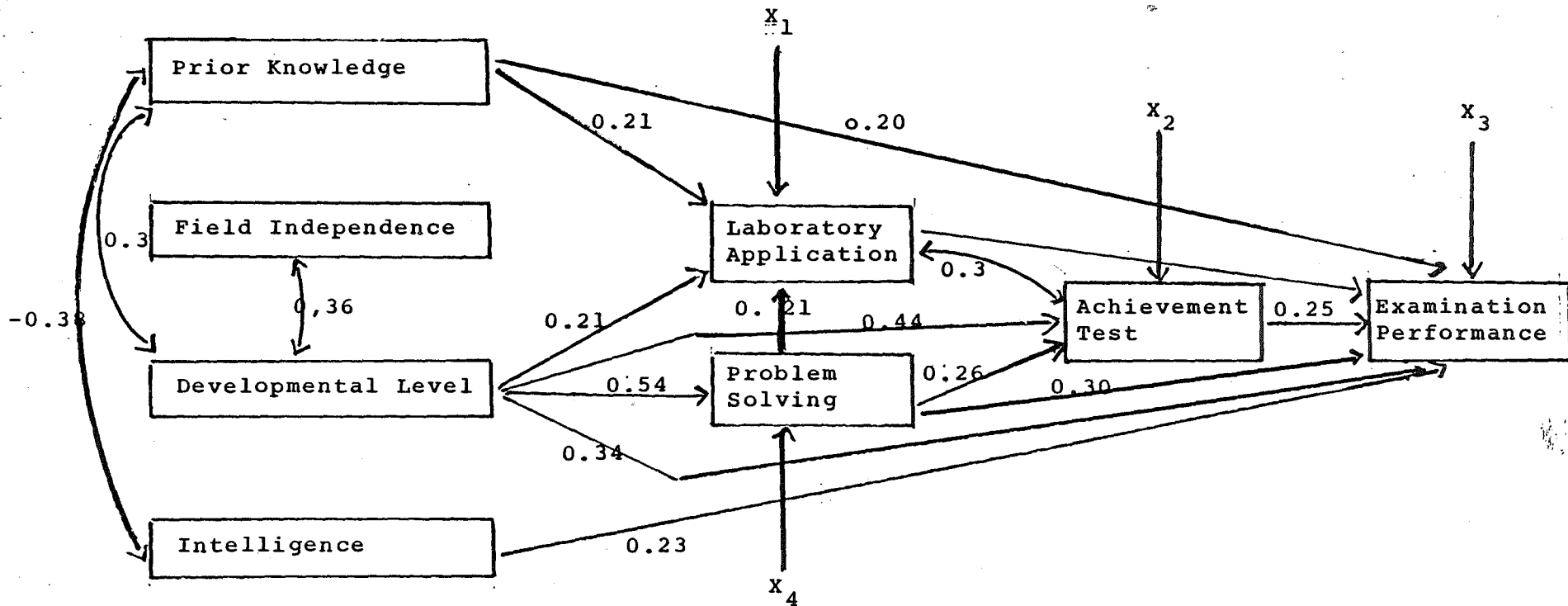
The path model in figure 1 shows that developmental level is the best predictor of all the performance variables. Problem solving ability, considered as a predictor variable in its own right, also appears to be a good predictor for the other performance variables. Prior Knowledge appears to be the next most important predictor variables influencing performance in laboratory application, problem solving and multiple-choice achievement test.

Implications

As developmental level followed by prior knowledge emerge as the key variables contributing to achievement in chemistry through problem solving ability, it may be useful to focus attention to these areas. The cognitive developmental theory of Piaget can significantly aid teacher's understanding of the puzzling differences that exist among students. If the students lack important information processing schemata or the required reasoning ability, then instruction should be designed to develop those schemata and reasoning skills.

Fig. 1

Achievement in Chemistry - A Path Model



X_1 to X_4 External Influences

→ Paths with path coefficients

↔ Correlations only

An understanding of the approaches to concrete and formal concepts (Karplus, 1978), using pseudo-examples (Cantu & Herron, 1978) with an understanding of underlying reasoning patterns and their applications (Karplus, et al., 1977) would help science teachers to develop the strategy to promote formal reasoning required of high school chemistry (Shayer, 1978).

As prior knowledge also significantly influences achievement in chemistry, attention should be focussed on the ideas of familiarity and relevance as Ausubel (1963) claims that "meaningful learning occurs when a new concept is linked to relevant ideas in the student's existing store of knowledge." Concept maps (Novak, Gowin & Johansen, 1983) have been successfully used as tools in enhancing understanding of science concepts and their inter-relationships. Many ideas are available from the successful studies done in the area of Ausubelian Psychology for teachers which could be beneficially used in the classroom.

Problem solving ability has also emerged as a significant variable in determining achievement. Problem solving is seen as a cognitive process (Boekaerts, 1978) involving mathematical ability (Gabel & Sherwood, 1983). Visual approaches such as sequential flow diagrams to minimise mathematical anxiety and hence improve problem solving skills have been recommended (Gabel & Sherwood, 1983). Several teaching strategies have been developed to improve problem solving skills, such as in experimental situations (Ross & Maynes, 1980), in classroom exercises (Gilbert, 1980), in quantitative problem solving in chemistry (Kramers-Pals, Lambrechts & Wolff, 1982) and many others. It is useful for teachers to familiarize with some of the problem solving strategies and use them as appropriate.

It appears that a closer look at chemistry achievement enables one to discover different aspects of achievement. The type of analysis used in the present study in which different aspects are utilized allows such an analysis. Most important of all is the teacher's commitment to promote formal reasoning ability, to develop meaningful verbal learning and improve the students' problem solving ability that will help achieve the goals of chemistry education which will also accelerate achievement in chemistry.

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SECONDARY STUDENTS' ABILITY TO ACCURATELY READ SCALES
OF SCIENTIFIC INSTRUMENTS

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INTRODUCTION

The recent findings of the Beazley (1984) and McGraw (1984) committees suggest that teachers will need to justify the subjects, topics and areas of science that are currently offered in secondary schools. Certainly, the general public appears to be thinking in terms of "greater accountability" for those who work in the educational systems within this country.

One aspect of school science that could become more accountable is laboratory work. In earlier decades the role of practical work in science has been to verify laws and illustrate theory. This view, established in the late 19th Century, has only been seriously challenged in the last twenty years. Over the past three decades, however, many studies have been conducted into the significance of practical work. Reviews of such studies (Kreitler and Kreitler, 1983; Sonntag, 1984) have found little evidence to support practical work in school science in terms of gains in cognitive, affective or psychomotor measures. The significance of these reviews of laboratory work is that the traditional role of the laboratory in assisting learning comes into question. Are students completing Year 10 with any marketable skills gained from practical work? Also of importance are the implications for the teachers of Year 11 - 12 classes in the physical and biological sciences.

One area of laboratory work which would appear to be of considerable value for further education in science, for entering the work force and for everyday living, is the ability to read scientific instruments. Indeed instruments of one type or another are encountered in all walks of life so the ability to accurately read scientific instruments would be an important outcome of the any school laboratory program.

The syllabus for Lower School Science (1979) co-ordinated by the Curriculum Branch of the Education Department of WA (1979) reinforces the importance of students being able to read scientific instruments. The educational objectives of the psychomotor domain state that students should be able to "make reliable measurements quickly and confidently". From section 5, titled "The Core Concept Statement", areas of measurement which are considered essential to the development of the science syllabus are: acceleration, ampere, volt, area, density, displacement, energy, force, weight, length, mass, power, pressure, temperature, time, velocity, volume, work. The document goes on to say, "students should also become proficient in measurement and appreciate the accuracy of common laboratory instruments (p.9). In addition, in the special section on skills in appendix 8.5 and under the heading "Experimental Procedures and Data Collection" students are expected to be able to set up and use familiar apparatus and to use instruments to measure length, time, volume, mass, force, temperature, and humidity.

Schools attend to these syllabus requirements in a variety of ways. Some schools have designed equipment, measurement and instrumentation courses in an attempt to quickly allow students familiarization with different instruments. Other schools use specific packages such as the Australian Science Education Project (ASEP 1969-74) unit called "Made to Measure" and/or the Junior Secondary Science Project (1974). Still other schools

leave the teaching of reading instrument/training to the discretion of the individual teacher or to the requirements of the old lower secondary science programmes.

PURPOSE OF THE STUDY

The purpose of this study was to measure the ability of students to read scientific instruments. These instruments -- voltmeters, ameters, graduated measuring cylinders, laboratory time clocks, laboratory thermometers and clinical thermometers -- should be in common usage in lower school science classes. Consequently, it is anticipated that students should have developed the reading skills to be able to interpret the variety of vertical linear, horizontal linear, and curvilinear facial displays used on most scientific instruments. An additional purpose was to consider any effects of different lower secondary science programmes on the instrument reading ability of the Year 10 students.

METHOD

Instrument Development

The importance of being able to read instruments suggests that this area is fertile for research. However, few recent studies could be found which addressed this important skill. Consequently, the initial aspect of this study involved the construction of a valid and reliable measure for assessing specific instrument reading ability. The 34 item Scientific Instrument Reading Inventory (SIRI) developed by Carboon (1984) consists of drawings of the following instruments: voltmeters, ameters, graduated measuring cylinders, laboratory clocks, laboratory thermometers (scales of -5°C to 50°C and -10°C to 110°C) and clinical thermometers (scale 35°C - 42°C). All these six instruments are in common use in WA high school science laboratories. From these drawings a booklet of diagrams was produced which

was non-consumable. A corresponding answer booklet was constructed so that students could read the booklet of diagrams and record straight into the answer booklet.

The six pages of the SIRI were as follows:

Pages 1 and 2 consisted of four diagrams of voltmeters and ameters respectively; the reading scale for each diagram was different. Page 3 contained a diagram of a complete graduated measuring cylinder and seven cut-off sections of graduated measuring cylinders. The reading scale for each graduated measuring cylinder was different. Page 4 contained a diagram of a complete laboratory clock and five facial displays of laboratory clocks. Each facial display required the reading of the minute and second hand for five different displays. Page 5 contained a diagram of a laboratory thermometer with a scale of -5°C to 50°C and three cut away sections of thermometers. An additional laboratory thermometer with a scale of -10°C to 110°C and four cut away sections of thermometers were also incorporated on this page. Page 6 contained a diagram of a clinical thermometer (scale 35°C to 42°C) with seven cut away sections of thermometers.

The students responses were scored as either right (100% accurate), almost right (slightly off the reading but very close), and wrong (making use of the wrong scale or the wrong reading). Scores were recorded as 1 (right), 2 (partly right) and 3 (wrong).

Sample

Three Perth metropolitan high schools were selected to participate in this study on the basis that one exclusively used the Australian Science Education Project (ASEP) in the lower school program, another used a partial ASEP program, and the third school used no ASEP or externally

developed science materials at all. The sample of 622 Year 10 students were approximately equally divided by gender. Data were also sought on their achievement levels as designated by the Board of Secondary Education.

RESULTS & DISCUSSION

Instrument Reliability

The reliability of the 34 item SIRI based on the student sample was 0.88 as measured by Cronbach's alpha. Reliabilities of the six subscales, together with the number of item in the scale, are shown in Table 1.

Table 1

Reliabilities for the Total Scale and six Subscales of the Scientific Instrument Reading Inventory (n = 622)

Scale	Instrument	Number of items	Alpha Cronbach
1. Curvilinear	Voltmeter	4	0.53
2. Curvilinear	Ameter	4	0.68
3. Vertical linear	Graduated Measuring Cylinder	7	0.75
4. Circular Facial display	Laboratory clock	5	0.72
5. Horizontal Linear	Laboratory Thermometer	7	0.76
6. Horizontal Linear	Clinical thermometer	7	0.86
Combination of Scales 1-6		34	0.88

Descriptive Data

The combined data for percentage of students for all three schools who scored each item correct, partially correct and wrong are shown in Table 2.

For Scale 1, on voltmeters, most students handled this scale with ease; however, only 50% correctly answered diagram 2 and 46% were completely wrong. For Scale 2, on ameters, the lowest percentage correct was for diagram 8 with 84%. Most students handled this scale very well. For Scale 3, on Graduated Measuring Cylinders, very good results were produced with most correct being above 90% for these diagrams. However, only 70.1% was recorded correct for diagram 12 where students were expected to estimate between one graduation and another. On this diagram, due to the requirement for estimating, two answers were accepted but 20.7% of students were completely wrong. The otherwise very good results obtained is probably due to the graduated measuring cylinder being one of the more widely used pieces of scientific measuring apparatus in science laboratories.

For Scale 4, on laboratory clocks, the results range from good to fair. One reason for this is that many students appeared to confuse the minute and hour hands. There is also the added problem of teaching students who cannot read a clock face and who therefore would have considerable difficulty with the use of a laboratory time clock. For Scale 5, on laboratory thermometers, the results were very good. However, students had some difficulty with diagram 22 where 24.0% were wrong. This diagram involved an answer where students had to count up from zero and the answer was expected accurate to one decimal place. For Scale 6, on clinical thermometers, the results were very good but most difficulty was observed where students were expected to estimate between graduations. For diagram 33, 23.2% of the students obtained the wrong answer. Students were expected to differentiate between 37.0°C and 37.1°C (the answer being 37.03°C) and this caused many to record the wrong reading.

Table 2

Percentage responses for each item and subscales on the
Scientific Instrument Reading Inventory (n=622)

Question	% Correct	% Almost Correct	% Wrong
1	89.4	0.2	10.3
2	50.7	3.2	46.1
3	80.8	0.2	19.0
4	89.5	0.2	10.3
Average Total Scale 1	77.6	0.9	21.4
5	89.1	0.8	10.1
6	92.8	0.3	6.9
7	88.9	0.0	11.1
8	84.4	0.2	15.4
Average Total Scale 2	88.8	0.3	10.8
9	91.8	3.2	5.0
10	94.2	2.1	3.7
11	92.0	1.6	6.4
12	70.1	9.2	20.7
13	91.6	1.9	6.4
14	92.1	2.1	5.8
15	89.9	1.8	8.8
Average Total Scale 3	88.7	3.1	8.1
16	73.4	2.7	23.8
17	77.8	1.4	20.7
18	87.9	0.6	11.4
19	85.2	1.9	12.9
20	60.1	4.8	35.0
Average Total Scale 4	76.9	2.3	20.7
21	90.5	1.0	8.5
22	74.3	1.8	24.0
23	91.0	0.2	8.7
24	88.9	0.5	10.6
25	93.2	0.5	6.3
26	91.8	0.2	8.0
27	82.6	0.0	17.4
Average Total Scale 5	87.5	0.6	11.9
28	81.8	0.8	17.4
29	90.0	0.6	9.3
30	78.6	4.7	16.7
31	90.3	0.6	9.0
32	75.7	5.0	19.3
33	72.9	3.9	23.2
34	92.4	0.2	7.4
Average Total Scale 6	83.1	2.3	14.6

Comparative Data Analysis

The data in Table 3 show that a significant difference ($p < 0.01$) was observed between the three schools taking part in the study with respect to Scales 1, 2, 4, 5 and 6. No significant difference was observed with Scale 3 (Laboratory Time Clocks). School 1 recorded the lowest mean values for Scales 1, 2, 3, 5 and 6 and hence it can be stated that the students at School 1 handled the S.I.R.I. with less difficulty than students at the other two schools. School 3 recorded the highest mean values for each of the six scales on the S.I.R.I.

Table 3

Year ten students performance on the Scientific Instruction Reading Inventory (SIRI) according to school (n = 622).

School	N	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Scale 6
		x + sd.	x + sd.	x + sd.	x + sd.	x + sd.	x + sd.
1	263	1.34+0.39	1.14+0.32	1.17+0.36	1.41+0.54	1.20+0.38	1.24+0.44
2	178	1.42+0.54	1.21+0.44	1.18+0.33	1.37+0.48	1.22+0.38	1.26+0.44
3	181	1.59+0.54	1.34+0.56	1.22+0.33	1.54+0.58	1.32+0.46	1.46+0.60
F-ratio		14.27**	11.63**	1.23	4.79**	5.73**	11.63**

**P < 0.01

Year ten students' performance on the Scientific Instrument Reading Inventory according to Achievement level (n=620).

Achievement Level	N	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Scale 6
		x + sd.	x + sd.	x + sd.	x + sd.	x + sd.	x + sd.
Adv.	240	1.26+0.40	1.00+0.30	1.09+0.22	1.30+0.47	1.15+0.36	1.13+0.33
Inter.	294	1.48+0.47	1.22+0.42	1.20+0.32	1.46+0.54	1.23+0.35	1.32+0.47
Bas.	86	1.75+0.59	1.54+0.65	1.41+0.52	1.69+0.62	1.52+0.55	1.78+0.72
Ratio		37.21**	34.31**	29.73**	17.53**	27.78**	61.52**

* p<0.01

Table 5

Year ten students' performance on the Scientific Instrument Reading Inventory according to gender (n=622).

Gender	N	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Scale 6
		x + sd.	x + sd.	x + sd.	x + sd.	x + sd.	x + sd.
Female	327	1.40+0.49	1.20+0.44	1.17+0.30	1.39+0.51	1.22+0.40	1.30+0.51
Male	293	1.47+0.49	1.23+0.44	1.21+ 0.38	1.49+0.57	1.26+0.40	1.33+0.51
Ratio		2.41	0.97	2.69	4.83	1.01	0.46

Students' performance on the six scales of the SIRI were analysed with respect to the three achievement levels of Advanced, Intermediate and Basic (see Table 4). Significant differences were obtained with respect to the three Achievement levels over six scales (p< 0.01). One could reasonably argue that this result could be expected as academically more able students would have greater ability to read instruments. However, it is the authors' claim that all students should have similar ability to read

authors' claim that all students should have similar ability to read scientific instruments despite their achievement level within the educational system. There appears to be no common thread of difficulty with respect to the different achievement levels. Advanced level students found Scale 4 (1.48+0.47) the most difficult, Intermediate level students found Scale 1 (1.48+0.47) the most difficult and Basic level students found Scale 6 (1.78+0.72) the most difficult.

From the data in Table 5 no significant differences were obtained with respect to the answers provided by male or female Year 10 students over the set of six scales. This finding is interesting in light of the fact that it is believed that many girls do not select science orientated subjects because they do not receive sufficient encouragement and do tend not to regard themselves as potential upper school science and mathematics students. However, on the reading of the SIRI, girls proved to be the equal of boys on all scales. Hence female students should not allow themselves to be discouraged from science and mathematics orientated subjects on the basis of their ability to read scientific instruments.

Conclusions

This study has reported on the development of a valid and reliable instrument called the Scientific Instrument Reading Inventory which was used to assess Year 10 students ability to read a variety of scales commonly used in school science laboratories. The scales were curvilinear (voltmeters and ameters), vertical linear (graduated measuring cylinder), circular facial display (laboratory clock), and horizontal linear (laboratory and clinical thermometers). Based on the average number of students correctly answering the questions on each scale (see Table 2), the Curvilinear Scale on the voltmeter and the Curvilinear facial display on the laboratory clock proved to be most difficult. However, some of the

items within these scales appeared more difficult than others resulting in lower reliability of the scales (see Table 1), and are worthy of further attention.

School 1, which used ASEP in lower secondary science, scored the highest percentage correct on all scales (see Table 3), followed by school 2 which had no ASEP in lower secondary science. Subsequently, based on the sample of schools, there would appear to be no relationship between type of the science course adopted in lower secondary science and ability to read scientific instrument scales. It is likely there is a relationship between the socioeconomic status of the schools and scores on the SIRI but this was not investigated in this study.

The difference in performance on the SIRI between achievement levels (see Table 4) is perhaps to be expected but the number of students making errors on reading these scales is disconcerting since following ten years of schooling all young people, regardless of achievement level, should have an ability to accurately read instruments encountered in all walks of life. Certainly there is an increasing incidence of "digital readout type instrumentation" but it is still essential to correctly read scales. For example, the purchase of a basic off-the-shelf vitamin supplement requires the purchaser to be able to differentiate between 0.54mL and 0.15mL so that the supplement can be added to an infants' milk formula. Vitamin overdoses may not make the headlines of the national dailies, however, some vitamins can cause toxicity especially the fat soluble ones (vitamins A, D, K and E). Hence the correct reading of the graduated pipette (supplied with the formula) is a desirable objective for all people and especially mothers-to-be and the mothers of infants and small children.

The lack of any gender differences in ability to read the scales is interesting and certainly would appear to be at odds with some of the recently published literature about girls not performing as well as boys in the science area.

This study has important implications for the secondary science classroom. All students upon leaving Year 10 either to complete further studies or to enter the work force should be expected to be able to read scales of scientific instruments, especially those such as thermometers likely to be frequently encountered in everyday life. It is reasonable to suggest that students of all levels of achievement should reach minimum competency in reading scientific scales. The fact that this does not appear to be the case implies that such skill is worthy of greater attention in lower secondary science classes.

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Sex-stereotyped Attitudes About Science : Can They Be Changed?

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Introduction

This paper describes and discusses some attitudes about science held by a group of Western Australian primary school children. It reports short term changes in these children's attitudes following an inservice program attended by their teachers.

The general area of children's attitudes to science has been researched extensively, as indicated in reviews by Gardner (1975) and Ormerod and Duckworth (1975). Some of this research claims that boys overall are more interested in science than girls. Much of it also reports an apparent preference of girls for the biological sciences and boys for the physical sciences. The latter finding, particularly, is of some concern, given that this orientation is now known to place girls at a disadvantage in terms of their subsequent pursuit of occupations and careers in an advanced technological society (Kelly, 1978; Parker, 1984).

Recently it has been suggested that the primary school experiences of girls may have an important influence on their attitude towards and participation in science at the secondary and tertiary levels. (Kelly, 1982) At least two major pieces of evidence can be offered in support of this suggestion. Firstly, a large amount of research, summarised in Ormerod and Duckworth's review (1975) indicates that children acquire an abiding interest in science at an earlier age than in most other areas of study. And secondly, Ormerod and Wood (1983) have shown that sex differences in the direction of children's interest in science are established well before secondary school

age. Some research on secondary school students explains these differences in the direction of science interest in terms of sex-role stereotyping. Such is, for example, the position of Vockell and Lobonc (1981) who see the development by females of unfavourable attitudes towards the physical sciences as an 'unintended effect of coeducation' (1981:218).

Little is known about relevant influences in the primary school, however, and in particular about the influence of teachers on the development of their pupils' attitudes towards science. This paper therefore focuses on the primary school. The position taken is that both girls and boys should be encouraged to develop positive attitudes towards the physical sciences and, in particular, towards the participation of women in the physical sciences. In addition, like McMillan and May (1979), this paper assumes that teacher attitudes and behaviours in relation to science are a critical influence on the attitudes to science developed by their pupils.

The Major Project

The findings presented here form part of a major project entitled The Effect of Inservice Training on Teacher Attitudes and Primary School Science Classroom Climates, funded by the Commonwealth Schools Commission and carried out in 1983. The actual inservice program is described in detail in an earlier paper, (Parker, Rennie and Hutchinson, 1984). This present paper concerns only those sections of the project relevant to the children's attitudes to science. The data were gathered by means of two attitude questionnaires, administered respectively before and after the teacher inservice. Appendix 1 shows a flow chart of the whole project, indicating the place of the attitude questionnaires in the total sequence of events.

The general aim of the project was to devise, implement, and monitor the effects of, an inservice program devoted to the teaching of a primary school physical science topic in a non-sexist manner. More specifically the project

aimed, firstly, to raise teacher awareness of the adverse long-term effect on girls produced by the general tendency in the community to see the physical sciences as an almost exclusively male domain. As a consequence of such raised awareness it was considered that teachers would develop a more positive attitude towards the participation of girls in the physical sciences. Secondly the project aimed to assist teachers to acquire skills in creating and maintaining a non-sexist science classroom environment, while simultaneously giving them the opportunity to update their knowledge and skills in relation to Year 5 Electricity, the particular physical science topic selected.

A third specific objective was to monitor the effectiveness of the program by

- (a) assessing the nature and extent of attitude change and skills acquisition amongst the teachers;
- (b) observing and documenting the patterns of classroom interaction during the teaching of the topic Electricity; and
- (c) assessing the nature and extent of any changes in attitude towards science amongst the children, with specific reference to electricity. (The data gathered during this particular section of the monitoring of the program form the basis of this present paper.)

Twenty Year 5 teachers (ten males and ten females) who showed relatively low levels of skills and confidence in relation to teaching Energy topics were selected to participate in the study. Ten of the teachers (five males and five females, designated the 'experimental' group) participated in a two-day inservice program presenting skills for non-sexist teaching and skills for teaching Electricity. The other ten teachers formed a control group, matching the experimental group as closely as possible in terms of age, sex, training, experience and teaching methods. The control group participated only in a

half-day of the inservice program which focused on skills for teaching Electricity. Thus the experimental design also controlled for any variation between the two groups which might have been due to extra inservicing in science-teaching skills.

Instrumentation

As indicated earlier the instrumentation relevant to this paper consisted of two attitude questionnaires: the 'Before Inservice' questionnaire and the 'After Inservice' questionnaire.

The aim of the 'Before Inservice' questionnaire was primarily to measure the children's attitudes towards the four areas of science in the Year 5 Western Australian science syllabus - Animals, Plants, Matter and Energy. Three secondary aims of the questionnaire were to tap the children's attitudes specifically towards finding out about electricity, to assess their personal inclination towards a career in science, and to estimate their perceptions of their performance in school science and of the factors affecting this performance. Results pertaining to the last of these aims are reported elsewhere.

A variety of items and formats for the questionnaire were considered, similar to those described by Ormerod and Wood (1983). Ultimately a modification of the Likert-type response format was adopted, with four levels of response ranging from 'not at all' through to 'a lot'. No neutral category was provided; other research has shown that children tend to like rather than dislike science, so the use of four 'like' categories reduces the risk of a ceiling effect in the responses. Moreover, previous experience had shown that a neutral or undecided category usually collects 'no opinion' or 'don't know' responses which may lead to inaccuracies in the analyses of the results. Following Harlen (1971) and Harvey and Edwards (1980), circles of increasing diameter were used to designate the four levels of response, a technique considered to be appropriate to the age of the children in the present study.

The science-related content of the questionnaire, while confined essentially to the four syllabus areas noted earlier, did not focus only on school based activities. An attempt was made to incorporate aspects of the children's likely out-of-school science experiences since these are known to be a significant influence on attitudes to science (Lowery, 1967).

A draft of the questionnaire was piloted with a small group of Year 5 children. The final version of the instrument contained 31 items, 16 of which related to general interest in science, five to electricity, nine to perceptions of ability and one to careers in science. The first 16 items actually consisted of four sets of items; each set contained one item related directly to each of the four areas of the science syllabus: Animals, Plants, Matter and Energy.

The 'After Inservice' questionnaire followed a somewhat similar format to that just described, except that all items related to electricity. The specific aim of this instrument was to identify any differences between the experimental and control groups in relation to attitudes towards electricity. The final version of the instrument together with a guide to the scoring of the items, is shown in Figure 1. Of the eleven items, five (numbers 1-4, 8) asked about the children's enjoyment of the topic Electricity, one (number 9) about the difficulty of the work, three (numbers 5-7) about perceptions of boys', girls' and own performance in the activities associated with the topic and two (numbers 10, 11) about a career as an electrician. It was anticipated that changes in attitude, if any, would be detected in the responses to some items which were common to the 'Before' and 'After' questionnaires, namely three items (numbers 1, 2 and 4) pertaining to working directly on the Electricity topic.

Figure 1

The 'After Inservice' Questionnaire

Here are some questions about the science work in electricity you have been doing, using globes, and batteries.

PLEASE ANSWER THESE QUESTIONS WITH A TICK IN THE CIRCLE WHICH IS RIGHT FOR YOU.

HOW MUCH DID YOU ENJOY	Not at all	A little bit	A fair bit	A lot
1. working out ways to make a torch globe light up	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. testing things to see if electricity passed through them	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. using globes, wires and batteries to make different circuits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. making your own switch to turn a light on and off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

THINK ABOUT YOUR CLASS MATES WORKING IN SCIENCE	Hopeless	Not much good	Pretty good	Really good
5. How good are MOST <u>BOYS</u> at working with globes, wires and batteries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. How good are MOST <u>GIRLS</u> at working with globes, wires and batteries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. How good are <u>YOU</u> at working with globes, wires and batteries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Scoring 1 2 3 4

FOR EACH OF THESE QUESTIONS, PLEASE TICK THE ONE BOX WHICH IS THE RIGHT ANSWER FOR YOU

8. How much did you enjoy working with globes, wires and batteries? *Scoring*
- LESS than I thought I would 1
- AS MUCH as I thought I would 2
- MORE than I thought I would 3
9. How hard did you find the electricity work with globes, wires and batteries?
- always hard 1
- mostly hard 2
- sometimes hard, sometimes easy 3
- mostly easy 4
- always easy 5
10. Most electricians are men. Do you think women could learn to become electricians?
- (say yes or no) _____
- yes = 1
no = 2
11. Could you learn to be an electrician if you wanted to?
- (say yes or no) _____

Results and Discussion

The 'Before Inservice' Questionnaire

The 'Before Inservice' questionnaire was administered to 394 boys and 373 girls in Year 5 of primary school. The average age of the children was 10 years. In the analysis, the responses to each item were scored over a range of one point (for 'not at all') through to four points (for 'a lot'). The exception was the item asking about science career orientation, for which 'yes' was assigned a value of one and 'no' a value of two. Table 1 shows the means and standard deviations of girls and boys for each item, and the relevant t-test values.

Examination of Table 1 reveals that the sex-stereotyping of science interests referred to earlier in this paper exists to some extent in this sample of Year 5 Western Australian children. These results do not, however, offer support for one of the other findings of earlier research, namely that boys are more interested than girls in science overall; while sex-differentiated directions of interest are shown by these children, the girls' and boys' overall levels of interest in science are very similar.

Specifically, in relation to sex-differentiated directions of interest, these data reveal that the boys, on average, seem to be more interested than the girls in science about matter and energy (items 1, 2, 11, 13, 14, 17-21) while the girls on average seem to be more interested than the boys in science about plants and animals (items 3, 4, 7, 10, 12, 15, 16). Exceptions to these generalisations are the greater interest of the boys in earthworms (item 5), the greater interest of the girls in shadows (item 6), and the similar interest of boys and girls in water (item 8), and weather (item 9).

Thus, although it seems reasonable to say that boys and girls may have different science interests, the differences are not as clear-cut as other

Table 1: Pupils' Responses to Before Inservice Questionnaire

	Means		Standard Deviations		t-test
	Boys	Girls	Boys	Girls	
HOW MUCH WOULD YOU LIKE TO FIND OUT					
1. how iron ore is made into steel	2.87	2.45	1.02	0.99	5.77**
2. how electricity makes the television work	3.45	3.13	0.80	0.90	5.16**
3. how compost helps plants to grow better	2.33	2.64	1.08	1.00	-4.13**
4. how germs can make you sick	2.95	3.25	1.10	0.98	-3.96**
HOW MUCH DO YOU LIKE TO DO					
5. experiments with earthworms	2.70	2.44	1.08	1.12	3.36**
6. experiments with shadows	2.40	2.55	1.04	1.04	-2.10*
7. experiments with seeds	2.53	2.98	1.08	0.94	-6.20**
8. experiments with water	3.19	3.25	0.96	0.89	-0.88
HOW MUCH DO YOU LIKE TO DO SCIENCE WORK					
9. about the weather	2.55	2.47	1.06	0.94	1.11
10. about moths, butterflies and caterpillars	2.60	3.06	1.11	0.97	-6.07**
11. about wheels and motors	3.55	1.91	0.81	1.01	24.83**
12. about mushrooms and toadstools	2.19	2.65	1.11	1.08	-5.77**
HOW MUCH WOULD YOU LIKE TO					
13. collect rocks and minerals	3.07	2.85	1.02	1.07	2.94**
14. make working models from Lego or other kits	3.74	3.03	0.64	1.03	11.63**
15. grow your own vegetable or flower garden	2.73	3.52	1.07	0.74	-11.81**
16. look after mice or goldfish as pets	3.38	3.64	0.90	0.70	-4.48**
HOW MUCH WOULD YOU LIKE TO					
17. work out ways to make a torch globe light up	3.28	2.74	0.92	0.94	8.03**
18. test things to see if electricity passes through them	3.38	2.90	0.90	1.00	7.01**
19. cut up a battery or a torch globe to see what's in it	3.46	3.12	0.86	1.03	4.94**
20. make your own switch to turn a light on and off	3.58	3.25	0.79	0.94	5.21**
21. do an experiment to see how brightly a torch can shine	2.85	2.58	1.02	0.98	3.82**
If you wanted to, could <i>you</i> , be a scientist when you grow up?	1.45	1.52	0.50	0.50	-1.82

* p<0.05, ** p<0.01

reports would suggest. Moreover, as is revealed by an examination of the exceptions cited above, boys' and girls' levels of interest appear to be related quite closely to their likely out-of-school experience. Where the experience is one which is likely to be universal (eg earthworms, shadows, germs, water and weather) very little sex differentiation of interest is shown. In other areas, such as wheels and motors and growing a vegetable or flower garden, where boys' and girls' out-of-school experiences are likely to be quite different, clear sex-stereotyping is revealed.

This appears to be an important point for teachers and curriculum developers to note. Others (eg Kahle and Lakes, 1983; Lie and Bryhni, 1983) have also pointed out that girls' out-of-school experiences with science are both different and fewer than those of boys. Of the 11 year olds in Lie and Bryhni's study (1983), the boys had already had a lot of experience in 'tinkering' activities and the girls considerably less science experience, with an orientation towards biological and domestic activities. It is considered that this could well lead to girls' feeling inadequate in physical science classes, and to their continuously decreasing interest in this area. Lewis (1983) sees this as applying particularly in areas such as electronics, which are likely to be hobby areas for boys but not for girls. Mallow and Greenburg (1982) have pointed out that such sex-role stereotyping is likely to lead to chronic 'science anxiety' on the part of girls.

Where large sex differences are evident, or could be predicted, it is perhaps desirable for teachers to consider supplementing the students' out-of-school experience with special activities, and relating ideas to objects which are familiar to both girls and boys. In the case of wheels and motors this could be done by referring to gears on all kinds of devices, including egg beaters and hand drills, and, similarly, providing many different examples of brakes, including bicycles and baby carriages.

As indicated earlier, the questionnaire also asked the children whether they could become scientists when they grew up, and further requested them to give reasons for their answers. As shown in Table 1 there was no significant difference between girls' and boys' responses to this item in quantitative terms, again suggesting, as did Kahle and Lakes (1983), that girls and boys of this age are equally interested in participating in science. Qualitatively, however, there were certain sex differences: there was a tendency for girls' reasons more than boys to reveal a basic lack of self-confidence in their scientific potential, a perennial problem which has been noted by other researchers (eg Peterson *et al*, 1980, Dynan *et al*, 1979). Typical of girls' reasons for not becoming a scientist were

... I might put the wong (sic) thing in the bottles.

... I would have bad luck. I would make a lot of mistakes. If was doing an experiment I would put the wrong potion in.

... I am so dumb that I would mess every think (sic) up.

The 'After Inservice' Questionnaire

The 'After Inservice' Questionnaire was administered to all children in the experimental and control groups as soon as possible after they had completed the topic Electricity. The analysis of the responses is shown in Tables 2 and 3.

Perusal of Table 2 reveals a number of interesting points. For items 1-4, concerning enjoyment in working with electricity, the girls in the experimental group scored relatively highly. Indeed in the case of the female teachers' classes the girls' scores were higher than those of the boys. These same girls indicated (item 8) that they had enjoyed working on the topic much more than they had expected, a point which is confirmed further by data shown in Table 3.

**Table 2: Pupils' Responses to 'After Inservice' Questionnaire:
Responses Averaged using Class as Unit of Analysis**

	Control Group				Experimental Group			
	Male Teacher		Female Teacher		Male Teacher		Female Teacher	
	Boys (n=55)	Girls (n=52)	Boys (n=60)	Girls (n=59)	Boys (n=75)	Girls (n=70)	Boys (n=80)	Girls (n=76)
1.	3.73	3.08	3.45	3.02	3.35	3.24	3.28	3.43
2.	3.09	2.92	3.18	2.91	3.12	3.05	3.17	3.33
3.	3.59	3.18	3.40	3.26	3.31	3.23	3.43	3.42
4.	3.70	3.42	3.40	3.26	3.54	3.37	3.66	3.67
5.	3.44	3.23	3.70	3.28	3.45	3.17	3.35	3.30
6.	2.67	3.26	2.50	3.00	2.75	3.29	2.68	3.12
7.	3.27	3.04	3.30	2.74	3.29	2.89	3.17	2.92
8.	2.56	2.41	2.62	2.31	2.45	2.49	2.44	2.53
9.	3.43	3.16	3.86	3.44	3.65	3.58	3.70	3.40
10.	1.09	1.04	1.22	1.08	1.23	1.10	1.22	1.02
11.	1.13	1.29	1.10	1.30	1.12	1.18	1.07	1.11

**Table 3 Differences Between Means of Responses to Three Items
Common to Both 'Before Inservice' and 'After Inservice' Questionnaires**

Item* Number	Control Group		Experimental Group	
	Male Teacher	Female Teacher	Male Teacher	Female Teacher
Boys				
1	+ .16	+ .14	+ .18	- .14
2	- .57	- .20	- .19	- .39
4	+ .03	- .21	+ .05	- .05
	<u>- .39</u>	<u>- .27</u>	<u>+ .04</u>	<u>- .58</u>
Girls				
1	+ .35	+ .10	+ .76	+ .43
2	+ .16	+ .10	+ .36	+ .14
4	+ .41	+ .02	+ .32	+ .22
	<u>+ .92</u>	<u>+ .22</u>	<u>+ 1.44</u>	<u>+ .80</u>

*Indicates item numbers from 'After Inservice' questionnaire
- see Figure 1.

Table 3 focuses on three items (numbers 1, 2 and 4) which were common to both the 'Before Inservice' and the 'After Inservice' questionnaires. In other words it indicates a comparison between the 'How much would you like to ...?' and 'How much did you enjoy ...?' responses. It shows that girls in all groups enjoyed the work more than they had anticipated, and that this was especially true of the girls in the experimental groups. It suggests two possible interpretations. Firstly, the section of the teacher inservice emphasising a non-sexist approach to the teaching of Electricity appears to have had a small but positive impact on girls' attitudes towards the topic. Secondly, and consistent with the findings about girls' out-of-school experiences with science reported earlier in this paper, girls may have been relatively ignorant about electricity before this opportunity to learn about it at school, and thus may have felt relatively negative about the prospect of manipulating globes, wires and batteries. Having actually done so, however, their attitude improved. Thus, as suggested earlier, girls' documented relative dislike of some physical science topics may be associated with their lack of previous experience with these topics. Researchers and teachers should be aware that making curriculum decisions based on expressed interests may have the effect of precluding girls even further from experiences in physical science.

The responses to Items 5, 6 and 7 are also of interest. Boys, in their responses, show considerable confidence in boys' ability to work successfully with globes, wires and batteries, but rather less confidence in girls' ability. (This attitude was confirmed by comments and behaviours noted by the researchers during classroom observation of the students working on Electricity. In several cases boys were heard to define the work as 'men's work', and either to monopolise the equipment or to share it with girls in a somewhat paternalistic fashion.) By contrast, girls' estimates of boys' and

girls' ability are much closer: two groups of girls actually saw girls' ability as greater than that of boys. In all cases both boys' and girls' respective estimates of their own personal ability are lower than their estimates for boys in general and girls in general. This is especially so for girls.

Responses to Item 10 reveal similar attitudes to those to Items 5 and 6. In general boys in both the experimental and control groups have little confidence in women's ability to become electricians. Between 90 and 98 per cent of girls, however, believe that women could be electricians.

Item 11 reveals boys' general confidence in their own personal ability to become electricians. As with responses to Item 7, however, girls' confidence in this regard is lower than that of boys, especially the girls in the control group. It appears from this latter finding that the experimental group teachers, both male and female may have had the desired effect on their female students. This is of interest, given that the career potential of the physical sciences was highlighted in the inservice, as was the necessity to project a non-sexist image of careers to students of all ages.

Concluding Comments

This paper and the major project of which it is part, began from the premise that teachers' science-related attitudes and behaviours; at all levels of schooling, are a critical influence on the attitudes to science developed by their pupils. Indeed, a major aim of the teacher inservice which was central to this study was to develop, in selected primary school teachers, attitudes and skills conducive to effective, non-sexist teaching of a physical science topic. The assumption was that a competent, non-sexist approach by teachers to the topic would encourage both their girl and their boy students to develop positive attitudes towards the physical sciences, and, in particular, towards the participation of women in the physical sciences.

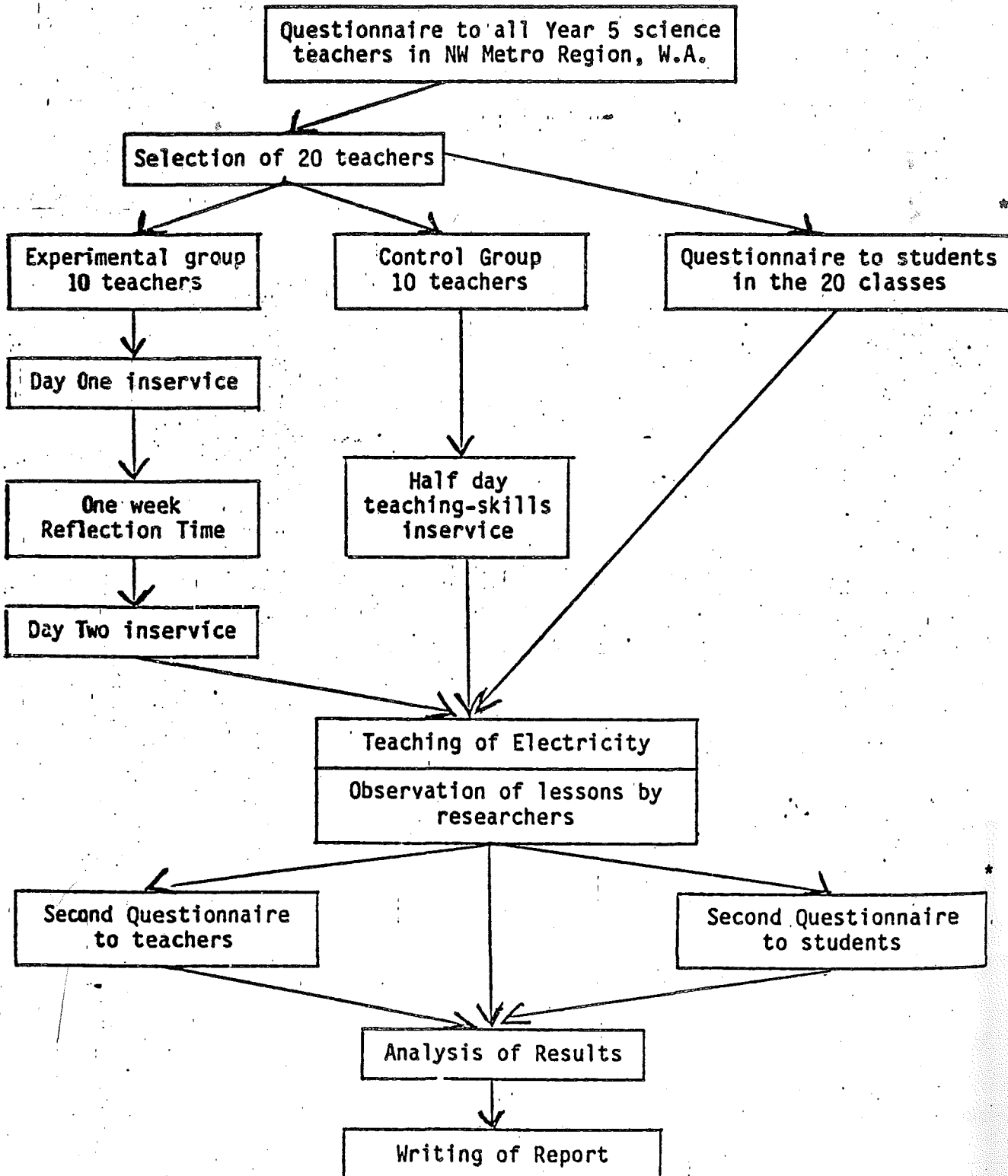
The findings reported in this paper indicate that the project can claim a modest degree of success as regards changes in students' sex-stereotyped attitudes about science. While some students' attitudes, notably the attitudes of boys, appear to have been relatively unaffected by the teacher inservice, there do appear to be at least small, short term gains in relation to other attitudes. The latter include the attitudes of girls towards working with globes, wires and batteries, and the level of confidence expressed by girls in their own personal ability to become an electrician.

This paper underscores three matters of importance. Firstly, properly targetted teacher inservice programs can be effective in bringing about change in student attitudes. Secondly, it is essential for professional development activities and preservice education for primary school teachers to include skills for competent, non-sexist teaching of physical science topics. Otherwise, as Ormerod and Wood (1983) have noted 'secondary science is merely conducting a somewhat forlorn rearguard action to divert girls' interests towards physical science'. Small gains have been made from a relatively short, isolated inservice program. How much greater might these gains be if a concerted, systematic effort were made to include these issues widely in professional development and teacher education programs?

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Appendix 1FLOW CHART OF PROJECT

* Discussed in this paper

STUDENTS, SCIENCE AND THE MASS MEDIA: AUSTRALIAN STUDIES

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In the paper "Images of science and scientists and science education" presented to the 1982 conference of the Association, studies of the images of science and scientists were analysed. Most of the research examined in that paper had been conducted in the U.S.A. or the U.K.

This overseas work revealed a number of important features. The first was that the image of scientists in popular culture was generally a negative one. Scientists were usually portrayed either as mad or so dedicated to truth that they were completely insensitive to their colleagues and families. These images were rarely counterbalanced by portrayal of "normal" scientists, those who were neither mad nor impervious to human emotions. Second, the image of science portrayed in popular culture did not reflect the actual way in which science progresses. Thus, for example, the slow, painstaking way in which scientific knowledge is gradually built up is rarely portrayed. More commonly, the "gee whizz" syndrome is evident in which the crucial breakthrough appears as a result of five minutes of serious thinking! This appears to be particularly true of material produced in the U.S.A.

The purpose of this paper is three-fold. First, it analyses studies which have been conducted in Australia of science and the media. Second, it analyses Australian studies of student perceptions of science and scientists. Third, it attempts to link these two areas of inquiry together.

Science and the Australian media

A number of systematic studies of science and the Australian media have been conducted by Webb and his co-workers. These have included analyses of the following: Towards 2000 (Zadnik and Webb, 1982) and The Science Show (Webb, Glover, Wild, Adeloju and Bowers, 1980) both on the ABC; newspaper coverage of energy issues (Bascombe and Webb, 1981); and, the ANZAAS congress (Chivilo, Staniford, Unkovich and Webb, 1980).

The analysis of the Towards 2000 television series resulted in the following conclusion: "With its emphasis on the novel, unusual and extravagant, Towards 2000 was afflicted by the 'break through syndrome' that is all too common in media treatment of science and technology" (Zadnik and Webb, 1982, p.252). As pointed out in the introduction, this "gee whizz" syndrome is a feature of the portrayal of science and technology in the media in the U.S.A. The analysis of the ABC's Science Show confined itself to a classification of segments of the programme by disciplines (meteorology, biology, science policy and so on). No comment was offered on the image of science and technology being presented.

Bascome and Webb (1981) noted, in an analysis of newspaper coverage of energy issues by the West Australian during a four month period, that a relatively small proportion (0.41%) of newspapers was devoted to energy issues, although in editorials and letters to the editor, energy issues were more evident. They also noted that energy conservation policies of various groups received little attention. Finally, Chivilo et al (1980) concluded that newspapers, in reporting on the 49th ANZAAS congress, appeared to confine

themselves to presenting summaries of papers presented, with little evaluative comment. That is, few reporters availed themselves of the opportunity to interpret and analyse the papers. This possibility for "in-depth" analysis, which is sometimes cited as a strength of the printed media, was certainly not exploited.

There is no evidence from these reported studies of science and the Australian media that portrayals of science and scientists are any more accurate than those in the U.S.A. or the U.K.

Student perceptions of science and scientists

There are many procedures for assessing student perceptions. Most of these are paper-and-pencil techniques which suffer from serious disadvantages, especially with children in the early primary school years. Sometimes these children find it difficult to verbalize and are limited in their ability to read or write, making the use of group tests difficult. Individual tests, on the other hand, are time-consuming. For these reasons, a number of alternative procedures have been developed, such as the projective technique developed by Lowery (1966), this is a procedure which continues to be used in a limited way; Hofman, (1977), for example used it with eight-year old children.

More recently, the study conducted over two decades ago by Mead and Metraux (1957) has stimulated the development of a simple procedure for assessing student perceptions. This method, developed by Chambers (1983) at Deakin University, has the potential for overcoming some of the problems of

assessing perceptions in young children. This approach is called the "Draw-A-Scientist Test" (DAST). Very simply, the students are asked to draw a scientist. A number of indicators are used to assess the stereotypic image of the scientist held by the student. Indicators used by Chambers were the following: Lab coat (usually but not necessarily white); Eyeglasses; Facial growth of hair -- beards, moustaches; Symbols of research: scientific instruments, laboratory equipment; Symbols of knowledge: principally books, filing cabinets; Technology: the 'products' of science; Relevant captions: formulae, taxonomic classifications, the 'eureka' syndrome, and so on. Chambers' use of DAST spanned eleven years: 4,807 children in Australia, Canada and the United States took the test. Each indicator "portrays directly some part of the scientist's actual world" or "may be taken as symbolic of some part of that world". Further, he claimed, even scientists, when asked to draw a scientist, use this standard image.

Australian primary school students

The perceptions of scientists of a number of samples of students in Western Australia have been investigated. In one study (Schibeci and Sorensen, 1983) students were drawn from three different schools. One school consisted of Aboriginal children, and was located in the north of Western Australia. The other two schools were attended predominately by white children in Perth. Each class teacher at each school was requested to ask children in the class to draw a picture of a scientist. Teachers were asked not to prompt students; however, children who were unable to draw a scientist were to be asked to draw a person. The drawing of scientists were analyzed independently by two persons, using the criteria developed by Chambers. The two coders discussed these criteria prior to the analysis. The average number of

indicators for grades 1 to 7 were, respectively, .7, 1.8, 2.4, 3.1 and 3.2. (The corresponding data from Chambers study were: 0.3, 0.4, 1.3, 1.3 and 1.6). Thus, for the Western Australian sample, the average number of indicators, per student rose from 0.3 in grade 1 to 3.0 in grade 7. For Chambers' international sample, the average number of indicators per student rose from 0.3 in grade 1 to 3.2 for grade 5. Both sets of results show a similar general trend: the average number of indicators increase with grade level.

The differences between the absolute values (of average number of indicators per student) in the two studies indicate that it is possible only to draw conclusions about trends across grade levels. It is reasonable to conclude that for the Western Australian primary school children the image of the scientist becomes more stereotyped as the children move through the primary school grades, and that this reflects a trend in the U.K. and North America.

Australian high school students

A study by the author of students (in years 8-10) in a country high school in Western Australia revealed that they also held stereotypic images of scientists. The 52 students averaged 2.0 indicators on the "Draw-a-Scientist Test". In addition, their written descriptions of science and scientists confirm the stereotyped negative images revealed by the drawings.

The results of two further Australian studies of high school students, on the other hand, appear to conflict with the view that students generally hold negative images of scientists. Fraser (1977) investigated the perceptions of

1,158 grade 7 students in 46 co-educational high schools in Melbourne. Sample items which were used to assess these perceptions of scientists are:

"Scientists usually like to go to their laboratories when they have a day off"; "Scientists are about as fit and healthy as other people"; and, "Scientists do not have enough time to spend with their families". These statements formed part of a larger set of items, developed by Fraser (1978), to assess a number of different attitudes of students to science. A score of 30 on this set of items represents a neutral score; 10 represents a very negative score, and 50 a very positive score. Fraser (1977) reported that girls perceived scientists to be "more normal" than did boys "at pretesting, posttesting and in terms of relative changes during the year". As all the means were above the neutral point, indicating that students in general believed scientists to be normal people.

A similar result has been found in a study which included 543 grade 8 students at two metropolitan schools in Perth, Western Australia. In this study students' perceptions of the normality of scientists were examined as part of a larger investigation of the home, school and peer group influences on student attitudes and achievement in high school science (Schibeci, 1984). The mean scores on this "Normality of Scientists" scale were: 34.7 (girls) and 36.7 (boys). These results are similar to Fraser's, with the exception that in the 1984 study boys' perceptions appear not to have changed during the year.

It appears that the results of these two studies are in conflict with studies which report negative images of scientists. The discrepancy may be explained, however, by the finding that during discussions with many of the students, it became clear that they equated "scientist" and "science

teacher"! That is, students were rating science teachers, not practicing scientists. In support of this, Munro (1984) reported that over 80 per cent of students in year 9 regarded their science teachers as scientists.

Science, students and the mass media

The first part of this paper, based on a limited number of Australian studies suggests that the portrayal of science and technology appears to be similar to that in the U.S.A. and the U.K. That is, the image of science and technology is an inaccurate (and sometimes a negative) one. The second part of the paper suggests that those students included in Australian studies generally hold stereotyped views of scientists.

An obvious conclusion, would be that the naive (or distorted) image of science and scientists in the media is responsible for students' negative (or distorted) images. However, we must be cautious in drawing such an obvious conclusion from the limited data reviewed in this paper. Indeed, it would be inappropriate to reach this conclusion even if relevant studies in the U.S.A. and the U.K. were to be included.

In a recent review of the literature on informal learning in science, Lucas (1983) divided out-of-school sources of learning into those which "are intentionally established to teach, and those that teach accidentally" (p.3). Further, he noted that the intentions of the learner were important: in some instances, the potential learner actively seeks out the knowledge; in other instances, the learning occurs from an accidental encounter. According to Lucas, the press and electronic media generally "provide instances of

Table 1

Possible Interactions Between Two
Source of Learning A and B
(adapted from Lucas, 1982, 94-95)

Possible Interaction	Example
A → B A facilitates learning from source B	Principles of biological classification taught in school may facilitate learning the classification of bees and wasps from a museum display.
A ← B B facilitates learning from source A	On a family visit to the zoo, close observation of monkeys feeding on a variety of food may facilitate later understanding of a lesson human tooth structure and function.
A ↔ B A and B are mutually facilitatory	Reading <u>The Andromeda Strain</u> (Crichton, 1969) at the same time as studying microbiological techniques may facilitate both the understanding of the idea of sterile technique and experimental control and this may help the reader learn from other aspects of the book.
A ←/-B B inhibits learning from source A	The everyday language use of 'mixed blood' and 'blood lines' may inhibit understanding and learning of the particulate gene theory in biology.
A -/→B A inhibits learning from source B	Oversimplified, but well taught, accounts of hormonal cycles in humans may produce confusion when viewing a more realistic TV programme on the complexities of control of the reproductive cycle.
A ←/→B A and B are mutually inhibitory	The use of the lens of short-sighted Piggy spectacles to light the fires in <u>Lord of the Flies</u> (Golding, 1954) may produce difficulty in understanding real and virtual images in physics lessons and the teaching of optics as pure rather than applied may not allow critical application of accidental learning sources.

Note: A is the overt school curriculum; B can be an intentionally educative source or an accidental source of learning.

interactions where neither the producer nor the consumer intended to be involved in a science learning episode" (p.18). An obvious exception to this generalisation are materials produced with a specific educational intention, such as a science television programme produced specifically for viewing during school hours.

Lucas (1982) described a number of ways in which interactions could occur between two sources of learning, A (the overt school curriculum) and B (an intentionally educative source or an accidental source of learning). These possibilities are summarised, with examples, in Table 1. It is clear that there are very many different possible types of interactions and we must be cautious in drawing conclusions which are not warranted by the data.

Nevertheless, it is reasonable to suggest that, given the consistency of the generally inaccurate portrayals of science in the mass media, such images would be a potentially powerful influence on the formation of students' images of science and their views of scientists. If this is true, we must ask whether it is possible to remedy the current situation.

Experience with the American television series "Freestyle" (Johnstone and Ettema, 1982) suggests that it is possible to influence students views so that they become more realistic. This television series was produced specifically to combat negative and stereotyped gender images among many children. The results of evaluation of this project suggest that such positive actions towards producing more realistic images are possible, especially when such a programme is used as the basis for a discussion of the issues raised.

The showing of programmes which portray reasonably accurate views of science and television, together with a discussion in science classrooms of the issues raised, appears to offer the possibility of inducing in our students a more realistic view of the institution of science, and the practice of scientists.

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