An Analysis of Geology Curricula in Secondary and Tertiary Education.

IAN CLARK

Thesis submitted for the degree of
Doctor of Philosophy in Geology

THE UNIVERSITY OF ADELAIDE
Department of Geology and Geophysics

October 1996

TABLE OF CONTENTS

ERRATA

p 45 10th last line should read:

"A review of the content of junior secondary school science curricula shows that the geoscience..."

p 48, Section 3.4 First sentence of the third paragraph should read:

"Each of the statements in each of the eight areas of learning is divided into content and process strands which reflect the major elements of learning in the area."

p 63, Section 3.55 Section heading should be:

"Comparison of Geology/Earth Science Curricula"

p 53 4th last line should read:

"In Victoria a 4 unit course over two years was available..."

p 85 First sentence of last paragraph should read:

"For all questions except question 4 the students who had studied geoscience at senior secondary level performed better than those who had not."

p 186 Sections 7.42 and 7.421 and Figure 7.2:

GP1 and GP2 on Figure 7.2 denote the Bachelor of Applied Science students and the Bachelor of Education students respectively.

ABSTRACT

This work investigates the geology curriculum at three levels and the relationship that exists between one level and the next. For the secondary school level the emphasis is on the senior geology/earth science curricula and the way in which they link to the introductory geology curriculum at tertiary level. The introductory tertiary geology curriculum is viewed from the perspective of the effect of prior knowledge on student performance and the advanced tertiary geology curriculum is investigated in the context of quality teaching and learning using the structural geology part as a focus.

The review of the senior secondary school curriculum compares geology/earth science curricula for the Australian states and the K-12 science curriculum statements for Australia, the United States, and England and Wales. The content of each of the Australian state senior secondary school geology/earth science curricula is described in detail and the aims and objectives and assessment methods are compared. The development of the goals and the content of the Earth Systems approach to science education is reviewed and is used as a framework for comparison of the content of all of the curricula including the K-12 statements. The content of the Australian state senior secondary school geology/earth science curricula is also compared using a more traditional framework.

The reviews of the Australian state senior secondary school geology/earth science curricula are used as the basis for studying pre-requisite knowledge required for introductory tertiary geology/earth science subjects. The methods and results of the study are described and recommendations are made for further study using a modified methodology.

The advanced geology curriculum study is concerned with the context specific skills that are important in coming to an understanding of what is good teaching in geology using the advanced undergraduate structural geology curriculum as a case study. It describes the results of an action research project which was carried-out with subsequent groups of second year undergraduate students at the University of Adelaide and the University of

South Australia. During the project the teaching methodologies were modified to try to improve the quality of student learning. The modifications involved changing the way information was delivered to students including the move towards the electronic classroom, changing the structure and organisation of the curriculum and introducing and encouraging students to use new learning strategies, particularly concept maps.

The outcomes of the modifications were evaluated quantitatively using end of year subject examinations results, and qualitatively by analysing student evaluation of the subject and teaching questionnaires, student interviews, and reflective journals kept by the students. The quantitative results showed that there was a statistically significant improvement in student learning as measured by exam performance as a result of the modifications and this was supported by their comments in the evaluation questionnaires and their journals.

STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Ian Clark, September 1996

ACKNOWLEDGEMENTS

In undertaking this research I have benefitted greatly from assistance, advice and technical support provided by a number of individuals and organisations.

My supervisors Associate Professor Patrick James and Associate Professor Brian McGowran provided invaluable support throughout the entire process from the development of the original ideas for the research to the careful and critical reviews of the various drafts. I am also deeply indebted to Associate Professor Patrick James for trusting me to work with his classes and for instigating many of the innovative teaching methodologies which were incorporated into the teaching. Without his deep interest and support this research would not have been possible.

Other staff members from the Department of Geology & Geophysics at the University of Adelaide provided valuable support both academic and technical as well as providing me with a room and access to facilities.

My colleagues at the University of South Australia, both past and present provided valuable encouragement and support throughout the project. I thank them sincerely for helping with my academic tasks and for providing valuable technical assistance with the development of the teaching technologies and the preparation of this thesis. I also benefitted from financial support provided by the University of South Australia for a period of Professional Experience Leave and for attendence at a number of conferences during my candidature.

An important part of the motivation for this research and the development of an interest in the processes of geological education comes from Professor John Carpenter. I thank him for his inspiration, for the many valuable hours spent talking to me about geological education and for introducing me to other geological educators in the United States from whom I have gained valuable insights. To his colleagues and graduate students at the Center for Science Education at the University of South Carolina I extend my special thanks for their friendliness and critical discussion of my work. I especially thank John and his wife Charlie for their generous and warm hospitality during my several visits to South Carolina.

Professor Joe Ryan from the University of South Carolina helped me with the analysis of the quantitative data and Dr Sara Samson helped me prepare the data for analysis and review the results. I thank both of them also for their generous hospitality and warm friendship.

My deepest gratitude is to my family; to my wife Lee and our children Christopher and Erin I can not thank you enough for your patience and support.

CHAPTER 1

INTRODUCTION

1.1 FOCUS OF THE STUDY

The focus of this study is the geology curriculum: in particular the content of the senior secondary school curriculum and the way it relates to the introductory tertiary curriculum; the importance of prior knowledge in the design and teaching of the introductory tertiary geology curriculum; and the effect of modified teaching techniques on the quality of teaching and learning in the advanced undergraduate geology curriculum, using structural geology as a case study.

In the sense of this study, curriculum is a broad concept which entails all aspects of the course of study including aims and objectives, the specific content, the assessment, and the evaluation processes. An important part of the consideration of the curriculum is the evaluation of the way that student learning is related to teaching in terms of the aims and objectives of the curriculum.

1.2 BACKGROUND FOR THE RESEARCH

For many years curriculum development has been the realm of the people involved in the teaching, with little external influence. In the case of university curricula, the people involved are the teaching staff whose other roles are research and scholarship. Recently two new factors have influenced the curriculum development process in universities. The first is the political context which has become much more influential, particularly in the area of how curricula are taught (quality) and efficiency (accountability). An outcome of this is the response by some universities to develop policies involving flexible delivery strategies in the hope of greater efficiency. The other factor which has influenced curriculum development is the rapidly developing technologies which are significantly influencing the tools (such as multi-media presentations) that are accessible to most university teachers.

1.21 The Political Context

Australian universities are now operating in a highly political environment which is controlled to a certain extent by the Federal Government's moves towards restructuring and maintaining quality. Although the concerns about quality can be traced back to the Williams Report of 1979 which was a report of the Committee of Inquiry into Education and Training, the real impetus comes from the former Minister for Higher Education and Employment Services, Peter Baldwin, and his policy statement *Quality and Diversity in the 1990s* (Baldwin 1991). In this statement Baldwin asserted the need for universities to equate teaching with research and the need for government to provide incentives for institutions to enhance teaching quality. This was more than rhetoric as the government provided funding through the National Priority (Reserve) Fund to establish good teaching practices in institutions, an outcome of which was the Committee for the Advancement of University Teaching (CAUT). Another aspect of this development was the need for staff development. The Second Tier Settlement for Academic Staff (1988) requires that universities:

> *establish staff development units which provide programs related to teaching development. Further all new academic staff without teaching experience should be encouraged to undertake training in teaching and their teaching loads adjusted accordingly.* (Second Tier Settlement, Staff Development Attachment, point 8)

The government has provided more than $5 million annually since 1993 through CAUT Grants for teaching development and other initiatives. These grants are to assist staff development and also to enhance teaching within institutions. Outcomes of this and other related initiatives include the AVCC's publications of its *Guidelines for effective university teaching* (1992) and *Guidelines for quality assurance in university course development* (1992).

1.22 The Developing Technology

The ability to incorporate multi-media into the presentation process, both during lectures and in the form of packages designed for students to use in place of lectures or in addition to lectures has had an important impact on the way teaching has changed. New technologies and easy-to-use software have made it possible for individual teachers to develop their own multi-media packages. This has encouraged university administrators to look to these as ways of increasing efficiency and catering for the differing needs of students (flexible delivery). There is a perception that the use of multi-media packages will lead to greater efficiency and reduce the time spent by teachers in face-to-face contact with students without reducing the quality of student learning. There is also an assumption that delivery in a flexible manner to accommodate more independent study and flexibility of pace and place is of benefit to student learning (Harrison 1994 p 33).

Thus there is a major push to enhance the recognition, status and quality of teaching in universities, and for all teaching and curriculum development to incorporate the use of multi-media technologies to enable flexible delivery and improve student learning

1.3 RATIONALE

In 1993 the Department of Geology and Geophysics at the University of Adelaide prepared a Draft Strategic Plan which included as its first goal:

> *to provide education and training for undergraduates, graduates and postgraduates, who not only will be responsible as professionals and citizens for encouraging the appreciation of the earth sciences at large, but will have to keep on responding to increasing rates of change in their various disciplines into the next century*
>
> (McGowran 1993, p 2)

A fundamental means of achieving this goal is the quality of the curriculum. The curriculum of the department needs to be interesting to attract students, relevant to be credible to professional peer groups and employers, and well planned to cater for the diverse range of students who study in the department. The range of students includes: those from the science and arts faculties who are seeking an education which includes an appreciation of earth history and its biosphere and of the environment; students from agriculture and engineering who require elements of geology as part of their professional training; students seeking a career in the earth sciences; and students intending to undertake research in the earth sciences.

This diverse range of students presents a problem for the curriculum designers, one which is exacerbated by the fact that the students also come to the introductory subject with different backgrounds in geology. Some have studied geology at Year 12, some have only studied geology in junior secondary science, and some have not studied geology at all. All of these factors need to be taken into account when planning and designing the curriculum.

An outcome of this first goal of the department, also described in the Strategic Plan is to 'sustain the quality of the teaching... by establishing more formal ways of monitoring the effectiveness of teaching and reviewing new initiatives...' (page 3). This is another problem for the Department which needs to be addressed in achieving its goals.

1.4 JUSTIFICATION FOR THE RESEARCH

Two related problems associated with the geology curriculum have been outlined in section 1.3. To address the problem of curriculum design at the introductory tertiary level it is necessary to investigate the links between the introductory tertiary geology curriculum and the senior secondary geology/earth science curriculum. The content of the senior secondary geology/earth science curriculum must be considered when designing the introductory tertiary geology curriculum because of its possible influence on students' prior knowledge when they begin introductory university subjects. Prior knowledge is likely to have an influence on students' attitudes and interests. A significant purpose of introductory tertiary geology subjects is to encourage students to study more geology, so it is important to know how prior knowledge of the subject influences their interest and attitudes.

Another reason for studying the senior secondary geology/earth science curriculum is to determine its ability to adequately prepare those who are not going on to further study in the earth sciences. It is our responsibility, as professional earth scientists, to ensure that society is as well informed as possible to make decisions, and to influence political decisions which bear on the future well-being of the planet. Therefore we should be informed about, and involved in, the curriculum development process at the senior secondary geology/earth science level.

A second aspect of the curriculum which is addressed by the department's Strategic Plan is the way that it is taught. The question of what is good teaching and how is it measured and monitored needs to be addressed. Neuman (1994) contends that teaching is a highly complex practice which has two aspects: a generic skills and expertise aspect; and a context specific skills and expertise aspect. The context specific aspect has been largely ignored by researchers and policy makers, concentrating on overarching teaching skills which, while important, only provide a partial practice picture of what teaching involves.

> *... in order to genuinely comes to grips with teaching quality, attention needs to focus on the specific context in which teaching occurs and on effectively utilising this knowledge to extend the dialogue about teaching within universities* (Neuman 1994, p 8).

It is this second aspect, the context specific skills, that this study is concerned with when addressing the second problem described in section 1.3.

In order to establish more formal ways to monitor the effectiveness of teaching and review new initiatives it is first necessary to address the question "what is good teaching?". Until recently, university teaching was simply about imparting knowledge (Laurillard, 1993). Since the knowledge was delivered by lectures, anyone who was able to speak and who had the knowledge could be a university teacher. However most university teachers know that the simple teaching aim of imparting knowledge does not always work. Many students demonstrate their lack of knowledge at examinations and in essays and assignments. Such an aim may have been reasonable in the past when universities were elitist and students could be expected to be responsible for their own learning. Today, however, universities are much more accessible so it has been necessary to modify the aim to one which involves student learning. A more acceptable statement is that proposed by Ramsden: 'the aim of teaching is simple: it is to make student learning possible' (Ramsden, 1992, p5).

Since the aim of university teaching is now more concerned with promoting student learning, it is necessary to develop and investigate the effectiveness of modifying the curriculum and the methods of delivering the content.

1.5 THE RESEARCH QUESTIONS

In this context the three questions to be addressed in this research are:

1. **How is the content and framework of senior secondary geology/earth science relevant to the widely accepted aims of geology/earth science education?**

2. **What influence does students' prior knowledge of geology/earth science have on their achievement in and attitude to introductory tertiary geology/earth science subjects?**

3. **How do modifications to the curriculum and to the teaching of geology affect student learning?**

1.6 ORGANISATION OF THIS THESIS

These questions are addressed in the following chapters of this thesis. Chapter 2 is a review of the relevant literature and reviews those aspects which are generally related to the methods of the research and those which form the background to it. Specific reference to the literature is also included in the more descriptive chapters where the methodology and the results are described. To avoid duplication some of the most relevant literature is only briefly referred to in this chapter and is more extensively treated in the context of later chapters.

Chapter 3 describes aspects of the senior secondary geology/earth science curricula and reviews the outcomes of the curriculum development efforts for Australia in the early to mid nineteen nineties; a time when the new national curriculum was being implemented and the pre-existing senior (Years 11 & 12) curricula were being taught. At this time K-12 curricula were being developed and implemented in the United Kingdom and in the United States so it is possible to describe the situation in each of these countries to provide a comparison for what has happened in Australia.

The purpose of the chapter is not to give an historical perspective of the development of geology/earth science curricula. However the outcomes of the largely independently developed curricula are similar, especially at the level of the major concepts, so it is instructive to look at the processes involved in deciding on these concepts. Because the best documented is the situation in the United States, this has been chosen for description to place the rest of the chapter in context.

Chapter 4 describes an attempt to determine the influence of prior knowledge on students' attitudes and achievement in introductory subjects. Two survey instruments were constructed and administered. The first was an orientation survey administered in 1991, the second was a more carefully constructed instrument given at the beginning of 1992. Analysis of the data collected provided an interesting insight into the range of prior knowledge of students.

Chapter 5 describes the investigation of quality teaching and learning in structural geology and in particular the way in which the delivery methods have been modified and the different learning strategies have been introduced to the students.

Chapter 6 explains the background of the evaluation processes that were used in this research to determine the effectiveness of the modifications to the teaching methods and the introduction of the different learning strategies. Evaluation of teaching is also used by some institutions as a way of demonstrating accountability. The nature of evaluation in this context and its relationship to evaluation as a means of gauging the extent to which effective teaching is going on, and to use the results to help improve the quality of instruction is also discussed in this chapter.

Chapter 7 describes the nature of the research into the teaching and learning of geology at the tertiary level. Two different curricula were used: the introductory geology curriculum and the second year undergraduate structural geology curriculum. It also describes the way that the research was designed, the quantitative and qualitative methods that were used, the way in which the data was collected, and the data that was collected. The results of the data analysis are also described in this chapter.

Chapter 8 contains a discussion of the results of both the qualitative and the quantitative data in terms of the effectiveness of the modifications to the teaching and learning methodologies and their effect on the way students learn.

Chapter 9 draws together the conclusions which have been reached about the different aspects of the geology curricula that have been studied and goes on to make some recommendations about the methodologies and follow-up studies and actions that should be pursued in the area. These conclusions and recommendations are grouped under the headings of the three main aspects of the geology/earth science curricula that have been studied: namely the syllabus framework and content, assessment and teaching of the senior secondary geology/earth science curriculum; the implications of prior learning for the introductory tertiary geology/earth science curriculum; and quality teaching and learning in the advanced tertiary geology/earth science curriculum.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There is a considerable body of knowledge in the literature which relates to the purpose of this research. This chapter reviews those aspects which are generally related to the methods of the research and those which form the background to it. Specific reference to the literature is also included in the more descriptive and analytical chapters of this work where the methodology and the results are described. To avoid duplication some of the most relevant literature is only briefly referred to in this chapter and is more extensively treated in the context of later chapters.

This study took the form of an action research project which is defined by Zuber-Skerrit (Zuber-Skerritt 1992) as "collaborative, critical enquiry by academics themselves (rather than expert educational researchers) into curriculum problems." The ultimate purpose was to improve the quality of the teaching and learning of structural geology by modifying the teaching methods to encourage more meaningful learning by the students. The modified teaching methods were based in the constructivist philosophy of learning using a variety of delivery techniques and teaching strategies. The outcomes were evaluated using a range of traditional methods and some methods which are less conventionally used in tertiary science teaching.

This chapter reviews the literature related to the three main aspects of the research which form the background setting for the research. These are:

- quality teaching and learning, particularly as it has been applied in Australia;
- concept mapping as a background to the main method which was employed to encourage students to learn more meaningfully;

- and the use of journals for evaluation.

Chapters 4 and 5 describe the methods of the research and also contain extensive reference to the literature which is specifically relevant to each part.

2.2 QUALITY TEACHING

Quality is a relative concept, not an absolute one. It is either high or low, good or bad. It is relative to purpose. Thus any discussion of quality teaching must be judged in relation to its purpose. Most workers today link teaching to student learning. The Australian Vice-Chancellors' Committee in their reports related to quality link quality teaching to student learning (AVCC 1993) (AVCC 1993b). They recommend having in place policies which assert the priority of quality teaching and learning overtly and unambiguously. The report of the University of Adelaide Working Party into quality in teaching and learning argues that any meaningful discussion of quality teaching rests on understanding the kind of student learning that is sought (Working Party on Quality in Teaching and Learning 1992). Research at the University of South Australia indicates that learning that is valued has amongst others the following characteristics: it is independent; it teaches how to learn; it lays the foundation for life-long learning. In this discussion Moore and Smith (1994) assert that valuing student learning 'entails more than valuing a particular type of learning' (Moore and Smith 1994, p24). If there is a commitment to all students achieving success it must result from improving the quality of teaching and not at the expense of standards of excellence.

There is now a wide body of research evidence to support the contention that improving the quality of teaching in higher education rests upon an authentic valuing of teaching in the general ethos of the university as a whole and in the university's policies and practices which promote, encourage, and support teaching (Lonsdale 1990; Pearson 1992; Ramsden 1992; Working Party on Quality in Teaching and Learning 1992; Mullins and Cannon 1993). In his opening address to the National

Teaching Workshop at Griffith University in February, 1992, Professor L.R. Webb, Vice-Chancellor of Griffith University, commented on the quality of the teaching at that university and attributed its [high] quality to the fact that it was monitored, and was an important criterion in selection and promotion of staff. However he went on to say that although it was possible, no-one has nominated teaching as their preferred criterion in applying for promotion from Senior Lecturer to Associate Professor (Webb 1993). Other research bears this out. This issue was raised by Minister Baldwin in his policy statement (1991) and by the NUS (1992) in its response to the HEC discussion paper on quality. Most academics are sceptical about the extent to which universities do value teachers and teaching and many academics believe that their own career interests are best served by actively engaging in research even if their teaching suffers as a result (Working Party on Quality in Teaching and Learning, 1992; Lonsdale, 1990; Mullins, 1993). It is difficult to know how important teaching is in promotion decisions because the discussions are confidential, but the fact that academics perceive teaching not to be rewarded equally with research is shown by research on academics and academic work overseas as well (Haneman 1975; Bassis and Guskin 1986; Clark 1987; Stevens, Goodwin et al. 1991). Other workers have shown that the recent trend amongst university academics is towards a research culture rather than a teaching culture (Corcoran and Clark 1984; Startup 1985; Everett and Entrekin 1987) however studies of academic work show that the vast majority of academics spend more time teaching than researching, and that they enjoy teaching (Neumann 1994). Clark (1987) found that most academics that he interviewed preferred a combination of teaching and research activities and Neuman (1992) showed that academics can clearly articulate the links between teaching and research.

Donald (1984) studied the quality indices used to assess research, teaching and service in Canadian and United States universities and showed that whilst student evaluation was the only index used to measure quality of teaching, research quality was measured by means of publications, citations and peer judgement implying that research quality was more important than teaching quality. This is further supported by the work of Lin, McKeachie and Tucker (1984) who showed in a study of factors affecting university promotion decisions in the United States that although promotion committees claimed to weight teaching and research equally, in practice statistical summaries of student ratings had little effect on promotion compared with research productivity.

2.21 Characteristics of Quality Teaching

Ramsden (1992; 1993) prefers to describe teaching as effective rather than using quality to describe good teaching. His judgement of teaching is clearly linked to student learning, 'the aim of teaching is simple: it is to make student learning possible.' (Ramsden 1992, p 5). This places much more responsibility on the teacher and implies that the teacher should know something about how students learn and what makes learning possible. This is what Laurillard (1993) terms mediating learning.

Ramsden (1993) proposes six principles that characterise effective teaching based on what students say is good teaching and on thinking about how to facilitate learning in relation to what is known about different approaches.

2.211 Principle 1: Interest and explanation

This principle deals with teaching itself. To stimulate, it must be interesting and be able to explain difficult concepts clearly. Although it is not possible to teach people to understand, it is possible to help them find understanding by using interesting and vivid examples which make the subject more interesting and approachable. This principle is supported by examples in almost every journal about science teaching where individuals report on ways of improving student learning by using examples. For example Morrell (1990) describes a way to help biology students visualise the conversion of ATP to ADP using a visual aid. Dantonio and Beisenherz (1990) propose that student interest in science is increased when it is taught using demonstrations and active participation of the students. In geology courses field trips provide an opportunity for this kind of activity (Kern and Carpenter 1984a; Kern and Carpenter 1984b; Clement 1987; Locke 1989; McCombs 1990)

2.212 Principle 2: Concern and respect for students and student learning

The second feature involves caring for students. Good teachers show respect for their students and have consideration for them as learners. This is supported by other research which stresses the importance of respect and consideration for students (Feldman 1976; Beyerbach and Smith 1990; Entwistle and Tait 1990; Lonsdale 1990; Working Party on Quality in Teaching and Learning 1992; Webb 1993; AVCC 1993b; Moore and Smith 1994). The worst kind of teaching is that which is indifferent to students' needs and to how effectively they are learning. Laurillard (1993) supports this and proposes that teachers need to know more than their subject. They need to know the ways it can be understood, the ways it can be misunderstood, and what counts as understanding. She stresses the importance of understanding individual student's needs but despairs that the current system of mass lectures and examinations make this approach impractical.

2.213 Principle 3: Appropriate assessment and feedback

The third principle is appropriate assessment and feedback on students' work. A common feature of student submissions to various enquiries is the importance of appropriate assessment and high quality diagnostic feedback about learning progress. These two characteristics are critical in students' judgement of what is good teaching (Marsh 1987; Working Party on Quality in Teaching and Learning 1992). Ramsden reported that this is the item which most effectively differentiated between the best and worst courses as judged by students (Ramsden 1991).

2.214 Principle 4: Clear goals and intellectual challenge

The need for clearly enunciated goals which present an intellectual challenge to students is Ramsden's fourth principle. He says that there is no point in having low level goals or being satisfied with mediocre achievement. This is supported by Moore and Smith, 1994. Good teachers challenge students to give their best. Research clearly shows that consistently high academic expectations are associated with high levels of pupil performance. This, says Ramsden, should be relatively easy for lecturers in higher education but what is not easy for them is explaining to students 'what must be learned to achieve understanding and what can be left out for the time being'. To achieve this, **key concepts** should be clear and the temptation to include too much content should be avoided. Otherwise students will be confused and will lose their excitement for the subject. There is a very strong temptation to include more and more into the practical curriculum in order to adequately prepare graduates to practise, and to be "up-to-date". However this practice often leaves students with a fragmented and disjointed view of the field rather than an understanding of the essentials (Candy, Crebert et al. 1994).

2.215 Principle 5: Independence, control, and active engagement

Effective teaching engages students to become involved and to become responsible for their own learning. Ramsden writes at length about this aspect of effective teaching. Vygotsky(1962), Piaget (1926) and Bruner (1966) argue for the active engagement of the learner rather than the passive reception of given information. This approach has been adopted by primary school teachers but not in universities (Laurillard, 1993) where there is 'a continued reliance on lectures and textbooks, the classical tradition of imparting knowledge still flourishes' (Laurillard, 1993, p4).

The essence of the new approach is that by engaging students we give them the opportunity to gain control of the learning and to develop an interest in the subject matter. It is well known now that different students learn in different ways (Entwistle and Ramsden 1983; Gibbs, Habeshaw et al. 1984; Biggs 1988; Entwistle 1988; Marton 1988). 'Active engagement, imaginative enquiry, and the finding of a suitable level and style are all much more likely to occur if teaching methods that necessitate student activity, problem solving, and cooperative learning are employed' (Ramsden,1992). Students report that this style of learning is more enjoyable than the traditional lecture, practical, tutorial approach. The benefits of cooperative learning compared to individualistic learning are well known (Johnson, Maruyama et al. 1981). Students are more likely to use deep approaches to learning and achieve higher quality learning outcomes.

2.216 Principle 6: Learning from students

'Effective teaching is a continuous process of trying to find out about what your students have learnt' (Ramsden 1993). This principle is the one that Ramsden regards as most important. Teachers should not take for granted the effect that their teaching is having on the students. They must provide opportunities for themselves to find out. Consequently good teaching is always open to change: 'it involves constantly trying to find out what the effects of instruction are on learning and modifying that instruction in the light of the evidence collected' (Ramsden 1992).

2.22 Quality Learning

Ramsden (1992) presents what students learn in terms of a series of qualitatively different levels. At the most abstract level he places general abilities and personal qualities such as critical thinking skills and ability to communicate. Next there is content understanding. This involves content-related changes in understanding linked to the particular discipline such as understanding of plate tectonics or the structure of the Earth. Also associated with this qualitative level, Ramsden includes the difficult to define concept of "thinking-like" a geologist or -like an engineer when faced with a particular problem. This learning, if it comes at all, comes later in a student's undergraduate career, even though it is often found as a desired outcome in course descriptions. Finally comes specific knowledge. This includes factual information, technical or manipulative skills, and specific problem-solving techniques. "Knowledge at all these levels and the ability to connect knowledge at each level to. each of the others, is regarded as essential if a graduating student is to be considered an educated person.'(Ramsden, 1992 p18).

Student learning must be clearly the focus of quality teaching. In many cases, university teachers think that improvement in the teaching will translate automatically into effective learning (Pratt 1992), however, too often the approach to learning which results is one in which the learner concentrates on the requirements of assessment rather than on engaging with the subject matter. This is what Sawyer (1943) described as learning *imitation subjects* rather than learning real ones. Teachers expect their students to develop intellectual abilities that go beyond the possession of technical skills and subject knowledge. To achieve this students must combine and relate ideas so that the knowledge can be used in new and unfamiliar situations. Students who have only learned imitation subjects have been involved in a process that has enabled themto acquire knowledge which is useful in a very limited range of situations. Much of what they have learned has no personal relevance to them nor any connection to the real world it is supposed to explain. An example of learning an imitation subject is learning the concept of dip and strike and using it to complete cross-section problems on simplified maps in the laboratory or classroom. Without actually using a compass and clinometer in the field the concept of dip and strike will never be applied to the real world and will remain an imitation subject.

It is harder to learn imitation subjects rather than real ones; it is also more dreary (Ramsden 1993). Learning imitation subjects equates to surface learning while learning real subjects equates to deep learning. Ramsden(1992) discusses these two different approaches to learning. Taking a deep approach involves trying to understand, relating evidence, ideas, and data. It means trying to make sense by relating parts of the material to the whole, using previous experience and knowledge to make sense of the new material, and taking a vigorous and active approach to learning the content. This relates to the cognitive and constructivist theories of learning (Ausubel 1968; Wittrock 1974; Anderson 1985; White 1988). Essentially these theories are that *learners construct their own meanings from the knowledge they acquire.*

White and Gunstone (1992) suggest that the 'first step in describing understanding is to sort out the targets we talk about, and see what lies behind understanding of each'. They specify six targets of understanding and describe the forms of knowledge which underlie each. The six targets are understanding of: concepts; whole disciplines; single elements of knowledge; extensive communications; situations ; and people. Understanding is a function of the number of elements of knowledge that a person has about a target and of the mixture of different types of element and of the pattern of associations that the person perceives among them. White and Gunstone (1992, p 5) define understanding of a particular topic as... "the set of propositions, strings, images, episodes and intellectual and motor skills that the person associates with the"... particular topic. Understanding is thus a continuum and it is difficult to say that one has a complete understanding of a particular topic or to say that one person's understanding is better than another's. White and Gunstone(1992) extend this stating:

> *understanding develops as new elements are acquired and linked with the existing pattern of associations between elements of knowledge. Addition of new elements will often stimulate reorganisation of the pattern as the person reflects on the new knowledge and sees how it puts the older knowledge in a different light.* (White and Gunstone 1992, p13)

Using surface approaches to learning (studying the imitation subjects of Sawyer, 1943) students do not remember what they have studied for very long, they cannot apply it to the real world, they cannot use their new knowledge to solve new problems. Generally students do not enjoy learning by the surface approach because they skate across the surface of the subject rather than getting involved with it (Marton and Saljo 1984). One of the main aims in the quest for quality teaching is 'to discover ways of encouraging students to use deep approaches' (Ramsden 1993). Part of this quest is to look at traditional methodologies. Candy (1994) suggests that some of these are not necessarily achieving what we would wish:

> *...it is patently clear that lectures -especially poorly presented lectures- do little to develop in students a 'deep' approach to learning, and an abiding love of learning or of their subject.* (Candy 1994,p64)

What do students say about what encourages one or other of these approaches? Surface approaches are encouraged by assessment methods which create anxiety and emphasise the recall of trivial details; too much content; poor teaching, especially lack of feedback about student progress; and a perception that they have no control over learning. On the other hand, deep approaches are encouraged by having clear aims and objectives, making clear what has to be known and what does not have to be known; encouraging long-term active engagement with the subject. Student feedback stresses the importance of stimulating and inspiring teaching and being taught by staff who care about what they are learning, who are concerned about students and who encourage independence and responsible choice over learning (Ramsden 1993; Candy, Crebert et al. 1994; Moore and Smith 1994).

Svensson (1977; 1988) introduced a second aspect of the approach to learning by students. It relates to deep and surface learning but is about the different ways that students organise information, particularly about whether they distort and segment the framework of the task. They may confuse the concept with the evidence which is presented to support it and see each separate component as a single sequence of facts. This is called an *atomistic* approach (Ramsden 1992). The alternative is to maintain the structure through integrating the whole and the parts: this is known as an *holistic* approach. These two aspects of student approaches to learning are summarised in Figure 2.1 from (Ramsden 1992). In practice the two aspects must be fused together.

Ramsden (1992) defines an approach to learning as the relationship between the student and the learning he or she is doing and stresses the need to distinguish between characteristics of students and the nature of different approaches to learning. This distinction is critical because by changing the approach to try to improve the quality of teaching one should not try to change the students, but should change the students' experiences, perceptions, or conceptions of the topic. Thus surface approaches are unacceptable in the ideal educational environment. Whilst this approach may enable a student to pass an exam, the information will almost certainly be forgotten within a few days. The deep/holistic approach is the only way to achieve understanding (Marton and Saljo 1984).

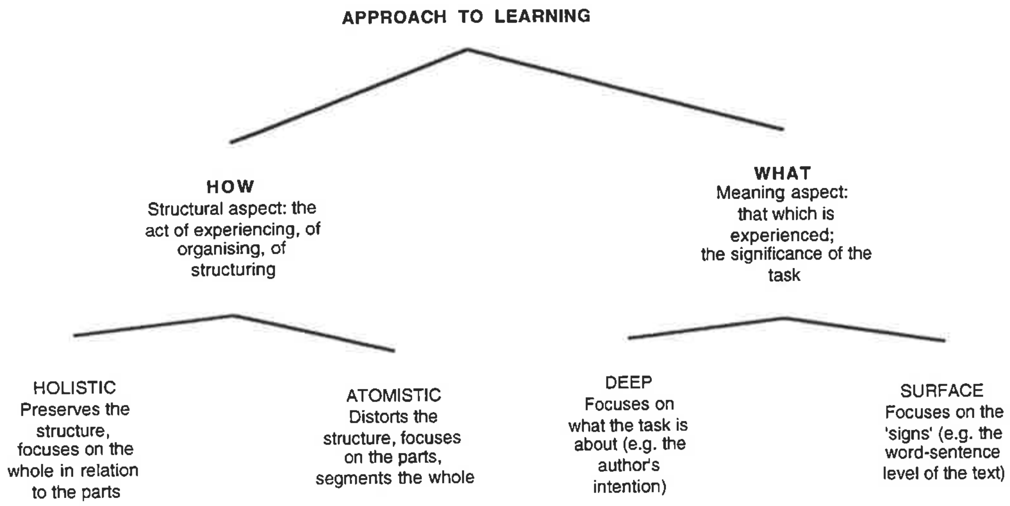


Figure 2.1 The logical structure of approaches to learning (from Fig 4.1 Ramsden, 1992)

2.3 CONCEPT MAPPING

One of the purposes of this research was to encourage students to adopt a deep/holistic approach to learning in order to develop a better understanding of the concepts of structural geology. Although structural geology is included in introductory courses, its treatment in second year involves many new concepts. An attempt has been made to present these concepts most effectively by using concept maps as both a teaching tool and a learning tool.

A concept map is a way of representing concepts and the organisation of subject matter. Concept maps help students see the subject matter more meaningfully. A concept map is a two-dimensional view of a discipline or a part of a discipline (Stewart, Van Kirk et al. 1979) that allows for the representation of the propositional relations between concepts. This method gives students a much different perspective to the traditional note-taking method which is one-dimensional and illustrates no relationships between concepts. The concept map not only identifies the major points of interest (concepts), but also shows the relationships between them in much the same way that a road map shows the links between cities.

Concept maps can also be used to show the hierarchy of concepts (Novak, Gowin et al. 1983). Usually not all concepts have equal weight. Some are more inclusive than others. Traditionally concept maps have the most inclusive concept at the top and progress down through to the least inclusive, more specific concepts.

The purpose of using concept maps was to achieve meaningful learning rather than rote learning. In the process of meaningful learning, the new knowledge is incorporated into the existing knowledge of the learner. On the other hand, rote learning is characterised as learning in which the information is arbitrarily stored because the learner does not have the relevant concepts required to incorporate the knowledge in any other manner. It is generally accepted that meaningful learning is much more effective.

2.31 Learning Theory and Constructivism

The central concept of the learning theory of David Ausubel (Ausubel 1963; Ausubel 1968; Ausubel, Novak et al. 1978) is the idea that meaningful learning takes place when new knowledge is consciously incorporated into the concepts and ideas previously acquired by the learner. Novak (1989) describes how this learning theory has been applied to facilitate meaningful learning.

> *... each person constructs his/her own representation of the world and these representations collectively determine the meaning of the events or objects the person deals with. Language codes much of this representation in the form of concept labels and propositions and this concept/propositional structure is the cognitive organisation that determines the meaning of experience for the person.* (Novak, 1989, p 206)

This approach to learning has come to be known as constructivism and is described by Savery and Duffy (1994) as 'a conceptual framework that addresses how we come to understand or know'. Constructivism contrasts directly with the behaviourist view and with the cognitive information processing view of the way we learn to come to understand. This *constructivist* view of learning suggests that knowledge is a human construction and that knowledge evolves across cultures and over time in an endless succession of conceptual change. Parker (1992) summarises what has come to be accepted as a constructivist view of the process of learning science by repeating the list of six issues articulated by Driver and Bell. The issues are:

- learning outcomes depend not only on the learning environment, but also on the knowledge, purposes and motivations the learner brings to the task;

- the process of learning involves the construction of meanings;
- the construction of meaning is a continuous and active process;
- having constructed meanings, the learners evaluate them and consequently accept or reject them;
- learners have the final responsibility for their learning ; and
- there are many situations in which the meanings constructed by one group of students are quite similar to those of another group.

Savery and Duffy (1994) extend this by relating the understanding which develops, to the environment in which learning takes place. They propose that this is the core concept of constructivism. The value of teaching methods that are explicitly constructivist has been extensively documented (Lochhead 1983; Confrey 1984; Clement 1987; Duckworth 1987; Steffe and Cobb 1987; vonGlaserfield 1989). This style of teaching is not new and has been practised intuitively by good teachers since the days of Socrates (von Glaserfield, 1989). Constructivism merely supplies a theoretical foundation that seems compatible with what has worked in the past and one which may help less intuitive educators to improve their methods of instruction.

2.32 Using Concept Maps for Teaching and Learning.

One of the outcomes of the research which followed these ideas was the concept map. Concept mapping had its origins in the research of Novak and others at Cornel University who were studying changes in students' understanding of science concepts over a 12-year period (Novak and Musonda, 1991). The research was based on Ausubel's (1968) assimilation theory of cognitive learning which proposed that new concept meanings are acquired through assimilation into existing frameworks. In an attempt to represent the frameworks and the changes to the frameworks as learning proceeds, Novak and colleagues developed the idea of concept/propositional frameworks which they described as "cognitive maps" or "concept maps" (Novak

1990). Following the additional ideas of Ausubel that cognitive structure is organised hierarchically, and that most new learning occurs through derivative or correlative subsumption[1] of new concept meanings under existing concept/propositional ideas, a hierarchical representation was incorporated into the concept maps.

There have been many studies published about the use of concept maps a selection of which is described in this section. Much work has been done using concept maps as part of studies of the cognitive development of children and the way that children learn science (Donaldson 1978; Symington and Novak 1982; Driver 1983; Carey 1985). It has also been suggested that concept maps helped children 'learn how to learn'. It was found that concept maps were a useful way to represent knowledge and therefore an aid for students in organising and understanding new subject matter. Studies have been undertaken to determine the relationship between the use of concept maps and enhanced performance/achievement; to enhance meaningful learning; the effect of student attitude towards learning; to compare the benefits for able and less able students; with teachers and training teachers to better prepare them for teaching science; to see whether long-term retention of knowledge is improved.

A recent study by Horton (1993) of many of these previously published investigations of the effectiveness of concept maps in improving student achievement and attitudes revealed that concept mapping has generally positive effects on both student achievement and attitudes and that there is little difference between the effectiveness of teacher constructed maps and student constructed maps.

A number of workers has reported the importance of conceptualising in improving meaningful learning (Novak, 1977; Ausubel, Novak and Hanesian, 1978; Gowin, 1981; Cullen, 1983; Novak and Gowin, 1984 Cohen, 1987). Heinze-Fry and Novak (1990) investigated the use of concept mapping as a tool to enhance

[1]See section 4. 3 for a fuller description of this process

meaningful learning in college biology students. They compared the test results of a group of 20 students who had been instructed on the construction of concept maps with a control group who had not. Although there were no statistically significant differences between the two groups on the evaluation instruments used, both multiple choice and interview data showed higher mean scores for the concept mapping group. They found that although concept mapping was not a 'quick-fix' it did appear to move students slowly towards more meaningful learning. They found that higher ability students (measured by Standardised Attainment Tests {SAT} scores) benefitted most from concept mapping and anecdotal evidence suggested that lower ability students benefitted over a longer period of time. Skill in concept mapping continued to improve over a long period of time with higher ability students making earlier gains. This confirms earlier work by Novak, et al (1983). Concept mapping appeared to enhance integration and retention of knowledge and although there was little difference between low-SAT mappers and the control group, the high-SAT mappers spent less time learning and had a tendency toward higher long-term learning efficiency. Heinze-Fry and Novak (1990) also claim that students' attitudes to learning improved, students felt more like active learners, mapping enhanced the clarity of learning, integration and retention of knowledge and less rote memorisation resulted.

A similar study of the use of concept maps with 9th grade high school chemistry laboratory classes was carried out by Stensvold and Wilson (1990). They set out specifically to investigate whether concept mapping is likely to be more helpful to some students than others. This research was based on previous studies (Koran and Koran 1980) which showed that no one instructional method is best for all students and, that different instructional methods are appropriate for students of different abilities. Using students with varying verbal ability as measured by a standardised vocabulary test, Stensvold and Wilson (op. cit.) compared the achievement of students who had been taught to construct maps with a control group who had not.

They found that for a comprehension test there was an increase in the mean score of the treatment group over the control group but that it was not statistically significant. They also found that higher ability students performing concept mapping achieved lower scores on the comprehension test than similarly able students who did not construct concept maps. They suggested that high ability students may prefer other learning strategies and that concept mapping may have limited their perceptions in the laboratory causing them to select and attend to too little information.

Jegede et al (1990) working with Year 10 students in Nigeria showed that concept mapping is significantly more effective than traditional/expository teaching strategies in enhancing learning in biology. They, like Heinze-Fry and Novak (1990), found that it reduces anxiety towards learning, especially in males. This is supported by Novak (1990) who has found that 'positive self-concept development' can be encouraged by helping students 'learn how to learn' with the emphasis here on meaningful learning.

Okebukola (1990) compared traditional teaching methods with a method employing concept maps for the teaching of genetics and ecology to pre-degree students aged between 15 and 22. It was argued that these topics traditionally were found difficult by students, and if concept mapping strategies enhanced meaningful learning there would be an improvement in both the students' interest and their performance. The students who were taught using the concept map method significantly out-performed those who were taught by traditional methods. A study of Year 9 Science low and medium achievers showed similar results although the significant improvement in test results was limited to those students who were able to construct good quality concept maps. Students who were rated as poor constructors of concept maps did not show any significant improvement (Fraser and Edwards 1985). Malone and Dekkers (1984) also demonstrated the value of the concept map as an aid to teaching science and mathematics.

Pankratius (1990) tested the effect of concept mapping on achievement by students in six high school physics classes all taught by the investigator. Two classes served as the control group and received standard instruction. Four classes were instructed in the design of concept maps for six weeks prior to the physics unit under study. Two classes drafted and submitted concept maps at the conclusion of the unit of physics. The other two classes drafted and submitted concept maps twice: at the onset and at the conclusion of the physics unit. Mapping concepts prior to, during and following instruction led to greater achievement for this sample of physics students.
Four college chemistry students were taught to construct concept maps to facilitate students' conceptual development and to enlist them as active participants in their own learning (Feldsine 1988). Employing the case study approach, students designed concept maps representing three phases of increasing complexity. They were interviewed during each phase concerning their maps and again after three months. Four types of data were collected: student-constructed concept maps, taped interviews, day-to-day logs kept by the investigator, and students answers to quizzes and examinations. Data were analysed across time for each student and across students to identify common factors. Feldsine (op. cit.) reported the following findings: concept mapping provides students with a more complete and unified understanding of chemistry; students feel that their concept maps represent their understanding; and, concept maps are valuable means for student evaluations.

Bousquet (1982) also studied the use of concept maps with college students. He showed that student concept mapping improved the achievement of students in a natural resources management class. His study also showed that skill in concept mapping could be used as a predictor of success in achievement tests.

Mason (1992) carried out a two year study of 62 training science teachers using concept maps to try to help them re-think their content knowledge and begin to comprehend the 'robust nature of scientific concepts'. She concluded that concept maps were an effective tool for overcoming the problem that science teachers have during their training; namely that they acquire a lot of factual information but rarely develop a conceptual understanding of science. Using concept maps helps overcome this deficiency by showing the relationships between the (facts) concepts and by . constructing maps for different levels it is possible to show relationships within and between individual topics and disciplines.

Beyerbach and Smith (1990) and Hoz, et al (1990) in studies involving teachers and student teachers point to the need for empowering teachers to learn meaningfully so that they can be more successful in helping their own students learn meaningfully. They concluded that the use of concept maps promoted this empowerment because of the attitudinal improvement described by other studies

Beyerbach (1988) also used concept mapping with undergraduate teacher education students to assess development of technical vocabulary. She found that students developed an increasingly shared technical vocabulary as they progressed through the program; students' concept maps became more differentiated and more like the instructor's and more like each other's. These ideas have been incorporated into the design of the Master of Arts in Teaching at Cornell University where undergraduate students begin coursework in education at the same time as their other studies so that the 'constructivist' ideas on teaching and learning can be used to achieve meaningful learning instead of rote learning in their science and mathematics studies (Novak, 1990).

The conclusions of these studies demonstrate the usefulness of concept maps. The use of concept maps as part of studies of the cognitive development of children and the way that students learn science (Donaldson 1978; Symington and Novak 1982; Driver 1983; Carey 1985) suggest that they help students 'learn how to learn'. It was found that concept maps were a useful way to represent knowledge and therefore an aid for students in organising and understanding new subject matter. Other studies conducted with students in higher education have demonstrated a relationship between the use of concept maps and enhanced performance/achievement; how the use of concept maps enhances meaningful learning, and positively affects student attitudes towards learning.

2.32 Concept Maps and Curriculum Design

Starr and Krajcik (1990) investigated the use of concept maps as a tool for science curriculum development with grade 6 teachers. They found that concept maps can assist both teachers and curriculum specialists in developing a curriculum which meets the needs of both teacher and learner. They found that it improved the way teachers viewed current research regarding constructivist theory and its application to the classroom. During the investigation they analysed three aspects of the maps: hierarchical structure, progressive differentiation and integrative reconciliation. They concluded that concept maps help develop science curricula that are hierarchically arranged, integrated and conceptually driven.

2.34 Other uses of concept maps

A variety of other uses for concept maps have been advocated which are relevant to tertiary teaching and learning. Stein (1988) advocates their use by students for note taking; Leahy (1989) suggests that the preparation of concept maps is useful for students in their understanding of literature, and Wallace and Mintzes (1990) showed that concept maps are a valid and useful way to demonstrate conceptual change in biology students.

2.4 OTHER TEACHING MODIFICATIONS TO IMPROVE QUALITY

2.41 Self -Directed Learning.

Woods (1989) recommends a variety of approaches to learning. One way that he finds successful is to let students take charge of their own learning by identifying clear goals and routes to achieve those goals. In this situation the teacher acts as a resource and a coach rather than the authority; students do not feel rushed and therefore have time to assimilate and are more likely to achieve understanding. Woods points out that once students achieve their goals, it is crucial that they receive feedback or some sort of evaluation. Lectures can be part of this process because they can be used to motivate students and help them identify the main ideas and the structure of the discipline. But because students do not all learn in the same way, they should have access to a variety of routes and activities. This kind of self-directed learning is appropriate to small groups and Woods suggests that it can also be used with classes of 40-60 by combining it with small group activities where students are expected to teach and learn from each other.

2.42 Problem-Based Learning.

This approach to teaching is not unlike the approach that has become known as Problem-Based Learning. This model of learning described by Barrows (1985; 1986) is used extensively in the early years of medical education. In it the traditional lecture-based approach to anatomy, physiology, etc is replaced by group work. Students are divided into groups of four or five when they enter medical school and are assigned a staff member who acts as a facilitator. Each group is presented with a problem in the form of a patient with a set of symptoms. The students' task is to diagnose the patient's illness and provide a rationale for the diagnosis and a recommended treatment. To achieve this they must determine for themselves what they have to learn and assume responsibility for the particular learning issues that they identify. In this form of self-directed learning the students are actively engaged in working out tasks and activities that are authentic to the environment in which they would be used. Problem-based learning is used in other areas such as Education, Business Schools, Architecture and Law. This method of instruction is described by Savery and Duffy (1994) as one of the best exemplars of a constructivist learning environment.

2.5 JOURNALS AND EVALUATION

Journals were used in this project to assist student learning by encouraging students to reflect on the subject content and its relationship to other parts of this subject and to the content of other subjects. Students were also encouraged to use journals so that the way in which individual student learning was proceeding could be determined; particularly to see if there were any common patterns within the class. The journals also provided feedback about the effectiveness and the students' perceptions of the methods which were being used during the teaching process. In this way they provided a valuable supplement to other subject evaluation.

2.51 Journals and Learning

Wilkes (1992) showed that students learned more of the science required for their work if they could clearly see the relevance of the subject to other subjects in their course and ultimately to their profession. She proposed that the use of reflective journals would help to demonstrate these relationships by identifying links between learning and practice and her subsequent research with nurse education students at the University of New South Wales (Batts and Wilkes 1993) indicated that reflective journal writing enhanced motivation of students to learn and increased their sense of adventure in striving to seek understanding. It also showed that for journal writing to be most effective, teachers must have a good understanding of the process and structured class time must be set aside for journal writing and discussion.

2.511 Reflective Journals

A reflective journal is a discourse with self and sometimes in part with others . It is a vehicle in which to explore events, thoughts, and the meanings of these (Holly 1987). Reflection implies careful or long consideration and thought about a topic. Dewey (1933) was one of the first people to write about the relationship between reflective thinking and the educative process. He argued for intuitive thought (reflection) which consists of active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends. Subsequently (Dewey 1938) he proposed that this process (reflection) is also useful in the learning process, recognising that all education comes through experience. Reflective practice and its role in the adult learning process is discussed by Friere (1972) who emphasises that relevance is made apparent when action follows thought. Mezirow (1981) described a model of reflective learning with seven levels of reflection from awareness to deep theorising. Schon (1983) refers to 'reflection in action' which involves bringing knowledge to bear on a situation and reflecting upon the experience of the situation. This is related to the *lectorial* sessions described in section 4.4 in which students were involved in collaboratively explaining aspects of the subject to other members of the class and then encouraged to record their impressions of the process in their journals.

Reflection is a part of the various learning cycles (Kolb 1984; Jarvis 1987) while Boud et al (1985) note that learning through reflection is a personal and individual process which should enhance learning. Boud and Walker (1991) describe three stages by which learning can be assisted through reflection on work. These are:

- preparing for the learning experience by thinking about what is to be learned, how it is related to prior experience (learning) and what learning strategies are going to be employed;
- awareness by the learner of how the learning process is proceeding and of the actions that the learner has taken;
- reflection after the learning in which the learner returns to the experience, attends to it and re-evaluates it.

The use of journals to promote reflection and thereby enhance learning has been advocated by a number of authors (Holly 1987; Kemmis and McTaggart 1988). Kemmis also proposes that time should be set aside for journal writing and that there should also be a time when the writing is shared with other members of the class. This is supported by student feedback reported in other studies (Batts and Wilkes 1993). Keeping a journal can bridge the gap between theory and practice (Smyth 1986; Cowan 1991; Emden 1991) because by encouraging students to write they are forced to order their thoughts and hence are more likely learn. Allen et al (1989) support this when they say that by writing to learn, application, analysis and synthesis are encouraged. Carroll (1994) expresses the same sentiment when he writes 'only when you write do you discover what you know'. Journal writing also provides an opportunity for students to monitor their progress in the learning process and recognise incremental change (Westhorp 1994). Fulwiler (1987) describes the use of colloquial everyday speech to question, observe, speculate, digress, synthesise and revise as the sign of successful journals. Writing in their own words enables students to make their own meanings which is part of learning (Brimley-Norris 1991). Students who are able to use their journals in these ways, engaging in dialogue with themselves, with their fellow-learners or with their teachers, work through the questions which arise out of their learning experiences both in and out of the classroom, and therefore become highly skilled at directing the course of their own learning. They are in a sense 'professionalising' their approach to learning (Schon 1988).

Candy et al (1994) in their report on the development of lifelong learners to the National Board of Employment, Education and Training strongly support the use of reflective practice in undergraduate education. Their recommendation 7.1 states:

> *It is recommended that wherever practicable and appropriate, undergraduate courses of professional preparation should include a reflective practicum to model the kind of learning undertaken by professionals in practice.* (Candy et al, 1994, p 157)

The value of reflective practice is its relationship to the situation faced by practitioners, namely the need for continuing learning. Since the problems they have to deal with daily are always changing and are not amenable to the application of simple formulae or rules they must adapt by reflecting on previous experience. Boud and Knights (1993) describe two kinds of reflection in this context. That which occurs in the midst of experience which they call reflection-in-action and that which occurs after the event. Both enhance learning by experience. 'Thus at its heart reflective practice is about lifelong learning' (Candy, Crebert et al. 1994, p147).

2.6 CONCLUSION

This chapter has reviewed the literature related to the three main aspects of the research which form the background setting for the research. These are:

- quality teaching and learning, particularly as it has been applied in Australia;
- concept mapping as a background to the main method which was employed to encourage students to learn more meaningfully;
- and the use of journals for evaluation.

As has been shown there is an extensive literature on quality teaching and learning. The main point which comes out of this review that is relevant to this research is the changing view of teaching in higher education and the need to focus on student learning and developing ways of making student learning possible.

The second part of this literature review looked at concept mapping as an aid to student learning and the basis of concept mapping in the constructivist model of learning. Much of the work has been done with primary and secondary school students. There is very little work reported in the literature about the use of concept maps in higher education, however, it is clear that concept maps can be used successfully to promote learning with school students and there is no evidence to suggest that their use cannot be successfully transferred to promote student learning in higher education.

Finally the literature on the use of reflective journals showed that, although they are rarely used as evaluation or learning tools in science, they are used extensively in other disciplines where they have been shown to be a valuable aid to learning both for the student and for the teacher. Their use for the purpose of evaluating the effectiveness of modified teaching methods, as proposed in this research, seems logical.

CHAPTER 3

GEOLOGY/EARTH SCIENCE IN THE SCHOOL CURRICULUM

3.1 INTRODUCTION

Most of the thinking about how to teach geology and what should be taught in introductory courses has taken place in relation to the senior secondary curriculum. In general much more time is spent developing these curricula than those of introductory tertiary geology/earth science subjects. This is partly because more people are involved in teaching at senior secondary level, the curriculum is applied across many schools and is externally examined and moderated. Nevertheless, a considerable amount of thought and effort has been expended in the development of these curricula by teachers, professional educators and administrators in K-12 schools and teacher-educators, subject and curriculum specialists, and the educational theorists from tertiary institutions.

This chapter reviews the outcomes of these efforts for Australia in the early to mid nineteen nineties; a time when the new national curriculum was being implemented and the pre-existing senior (Years 11 & 12) curricula were being taught. At this time K-12 curricula were being developed and implemented in the United Kingdom and in the United States so it is possible to describe the situation in each of these countries to provide a comparison for what has happened in Australia.

The purpose of the chapter is not to give an historical perspective of the development of geology/earth science curricula. However the outcomes of the largely independently developed curricula are similar, especially at the level of the major concepts, so it is instructive to look at the processes involved in deciding on these concepts. The best documented is the situation in the United States so this has been chosen for description to place the rest of the chapter in context.

3.2 MAJOR CONCEPTS IN GEOLOGY/EARTH SCIENCE CURRICULA

3.21 Development of K-12 Earth Science in the United States

Since about 1983 there has been increased funding for science and mathematics education at all levels in the United States (Carpenter 1993). This activity was prompted by the publication of the *"A Nation at Risk"* report by the National Commission on Excellence in Education which chronicled the dismal state of science and mathematics literacy being achieved by K-12 science classrooms across the United States. The report prompted an enormous increase in interest and involvement by teachers, administrators, university academics and practising scientists who recognised the need for a reform of K-12 science and mathematics education.

The science-education reform of the 1980s and 1990s has affected education in all of the sciences. Part of the reform has been an improvement in the quality and an increase in the quantity of geology/earth science in the curriculum at all levels. What was fundamentally different about these developments and specifically important to the earth sciences and the earth science education community was the equal status achieved by the earth and space sciences (Carpenter 1993).

A significant stage in the development of a K-12 geology/earth science curriculum for US schools was a meeting of educators and geoscientists held in September 1985 at the American Geological Institute in Alexandria, Virginia (Mayer and Armstrong 1990). The participants concluded that the top priority for improving programs in earth science education was the development of a K-12 earth science syllabus (Mayer and Armstrong 1990). This group also concluded that such a document, if supported by the scientific and science education communities, would have a strong impact on the content of textbooks, state and local curriculum guides, and state and national tests. A major aim of the meeting was to provide guidance to educators and geoscientists for their cooperative efforts to improve the teaching about Planet Earth in America's schools. Subsequent meetings of science educators and scientists concluded that the first step in the development of a K-12 earth science syllabus would be to convene a meeting of eminent scientists to identify the components of knowledge about the Earth that have relevance to the K-12 curriculum (Mayer 1991; Mayer, Brown et al. 1992; Carpenter 1993; Carpenter 1994).

For four and a half days in April 1988 nineteen scientists and twenty science educators and teachers met to identify the goals and concepts about Planet Earth that every 17-year-old should know when completing pre-college (high school) education. A full report of the conference is published by Ohio State University (Mayer 1988). The conference aimed to 'identify those understandings about Planet Earth that every citizen needs to know in order to live a responsible and productive life....' (Mayer and Armstrong 1990, p 159).

The goals and concepts arrived at by the participants of the 1988 meeting described above are summarised below and in Figure 3.1 and Table 3.1. The goals are dramatically different to those of earlier earth science curriculum reform efforts (the Earth Science Curriculum Project was the last effort before this one) (Carpenter, 1994, p 8). Goal four, aesthetic appreciation of the Earth and goal three, stewardship of the Earth, 'would not have been thought of as appropriate when considering science curriculum' in the past (Mayer and Armstrong 1990, p163).

The goals and concepts were subsequently refined by scientists, science educators, school administrators and teachers who attended one of more than six regional conferences conducted by the American Geological Institute during the period April-December 1988. The goals remained the same as those shown in Figure 3.1, but the concepts were reduced to eight essential concepts (Figure 3.2) which were considered profound and historically important (AGI 1991).

GOALS
Scientific Thought Each citizen will be able to understand the nature of scientific inquiry using the historical, descriptive and experimental processes of the earth sciences.
Knowledge Each citizen will be able to describe and explain earth processes and features and anticipate changes in them.
Stewardship Each citizen will be able to respond in an informed way to environmental and resource issues.
Appreciation Each citizen will be able to develop an aesthetic appreciation of the Earth.

Figure 3.1 Goals for K-12 geology/earth science as developed by the American Geological Institute

An outcome of these meetings was a new focus and philosophy for science curriculum, called Earth Systems Education. A National Science Foundation grant was awarded to the Program for Leadership in Earth Systems Education (PLESE) based at Ohio State University to infuse more content regarding the modern understanding of planet Earth into K-12 science curricula. The PLESE Planning Committee developed a "Framework for Earth Systems Education" based on the concepts and goals developed by the April 1988 conference (Mayer, Brown et al. 1992). These understandings are shown in Figure 3.3.

The goals, concepts and understandings developed in these processes provide a framework for comparison with other K-12 curriculum statements and the current secondary school geology/earth science curricula from Australian state education authorities.

Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
The earth system is a small part of a solar system within the vast universe. The sun is the primary source of Earth's energy. The sun is one of the billions of stars in the universe. The moon and Earth affect each other. All bodies in space (including Earth) are influenced by processes acting throughout the solar system and the universe. The nature of each planet is determined by its position in the solar system and by its size. The position and motion of Earth with respect to the sun influence tides, seasons, climates, etc.	**The earth system consists of the interacting subsystems of water, land, ice, air and life.** Water exists as a vapour, liquid and solid and changes form as a result of changes in energy. Oceans are in constant motion. The crysophere) is an Earth subsystem that has varying seasonal and global distribution. Atmospheric circulation is driven by solar heating and modified by interactions with other subsystems. The solid earth) interacts with the hydrosphere, atmosphere, crysophere and biosphere. The biosphere interacts with other subsystems. The sun is a major source of energyfor the earth system. Geothermal energy influences the dynamics of earth systems. Each component of the earth system has characteristic properties, structure and composition.	**The earth's subsystems (water, land, ice, air and life) are continuously evolving, changing and interacting through natural processes and cycles.** Water cycles through the subsystems. The outer layer of the solid earth is composed of plates which are and have been in motion. All new rocks are derived from old rocks by recycling. Major examples of the interaction between components of the earth system are the hydrologic cycle, rock cycle, carbon cycle, glacial cycle, trophic cycle.	**The earth's natural processes take place over periods of time from billions of years to fractions of seconds.** Physical processes in the universe range over time scales of seconds to billions of years and over very great distances. Earth is more than 4 billion years old and is continually evolving. The atmosphere is a thin, protective blanket composed of various gases and other substances that evolve over geologic time. Fossils are the evidence that the biosphere has evolved interactively with the earth over geologic time. Evolution results in a sequence of unique historical changes of Earth's subsystems. For example: changes in atmospheric composition, changes in life forms, changes in structure of the solid earth, changes in the composition of the hydrosphere. Time scales for Earth changes are variable	**Many parts of the earth's subsystems are limited and vulnerable to overuse, misuse, or change resulting from human activity. Examples of such resources are fossil fuels, minerals, fresh water, soils, flora and fauna.**

Table 3.1 Concepts for K-12 Earth Science program developed for an Earth Systems approach

Concept 6	Concept 7	Concept 8	Concept 9	Concept 10
The better we understand the subsystems, the better we can manage our resources. Humans use Earth resources such as minerals and water.	**Human activities, both conscious and inadvertent, impact Earth subsystems.** Human activities influence the: hydrosphere and vice versa. cryosphere and vice versa. atmosphere and vice versa. lithosphere and vice versa (mining, hazards, etc.) biosphere and vice versa. Human activities exert inordinate impact on the global environment. Human activities alter Earth's components such as burning fossil fuels, improper land use, war and war preparations, releasing hazardous chemicals and radioactive materials, releasing and disposing hazardous materials, extinction of species.	**A better understanding of the subsystems stimulates greater aesthetic appreciation.** Humans appreciate and manage the Earth by preservation, appropriate utilization and restoration. For example: natural parks, reclamation, conservation, recreation, legislation, land management and planning, international to local co-operation.	**The development of technology has increased and will continue to increase our ability to understand Earth.** Technology has improved our ability to understand the earth. For example: optical and electronic microscopes, optical and radiotelescopes, infrared sensing, doppler radar, submersibles, satellites, computers.	**Earth scientists are people who study the origin, processes, and evolution of Earth's subsystems; they use their specialized understanding to identify resources and estimate the likelihood of future events.** Observations of the atmosphere are used to forecast weather. Maps are scale models of the Earth. Knowledge of other planets helps us understand the Earth.

Table 3.1(cont) Concepts for K-12 Earth Science program developed for an Earth Systems approach

- The Earth is a unique member of the Solar System and may be replicated in other galaxies in the Universe
- The Earth is a complex planet with five interacting systems
- The Earth is at least 4.5 billion years old
- Changes in the Earth's system occur over periods of microseconds to millions of years
- The Earth's systems have evolved through time
- Repeated interactions and transitions occur in the Earth's system
- Scales in the Earth's system vary from sub-atomic to astronomical
- The Earth's systems contain a variety of renewable and non-renewable resources that sustain life

Figure 3.2 Concepts for K-12 geology/earth science as developed by American Geological Institute

Understanding #1: Earth is a unique planet of rare beauty and great value.

Understanding #2: Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.

Understanding #3: The development of scientific thinking and technology increases our ability to understand and use Earth and space.

Understanding #4: The Earth system is composed of the interacting subsystems of water, land, ice, air, and life.

Understanding #5: Planet Earth is more than 4 billion years old and its subsystems are continually evolving.

Understanding #6: Earth is a small subsystems of a solar system within the vast and ancient universe.

Understanding #7: There are many people with careers that involve study of Earth's origin processes and evolution.

Figure 3.3 Framework for Earth Systems Education consisting of seven understandings developed by PLESE Planning Committee.

3.22 Development of K-12 Earth Science in the United Kingdom

From 1996 onwards all students in government schools in England and Wales will be following the "National Curriculum". The National Curriculum for science includes an important component of earth science and there is an additional earth science component in the National Curriculum in Geography (Dineley 1990). Prior to the implementation of the National Curriculum, geology was taught to some students in some schools either at the ages of 14-16 years or at 16-18 years, or both (King 1993). The science taught in schools in England and Wales beyond the age of 11 years traditionally consisted of physics, chemistry and biology, the PCBs of Carpenter (1993). At the age of 14 years many students gave up one or two science subjects. One of the reasons for bringing in the National Curriculum in science was so that all students would have a broad and balanced science course up to the age of 16 years. The balance is achieved by having equal amounts of teaching in the three "traditional" subjects (the PCBs) with the breadth added by the addition of earth science and astronomy.

Science is one of eight major and four minor areas of study in the National Curriculum and should occupy approximately 20% of the total teaching time. Of the teaching time, the earth science theme forms one of 13 strands or about 8% of the science curriculum as shown in Figure 3.4 (King 1993). Because the science taught in UK secondary schools has a strong practical tradition (Yoxhall 1990), it has been necessary for those involved in bidding for an earth science component in the National Science Curriculum to show how earth science can be taught in a practical way. One of the important influences of the National Science Curriculum has been to emphasise investigational approaches to practical work (King 1993) so the Earth Science Teachers Association of the UK has developed and published its own material to help teachers use this investigational approach to teaching the laboratory component of the earth science topics.

Attainment Target 1: Scientific investigation	
Strand (I)	Ask questions, predict and hypothesise
Strand (ii)	Observe, measure and manipulate variables
Strand (iii)	Interpret their results and evaluate scientific evidence
Attainment Target 2: Life and living processes	
Strand (I)	Life processes and the organisation of living things
Strand (ii)	Variation and the mechanisms of inheritance and evolution
Strand (iii)	Populations and human influences within ecosystems
Strand (iv)	Energy flows and cycles of matter within ecosystems
Attainment Target 3: Materials and their properties	
Strand (I)	The properties, classification, and structure of materials
Strand (ii)	Explanations of the properties of materials
Strand (iii)	Chemical changes
Strand (iv)	The Earth and its atmosphere
Attainment Target 4: Physical processes	
Strand (I)	Electricity and magnetism
Strand (ii)	Energy resources and energy transfer
Strand (iii)	Forces and their effects
Strand (iv)	Light and sound
Strand (v)	The Earth's place in the Universe

Figure 3.4 An outline of the content of the National Curriculum for Science in England and Wales (after King, 1993).

3.3 GEOLOGY/EARTH SCIENCE EDUCATION IN AUSTRALIAN SCHOOLS

Most geoscientists agree that geology/earth science is relevant to, and should be part of the school curriculum (Locke 1989; Mayer 1989; Carpenter 1990; Dineley 1990; Mayer 1990; Mayer and Armstrong 1990; Yoxhall 1990; AGI 1991; Mayer, Brown et al. 1992; King 1993; Roy 1993; Kern and Carpenter 1995). However, in 1994 the majority of school leavers in Australia had not studied a year long or even a semester long course in geology/earth science. Many had never been taught geology/earth science topics even in basic science courses. It is unclear whether adoption of the National K-12 curriculum will remedy this despite a structure that contains a major content area entitled *Planet Earth in Space.* This is the situation in a country which has a multi-billion dollar budget deficit and where the products of the mining industry make-up more than half of export earnings.

3.31 The Nature of the Australian School System

Australia has seven separate education authorities which control the curriculum of their respective State or Territory. Although all are different in detail, it is possible to present a general picture of school geoscience education which is representative. Discussion can be divided into three areas of schooling:

Primary	K-6/7
Junior Secondary	6/7-10
Senior Secondary	11 & 12

3.311 Primary school geoscience education

In primary schools science education has only recently been considered to be important. This follows the trend in other countries like the United States, England and Wales and is related to concerns about the environment, and recognises the relevance of science to society. In particular science education has been recognised as having a role in achieving all of the *Common and Agreed National Goals for Schooling in Australia* (AEC,1992) where ‘science education will develop an understanding of the role of science and technology in society, together with scientific and technological skills.’ (AEC, 1992, p4). Although geoscience topics are most relevant to achieving these laudable aims, the various Education Authorities pay only lip service to them and provide little support for teachers to gain the skills necessary to implement them. Most of the opportunities for upgrading and acquision of these skills is provided, usually voluntarily, by science teacher associations, subject associations, and tertiary science educators and is done outside of normal school hours.

Most primary and junior primary teachers are not trained to teach science. Many did not take any science in their senior secondary school education and until recently, science was not a common part of primary teacher training courses. Consequently most teachers rely on commercial curriculum materials and in-service professional development to enable them to meet the guidelines for science in the curriculum. The guidelines are necessarily broad and result in sporadic treatment of geoscience topics.

3.312 Junior secondary geoscience education

All Australian states have a component of geology/earth science in their junior secondary school curriculum statements. Most stipulate that geology/earth science should occupy one quarter of the available time for science in the junior secondary curriculum along with physics, chemistry and biology. In reality few schools achieve this as schools develop their own curricula, the content of which are determined by the interests and expertise of the teachers.

Part of the problem is the lack of availability of trained geoscience teachers. Many secondary schools do not offer senior level geoscience courses which means that there is unlikely to be a science teacher on the staff who is able or willing to develop curriculum units that are relevant or exciting. A reiew of the content of junior secondary school science curricula shows that the geoscience that is taught is more often than not a watered down version of the senior course including topics such as fossils, plate tectonics, and rocks and minerals. Little consideration is given to the needs or interests of the students and because the curriculum designers usually have little experience in geoscience, the courses are mostly unstimulating to the students and to the teachers. This usually results in geoscience being left until last and often not being taught at all. There are obviously many exceptions to this, but it is true to say that a significant number of students complete their years of compulsory schooling without studying any geoscience.

3.313 Senior secondary geoscience education

In the senior secondary school the situation for geoscience education is much brighter. Prior to 1995 all states offered geology/ earth science courses at Year 11 and Year 12, however in 1995 Geology was arbitrarily removed from the subjects offered in the senior curriculum in Victoria. In some cases it is in the form of a single two year curriculum and in other states it is in the form of two discreet courses.

In most States the curriculum is fairly traditional. The curriculum offered in Victoria prior to 1995 departed from this tradition. A four unit course which emphasised the local geological environment and was slanted towards geology and society was offered. It was different also in that it did not build sequentially with students able to enter at unit two or unit three. Unit four required completion of unit three.

South Australia is in the process of developing a new syllabus which has moved away from the former classical solid Earth geology approach in an attempt for a more relevant and modern approach which links the major topics to each other and to the environment. The syllabus encourages students to explore the interrelationship between Earth processes and human activity and the need to consider environmental, economic and cultural implications.

A more detailed review of the senior secondary geology/earth science curricula is given in the section 3.4.

3.32 Assessment

In senior secondary geology/earth science much of the teaching is driven by external assessment and the need for students to achieve good results in order to gain entry to the higher education course of their choice. The mode of assessment varies from authority to authority.

In all States except Queensland assessment is partly based on an externally set examination and a school assessed component. In Queensland assessment is school based and externally moderated.

External examinations are similar in format for all states and contain a range of question types which include multiple choice, short answer questions often about practical aspects of the curriculum, and longer response (essay type) questions.

Tasmania, one of the leading states in terms of geoscience education has developed an interesting procedure which was used for the first time in 1992. The external examination component of the assessment is in the form of a three hour examination, in one hour of which candidates have access to given general information and resources and may engage in discussion and take notes and diagrams. The succeeding two hour session is closed during which candidates undertake a detailed thematic based task using the information gathered in the first session.

In the proposed new Year 12 curriculum for South Australia, the assessment is divided into two equal parts, an external examination component and a school-based component. Both are marked out of 200. The school-based component contains an assessment of the 20 hours of compulsory fieldwork that students must undertake throughout the year. The assessment of the fieldwork counts for 80 of the 200 marks with a recommended allocation of:

30 marks	for acquiring knowledge of geology
10 marks	for understanding and problem solving
25 marks	for using geological knowledge
15 marks	for communicating knowledge of geology.

Teachers are expected to make this assessment using students' field note books and field reports which must be made available for non-statistical moderation the purpose of which is 'to help ensure fairness to students and to provide the wider community with reliable information about student performance' (SSABSA 1996, p17)

3.4 THE AUSTRALIAN K-12 CURRICULUM STATEMENT

The development of a national curriculum was the most significant curriculum project in the history of Australian education. Collaboration between the states has produced 16 documents: a statement and a profile in each of eight areas of learning - english, mathematics, science, technology, languages other than english, health and physical education, studies of society and the environment, and the arts. The development of these statements and profiles was commissioned in 1988 by Australian Education Council (AEC) made up of the education ministers of the States, Territories and Commonwealth.

The statement provides a framework for curriculum development by education systems and schools. A statement is not meant to be a syllabus, rather, it is simply meant to provide a framework for a course which will meet students' needs and reflect advances in knowledge.

Each of the statements in each of the eight areas of learning are divided into content and process strands which reflect the major elements of learning in each area. Further they are structured in four bands which roughly correspond to the stages of schooling: lower primary (R-3); upper primary (4-6/7); junior secondary (6/7-10); and post compulsory (11 & 12).

The profile for each learning area is designed to assist in the improvement of teaching and learning and to provide a common language for reporting student achievement. They are divided into strands. Within each strand, eight levels reflect the full range of student achievement during the compulsory years of schooling

The profiles and statements are linked. The profiles show the typical progression in achieving learning outcomes, while statements are a framework of what might be taught to achieve these outcomes (AEC 1994).

3.41 Common and Agreed National Goals for Schooling in Australia

10 goals agreed to by all Australian Ministers of Education in April 1989, form the basis for cooperation and collaboration between schools, states and territories, and the Commonwealth. Two of the 10 parts of Goal 6 are related to geoscience but both are necessarily very general.

These require the curriculum to develop in students:

- an understanding of the role of science and technology in society, together with scientific and technological skills;
- an understanding of, and concern for, balanced development of the global environment. (AEC 1994, p43)

3.42 The Science Statements and Profiles

The document *A statement on science for Australian schools* establishes a framework for curriculum development in science education setting broad goals and defining the scope and sequence of learning. The content of the science curriculum is organised into five strands: one process strand and four conceptual strands. The five strands are:

- Working scientifically
- Earth and beyond
- Energy and change
- Life and living
- Natural and processed materials

The conceptual strand which relates to geoscience is " Earth and Beyond". It is further subdivided into 3 components or organisers. These are:

- Earth, sky and people;
- The changing Earth
- Our place in space;

The Statement on Science is not a syllabus or a guide for use in the classroom, and although it is intended principally for use by curriculum developers, it does give an outline of the sort of topics which should be included in the school based syllabuses which are developed from it. However, when compared with the content of the geology/earth science curricula which were in operation before the development of this initiative, it contains an inadequate treatment of geoscience topics. A detailed analysis of the content (Table 9 of Appendix 1) shows that most of the geoscience component relates to 'Earth in Space' and is proposed to be taught in the primary and junior secondary years. The proposed content for the other traditional geoscience topics such as ‘Earth Materials’ and ‘Earth History’ is not developed in any sequential fashion and omits large parts of the present curricula.

One of the stated goals for science education in the statement involves the role of science in preparing students for post-school options including helping them to make decisions about further education and careers and other life options (AEC 1994, p4). The treatment of geoscience topics in the statement does not stimulate the potential excitement that can come from a study of the Earth and its interactions. It is unlikely that many students will be encouraged to study further in the Earth sciences or choose them as a career as a result of their experiences in science classes guided by this framework. In the section ‘Contexts of Learning Science’ (AEC 1994, p12) there is a good general discussion of the importance of contexts in which students use their science but there is no mention of the Earth or the Earth systems. Later in the same section syllabus developers are warned about the danger of an imbalance between the biological and physical sciences whereby biological sciences take up more time than the physical sciences in the science curriculum of some primary schools. There is no mention of the Earth sciences.

3.43 Earth Literacy and the Australian Science Curriculum

Earth literacy is a term used by Mayer (1991) to mean a knowledge and an understanding of the earth system. If the science curriculum is to successfully prepare people to understand science as a rational attempt to learn about planet Earth and its environs, we need to ensure that we produce earth literate physical scientists, engineers, economists, politicians and industrialists. These people should understand the relationships between the processes scientists have harnessed for economic and defence purposes and the Earth system from which they were derived. There is plenty of evidence that this is not the case. Manufacturers encouraged by their chemists and engineers until recently recommended the use of CFCs and the continued inefficient use of fossil fuels. If our business leaders and politicians were earth literate and understood the relationship between species diversity and the well-being of the biosphere, would they support the logging of native forests for short term employment, economic and political benefits? Mayer (1992) proposes that a powerful case can be made for making the Earth System a central organising theme for future K-12 science curriculum development. He suggests:

> *Science, after all, is fundamentally our attempt to understand our habitat and how we came to be part of it - in other words, our attempt to understand our Earth System. Why shouldn't the science curriculum therefore be organised around the subject of science, the Earth System?* (Mayer, Brown et al. 1992, p69)

Although Mayer is making the case for the United States, it applies equally well for Australia. Global warming, species extinction, soil degradation and water quality will dramatically affect the exponentially increasing human population. An understanding of these short term global changes is essential for the health of future generations of humans and the planet as a whole. It is therefore disappointing that the statement on science for Australian schools does not address these issues very strongly.

3.5 REVIEW OF AUSTRALIAN SENIOR SECONDARY GEOSCIENCE CURRICULA

Not all States and Territories have the same framework for senior secondary education. The length of the course and its overall nature vary from state to state. In each of the States the curriculum and the administration of it are controlled by an independent body which usually has representatives of the Education authorities, the various school sectors, the Universities and other client groups of the school system. This body is also charged with the important task of assessment which because of its importance, sometimes becomes the over-riding activity.

3.51 Length Of The Course

In some States the senior curriculum is a one-year course taught in Year 12 of secondary school and in others the curriculum is designed to be studied over a period of two years. The details of the structure of the courses and the controlling authority are summarised in Table 3.2.

3.52 Nature of the Courses

The nature of the courses also varies from one State to another. In some States the course is divided into semester-long units and in others the curriculum is planned to be taught over a one year period or in other cases a two year period.

In Queensland the geoscience course is a two year program (Years 11 & 12) with no options which differs from the options which are available in New South Wales where two courses are available:

a 2 unit Geology course and

a 3 or 4 unit Science course.

The 3 or 4 unit course consists of a core and options. The core is equivalent to a substantial fraction of the cores of the 2 unit Chemistry and 2 unit Physics courses and includes some biology and geology to give all students a balanced view of science. The options are in five groups, one of which is geology. Students taking the 3 unit course must choose two options and students taking the 4 unit course must choose six options, with at least one from each of three groups.

State	Length of Course	Authority
Queensland	2 year course, Years 11 & 12	Board of Senior Secondary School Studies
NSW	2 year course, Years 11 & 12	Board of Senior School Studies
Victoria (last offered in 1995)	4 semester units, Years 11 & 12	Victorian Curriculum Assessment Board
Tasmania	Discreet Year 11 & Year 12 courses	Schools Board of Tasmania
SA/NT	Discreet Year 11 & Year 12 courses	Senior Secondary Assessment Board of South Australia
Western Australia	Discreet Year 11 & Year 12 courses	Secondary Education Authority

Table 3.2 The length and controlling authority for senior secondary curricula in Australian schools.

In Victoria a 4 unit course over two years is available. There are no prerequisites for entry into Units 1, 2 or 3. Units 3 and 4 are designed to be taken as a sequence and students must undertake Unit 3 prior to Unit 4. Tasmania has four separate syllabuses available, two for students in Years 11 and 12 studying Applied Science-

Geology and two for students studying Geology in Year 12. Of each pair, one is less demanding.

South Australia has separate syllabuses for Year 11 (Stage 1) and Year 12 (Stage 2). The Year 11 syllabus is a framework statement which does not prescribe the content, but defines four domains of knowledge within which individual teachers may choose their own content. At Year 12 the syllabus is totally prescriptive with the content and structure determined by the examining authority. In Western Australia the structure of the Year 11 and Year 12 geoscience is similar to those in South Australia. Year 11 and Year 12 are discreet and only Year 12 is examined externally.

3.53 Aims & Objectives of Australian Geoscience Courses

The aims of the individual syllabuses are similar in most aspects and can be grouped into the following areas:

Knowledge

This area relates to content and outlines the kind of knowledge that students should gain from the course. It also focuses on some of the processes, skills and concepts which students need so that they can collect and order information about the world.

Application of knowledge

Within this area problem-solving using the knowledge gained in the course is common to most State curricula and is especially emphasised in those where Year 11 is separate from Year 12.

Relevance to society

This aim is common to all curricula and relates to the social, political and economic considerations which are involved in exploitation of earth resources and natural hazards. This area will become increasingly important as environmental considerations are included in school curricula.

Science

In this aim geology is used as a vehicle to consider the nature of science, its purpose and philosophy and importantly its limitations. The application of the scientific method is also an important part of this aim and most curricula recognise the aptness of geology for demonstrating this.

In addition to the above areas, several curricula set out the kinds of skills which should be developed in students during the presentation of the course. These include: learning; communicating; group work; individual work; collecting and processing data; designing experiments; making judgements; and solving problems using scientific methods where appropriate.

3.54 The Content of Australian Geoscience Courses

The content of the courses varies from state to state. In some the emphasis is on a broad earth-in-space theme and includes earth science topics such as meteorology, oceanography, etc, while others deal only with solid Earth geology.

3.541 Queensland

The course is a two year course. Nine topics form the core of the Earth Science syllabus. All must be taught and at least five must be expanded beyond the minimum time stipulated. No more than one quarter of the total time in the full two year program can be allocated to any one topic. There must be at least one full day excursion in each of the four semesters.

The core topics and the minimum stipulated times are as follows:

Mineralogy (15 hours)

Petrology (15)

Physical geology (20)

Geotectonics (20)

Economic Geology (15)

Structural Geology and Geological Mapping (15)

Palaeontology and Geological Time (15)

Stratigraphy (10)

Astronomy (15)

The content of each of these topics is summarised in Table 1 of Appendix 1.

3.542 New South Wales

Two alternatives are available in NSW, a 2 unit course and a 4 unit course. Both span the two years of Years 11 & 12. The content of the core and elective units is summarised in Tables 2 and 3 of Appendix 1.

2 unit course - Geology

The syllabus is made up of a core and electives. The six core units are each designed to be taught for a period of six weeks. They are:

- Surface Processes
- Earth Materials
- Geological Time
- Solid Earth I
- Solid Earth II
- Geology and Society

The elective topics are divided into two groups. Students must study three topics, including one from each group. Each elective topic is designed to be taught for eight weeks of six periods per week. The electives are grouped as follows:

Group A	Group B
Mineralogy & Crystallography	Regional Geology
Contemporary Sedimentary Processes	Mountains
Igneous Rocks	Palaeontology
Metamorphism	Stratigraphy
Mapping & Structures	Exploration Geology & Geophysics
Economic Geology	Earth as a Planet
	History of Ideas in Geology

3 or 4 Unit Science Syllabus

The 3 or 4 unit course consists of a core and options. The core is equivalent to a substantial fraction of the cores of the 2 unit Chemistry and 2 unit Physics courses and includes some biology (Living Matter, Origins) and geology (Origins, Dynamic Earth) topics to give all students a balanced view of science.

The options are in five groups, biology, chemistry, geology, physics and interdisciplinary science which is made-up of such disciplines as biochemistry, communication, mineral exploration, etc. Students taking the 3 unit course must choose two options and students taking the 4 unit course must choose six options, with at least one from each of three groups. The five options in the Geology group are:

- Surface Processes and Stratigraphy
- Earth Materials
- Geological Resources
- Regional Geology
- Mountains

The content of the geology component of the core and the options is summarised in Table 3 of Appendix 1.

3.543 South Australia/Northern Territory

In South Australia there two discreet courses, one for Year 11 and one for Year 12. The Year 12 course is also taken by Northern Territory students

Year 11

At Year 11 students may take a 1 unit course (1 semester = 50-60 hours) or a 2 unit course (2 semesters = 100-120 hours) in Geology.

The course is designed around a structure controlled by four domains:

1. Acquiring knowledge of geology
2. Understanding and problem solving
3. Using knowledge of geology
4. Communicating knowledge of geology

Within each of these domains, a number of specified objectives must be achieved.

The syllabus is presented as a framework within which schools can develop their own individual content. Nine sample topics designed to be of 6-8 weeks duration, are presented as examples for schools to choose, modify or design other topics.

The content of the sample topics is summarised in Table 4 of Appendix 1

Year 12

The Year 12 (Stage 2) Geology syllabus is a very traditional geology course. It is a 2 unit syllabus taught over two semesters (total 120 hours). The content is set and there are no options, so all students study the same topics. Although it is possible to take only the first unit, in practice most students take both units 1 and 2. The content is summarised in Table 5 of Appendix 1. (At the time of writing a draft of a proposed new syllabus is being discussed and is likely to be introduced in either 1997 or 1998).

The content of the current syllabus is divided into four parts and the time allocation for each part is recommended. The parts are:

Earth Materials	40% time allocation
Earth Structures	20% time allocation
Earth History	20% time allocation
Earth Resources	20% time allocation

The content of the sample topics is summarised in Table 5 of Appendix 1

The proposed new syllabus is much different in structure and emphasis. It is divided into five parts and emphasises human impacts and interactions with the environment. The parts are:

The Rock Cycle - 25 hours

Global Patterns and Processes - 10 hours

The History of the Earth - 25 hours

Geological Hazards -10 hours

Impact of Human Activities on the Earth - 30 hours

3.544 Victoria

The two year course was divided into four units.

Unit 1	The geology of Victoria
Unit 2	Earth resources and their use.
Unit 3	The origin and structure of the Earth.
Unit 4	Unravelling the Earth's past.

Units 3 and 4 was designed to be taken as a sequence.

Unit 1 provided an introduction to geology based on the local context. Unit 2 dealt with the use of Earth materials on a national scale. Unit 3 explored the Earth as a planet and Unit 4 examined how landforms provide a history of past environments.

The content is summarised in Table 6 of Appendix 1.

3.545 Tasmania

Two syllabuses are available to Year 11/12 Applied Science students and two syllabuses are available to Year 12 Geology students.

Year 11/12 Applied Science - Geology .

The content of the less demanding and the more demanding syllabuses is the same. The difference is in the depth of treatment which is spelt-out in the description of the core.

Both syllabuses are task-based and emphasise the acquisition of scientific skills while developing and using communication and social skills to gain knowledge of applied scientific thinking through geological activity. They consist of a compulsory core of 50 hours integrated with a geology unit of 50 hours. The core is described under the following headings and it is the depth of treatment of these which differentiates between the more and the less demanding options.

Core topics

- Nature and aims of science;
- Methodology of science;
- Historical and cultural context of science;
- Science and society;
- Applications of science.

The geology topics which are to be integrated into the development of these core topics can be described as:

- Distribution of Earth resources;
- Evolution of Earth natural-resource forming processes;
- Impact of human use on Earth resources;
- Management of Earth systems;
- Preservation, utilisation, and restoration of Earth systems;
- Earth science technologies;
- Roles of earth scientists.

Year 12 Geology syllabuses

The content of the less demanding and the more demanding syllabuses is much the same. The difference once again is in the depth of treatment which is described in the criteria for assessment. The more demanding syllabus requires broader understanding, is more quantitative and treats a greater variety of examples.

Both syllabuses consist of a core and options. The core is 30 hours during which local geology is the basis for study of:

- maps, photographs and diagrams;
- relationship of events in space and time;
- earth materials;
- significance of local geology to human activity

The options consist of 'problem briefs' and it is expected that students will study a minimum of 4 and a maximum of 8 from the following concept areas:

- The Earth system as part of the Solar System in the universe;

- The interacting sub-systems of the Earth system, water, land, ice, air, and life;
- Interaction and evolution of the sub-systems through natural cycles;
- Time, time-scales and Earth history;
- Impact of human activities on the Earth system;
- Management of resources;
- The role of technology in understanding the Earth system;
- The roles of earth scientists.

3.546 Western Australia

There are two discreet courses in Western Australia, one for Year 11 and another for Year 12.

Year 11 Geology course.

This course is a general course covering the wide spectrum of Earth Sciences. It is divided into six sections as follows:

- Earth in Space;
- Earth Structure;
- Mineralogy;
- Rock Cycle;
- Palaeontology - Time;
- Geology and our Society.

The content of these topics is summarised in Table 7 of Appendix 1.

Year 12 Course.

This course is more analytical and interpretative than the Year 11 course and has a higher level of conceptualism. There is no prerequisite for the subject. The course is divided into five parts:

- Mineral Systems;
- Melting of the Lithosphere;
- Crustal Deformation
  - Metamorphism
  - Dynamics
  - Interpretation
- Reconstructing Past Surface Environments
  - Ancient Environments
  - Ancient Life Forms
  - Dating the Past
- Crustal Resources

The content of these topics is summarised in Table 8 of Appendix 1.

Appendix 1 contains in tabular form the detailed content of all of the senior school geology syllabuses discussed in this chapter. They have been tabulated so that they can be compared. The columns correspond to the five sections of the most commonly recommended textbook, *Geological Science: Perspectives of the Earth* (Clark and Cook 1983). The sixth column in each table contains a description of the content which is not covered by that book.

3.55 Comparison of Geology/Earth Science Curriculum

There are two clearly different frameworks which can be used to analyse the geology/earth science curricula described in the previous section. The traditional curriculum framework which deals mainly with the solid Earth has been widened with the addition of "Earth in Space" topics and the relatively new approach which is proposed by Mayer and others (Mayer and Armstrong 1990; Mayer 1991; Mayer, Brown et al. 1992) which can be called the Earth Systems approach.

Tables 3.3 and 3.4 compare the various Australian and overseas curricula in the two frameworks. Of the Australian curricula only the Tasmanian Year 12 curriculum covers most of the essential understandings outlined by the PLESE committee in their proposal for an Earth Systems approach. None of the Australian senior geology/earth science curricula, nor the National Curriculum addresses *Understanding 1 : Earth is unique, a planet of rare beauty and great value.* This understanding was intentionally placed as the highest priority by the PLESE Planning Committee because it is considered crucial to the understandings which follow and departs most dramatically from traditional science curriculum recommendations (Mayer, Brown et al. 1992). The stated purpose of this understanding is to provide students with an aesthetic appreciation of the Earth which will lead naturally into a concern for the proper use of resources and a concern for conserving the economic and aesthetic resources of the Earth (*Understanding 2*).

	Understanding 1 aesthetic approach	Understanding 2 Human impact	Understanding 3 Science & Tech	Understanding 4 Interacting syst.	Understanding 5 Time & evol.	Understanding 6 Space science	Understanding 7 Earth Sc. careers
Earth Sys. Sc.	√√√	√√√		√√√	√√√	√√√	√√√
AGI/ NSTA				√√	√√√	√	
UK Nat Sc Curric				√		√	
Qld.		√		√	√√	√	
NSW 2-unit		√√√			√√	√	
NSW 3/4-unit		√√		√√	√√	√	
SA Year 11		√√		√√	√	√	
SA Year 12		√√		√	√√		
SA New syllabus		√√√		√√	√		
Victoria		√√		√	√		
W Aust Year 11		√		√	√√	√√	
W Aust Year 12		√		√	√√√	√√	
Tasmania		√√	√√	√√√	√√	√√	√√
National Curric		√√	√		√	√√	

Table 3.3 Comparison of geology/earth science curricula with the Earth System Education framework understandings.

	Earth in Space	Earth Materials	Earth History	Earth Structures	Earth Resources
Earth Sys. Sc.	√√√	√√	√√√	√√	√√√
AGI/ NSTA	√√√	√√	√√√	√√	√√√
UK Nat Sc Curric	√√	√	√	√	√
Qld.	√	√√√	√√√	√√√	√√√
NSW 2-unit	√	√√√	√√√	√√√	√√√
NSW 3/4-unit	√√	√√	√√	√	√√√
SA Year 11		√√	√	√√	√√√
SA Year 12		√√√	√√√	√√√	√√√
Victoria		√√	√√	√√	√√√
W Aust Year 11	√√	√√√	√√	√	√√
W Aust Year 12	√√	√√√	√√√	√√√	√√√
National Curric	√√√	√	√	√√	√

Table 3.4 Comparison of geology/earth science curricula with the traditional geology framework.

Once these attitudes have been introduced to students they will have a greater desire to learn about the Earth. All of the Australian state curricula and the National Curriculum address *Understanding 2: Human activities, collective and individual, conscious and inadvertant, are seriously impacting planet Earth.* It is most comprehensively addressed in the newest geology/earth science curriculum, the proposed South Australian Year 12 curriculum which indicates the growing concern for the environment and the need to understand the importance of all aspects of the Earth system. Understandings 4, 5 & 6 are addressed to varying degrees by all of the state curricula with the exception of South Australia and Victoria which do not include anything about the Earth in Space *(Understanding 6).* Understandings 3 & 7 are not addressed by any of the states except Tasmania, which clearly is the closest of the Australian states to following the Earth Systems approach to the study of geology/earth science.

The National Curriculum is similar to the individual state curricula in its relationship to the the Earth Systems approach. If the more traditional approach to geology/earth science curriculum is used as a framework (Table 3.4), the National Curriculum is not similar to the individual state curricula. The National Curriculum treats the *Earth in Space* topic thoroughly but does not give adequate treatment to the other four areas which relate to the solid Earth and are the main topics of the more traditional geology/earth science curricula. All of the state curricula are similar when compared using this more traditional framework and give good to adequate coverage of the solid Earth topics.

3.56 Assessment Methods

There is a great variation in the assessment of the courses between the states. In some states there is no external assessment and in others only Year 12 is externally assessed. Some forms of external assessment include an examination component and some only moderate internally determined assessments.

3.561 Queensland

Assessment is continuous and is carried out in schools. All mandatory aspects of the course must be assessed in a way which provides a balanced result. Levels of achievement are given as:

Very High Achievement

High Achievement

Sound Achievement

Limited Achievement

Very Limited Achievement

A variety of assessment instruments must be used over the two year course with the following range of emphases:

Knowledge of subject matter	40-50%
Scientific process	25-30%
Complex reasoning processes	20-30%
Manipulative Skills	5-10%

Schools must provide a review folio as evidence of each student's achievement which is used to validate summative judgements of exit levels of achievement.

3. 562 NSW

Both the 2 unit and the 3/4 unit course are assessed externally as part of the process of awarding the Higher School Certificate which is used as a University entrance qualification. The assessment includes an externally set and marked examination.

3. 563 Victoria

Units 1 and 2 were assessed by schools and were reported as S (satisfactory) or N (not satisfactory). Assessment was based on the student completing all of the work requirements for the unit in accordance with the specifications.

Units 3 and 4 were partly assessed by schools and S or N results were derived in the same way as for units 1 and 2. In addition the Victorian Curriculum Assessment Board (VCAB) assessed students by means of four common assessment tasks (CATs). These were:

CAT 1	Investigation report
CAT 2	Structured questions
CAT 3	Field mapping project
CAT 4	Geological map interpretation

These were reported on a 10 point scale using five grades with two letters

A+, A ...... E+, E

CATs 1 and 3 were assessed initially by the school and were subject to verification. CATs 2 and 4 were taken under test conditions which means that they were externally set, directly supervised and completed in a fixed period of time under secure and specified conditions. These external exams were double marked by a panel appointed by VCAB. The assessment for each CAT was reported separately.

3.564 Tasmania

The two Year 11/12 applied geology courses are internally assessed (school based) against predetermined criteria. All nine of the criteria are rated on a four point scale (A,B,C & D) where each rating represents a range of achievement. A is the highest rating. The overall assessment is determined by the achievement of the individual criteria and is awarded as:

Satisfactory Achievement	7C ratings and 1D

High Achievement	6B, 2C, 1D
Outstanding Achievement	6A, 2B, 1C

The Year 12 geology syllabuses are internally assessed in the same way as the Year 11/12 Applied Science-Geology, but an additional external assessment of six of the eleven criteria is also used to determine the final award. The seventeen ratings (eleven internal and six external) are combined to determine the rating. The external assessment is by means of a three hour examination, in one hour of which candidates have access to given general information and resources and may engage in discussion and take notes and diagrams. The following two hour session is closed during which candidates undertake a detailed thematic-based task using the information gathered in the first session.

3.565 South Australia

The Stage 1 or Year 11 assessment is internal and designed and carried out by teachers during the academic year. The normal range of summative assessment tasks may be undertaken.

Teachers must submit an assessment plan which is required for moderation purposes. The measure of achievement will be Satisfactory achievement or Recorded achievement or in the case of unsatisfactory performance "requirements not met".

At Stage 2, or Year 12, assessment has two equal components, a school component and an external component. The school assessment advice recommends continuous assessment over the whole year related directly to the course objectives using a range of assessment tasks. The mark is reported in two parts, - out of sixty for course work and out of forty for field work. The assessment for the proposed new Year 12 course has already been described in section 3.32

The school mark out of 100 is moderated by the examination mark. The external assessment is a three hour externally set and marked examination, the nature of which is specified in the curriculum document.

3.566 Western Australia

Year 11 assessment is internal and is expected to be carried out over the whole academic year. The structure of the assessment is specified in three parts:

1. the components and learning outcomes to be included
2. the weightings to be applied to these components and
3. the types of assessment considered appropriate.

Year 12 is assessed in two parts. The school based assessment is similar in structure to that specified for Year 11. A three hour written externally set and marked examination makes up the second part of the assessment.

3.567 Significance of assessment

From this review it is apparent that there is a considerable emphasis placed on assesement, particularly at Year 12 and it is likely that much of the teaching and learning at the senior secondary level is assessment driven. This is principally because students need to obtain a high score to gain university entrance. There is little doubt that assessment exerts a disproportionate influence on what students actually choose to learn and this is exaggerated by the detailed statements of criteria for assessment which are included in syllabus documents (see for example pages 15-17 of the proposed Year 12 Geology syllabus for South Australia which details all of the criteria which should be used to determine whether the objectives have been achieved). At Year 12 level it appears that students focus their learning efforts on what they believe will be assessed. Learning tasks which are not counted for assessment are not important to students and many students refuse to complete them (pers comm, C. Pyle, 1994). Even though curriculum documents indicate that problem-based learning, critical thinking, high level analysis, and synthesis of ideas should be encouraged, the focus of assessment is end of subject exams which emphasise rote learning and uncritical regurgitation of information.

3.57 Teaching and Learning Advice

All of the State curriculum documents give advice on aspects of teaching and learning. Advice about the importance of and organisation of fieldwork is common, while there is a varying amount of advice given about the conduct of practical/laboratory type activities and the need to incorporate problem-solving exercises etc. By far the most detailed advice on teaching and learning is given in the draft of the proposed new South Australian Year 12 document (SSABSA 1996). It advises teachers to use a variety of teaching and learning strategies including lectures, class discussions, viewing of videos, use of computer simulations and directed research. The advice is given under the headings of acquiring knowledge, understanding and problem solving, using knowledge of geology, and communicating knowledge of geology. Under the heading of acquiring knowledge a considerable amount of advice is given about fieldwork, especially with respect to equity issues related to physically and financially disadvantaged students. Practical and research activities which are related to the course objectives are suggested for each of the content topics in the final section of the teaching and learning advice.

3.58 Student Numbers

Figure 3.5 shows student numbers for year 12 Geology/Earth Science from 1981 to 1991 for each of the states where the figures are available. It shows that not a very high proportion of students actually study geology at senior secondary school and that in some states that the number is declining.

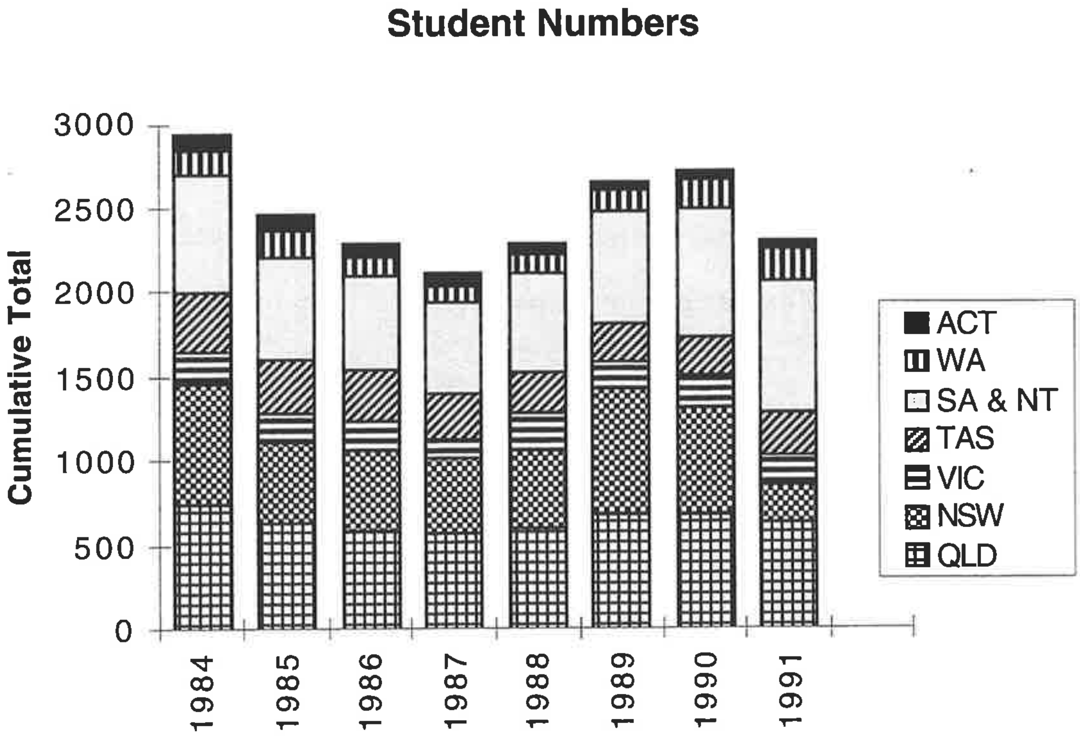


Figure 3.5 State by state summary of the number of senior secondary students studying geoscience subjects for the period 1981-1991.

3.6 SUMMARY

Geology/earth science is available to all secondary students at Year 11 or Year 12, but is only studied by a relatively small proportion of the total number of students studying at this level. Although there is some variation in the detail of the content, the curricula are much the same and relate closely to the more traditional solid earth geology curriculum model than the more recently proposed Earth Systems approach. Tasmania is the exception to this. Nevertheless there will be significant differences in prior knowledge and understandings between students who have studied geology/earth science at senior secondary level and those who have not. This has important implications for teachers and curriculum designers of introductory tertiary geology/earth science subjects. The number of students who have studied geology/earth science at senior secondary school may be small in any one class and may not be significant, but the effect of this prior learning on the interests and attitude towards the further study of geology/earth science at the tertiary level may be serious. It is also possible that these students will come with some mis-conceptions which, if not recognised, will affect their future learning.

The impact of the National K-12 curriculum also needs to be considered. If adopted, all students coming to university will have been taught some geology/earth science topics during K-10. This is a much different situation than presently exists and will have to be considered by tertiary geology/earth science departments.

CHAPTER 4

INTRODUCTORY TERTIARY GEOLOGY/EARTH SCIENCE CURRICULUM

4.1 INTRODUCTION

Most Australian Universities offer an undergraduate course in which geology subjects can be studied over a period of three or four years leading to a Bachelors degree with geology as a major. The content of these courses is very similar from institution to institution and for the introductory subject is also very similar to the content of the senior high school geology curricula described in the preceding chapter. The introductory subject also usually assumes no previous experience (ie no prerequisites).

This similarity between the senior high school geology curriculum and the introductory geology subject at university has been of concern to both high school teachers and university academics for a long time. Part of the concern of university academics is the fact that some students come to the introductory geology subject with no prior knowledge and some who have studied geology at Year 12 have covered most of the content of the introductory geology subject. This makes curriculum design difficult because of the range of knowledge about some topics that exists within the class. The dilemma for tertiary geology curriculum designers is whether or not to ignore the presence of students with prior knowledge of geology topics in introductory subjects.

If they are ignored, their attitudes to geology may be affected. It is thought that some of the students who have studied geology at Year 12 get bored by the repetition of topics that they have already studied and think, in many cases wrongly, that they know more about the subject than they in fact do. This boredom can lead to a poor attitude to geology and prevent the students from choosing further geology subjects during their courses, or even to fail. Two conflicting issues arise. Decreasing student numbers at senior levels is costly when a significant proportion of a department's income is derived from total enrolments. Alternatively, to mount a special subject for those students who have already studied geology is costly in time and resources because economies of scale cannot be achieved.

In response to this situation as part of the primary aim of this thesis it was decided to investigate the nature of prior knowledge held by students taking the introductory geology subject at the University of Adelaide.

4.2 AN INVESTIGATION OF THE NATURE OF STUDENTS' PRIOR KNOWLEDGE.

A study was carried out the purpose of which was to answer the following research questions.

- what is the nature of prior knowledge held by students;
- is there any difference in the prior knowledge held by students who had studied geoscience at senior secondary school with those who had not;
- is it possible to design an instrument to investigate the development of concepts during the introductory geology course;
- is it possible to design an instrument to identify common misconceptions that exist amongst students;

4.21 Orientation Study Of Students' Prior Knowledge

In 1991 a preliminary study was done at the beginning of the academic year. This was designed to be an orientation study to gain information about the feasibility of the proposed method. A questionnaire consisting of two parts was given to every Geology 1 student at the preliminary lecture held in Orientation Week. The first part of the questionnaire was a standard departmental form which was designed to gather information about students' other University studies, their senior secondary academic history, their reason for choosing Geology 1 and whether of not they intended to major in geology.

The second part of the questionnaire consisted of three different styles of questions designed to gather the first part of the information needed to answer the four research questions outlined above. The questions covered the range of concepts that were covered in the first semester of the subject and it was intended to be followed-up at the end of the semester. The concepts were identified from the list of lecture topics and brief content descriptions provided in the subject information booklet prepared for the students.

The first question was a Grid-square format covering the Earth in Space aspect of the introductory subject (Figure 4.1). The grid-square format was chosen rather than a series of multiple choice questions because it does not provide any hint to the correct answer and since it does not limit the choice of alternatives to one and is more able to indicate misconceptions. Another advantage of this format was that it could be used to cover a number of concepts in a relatively short period of time. The time allowed in the preliminary lecture was 10-15 minutes, so the format chosen had to be time efficient. The question is shown in Figure 4.1.

The following questions refer to the information contained in the boxes below.

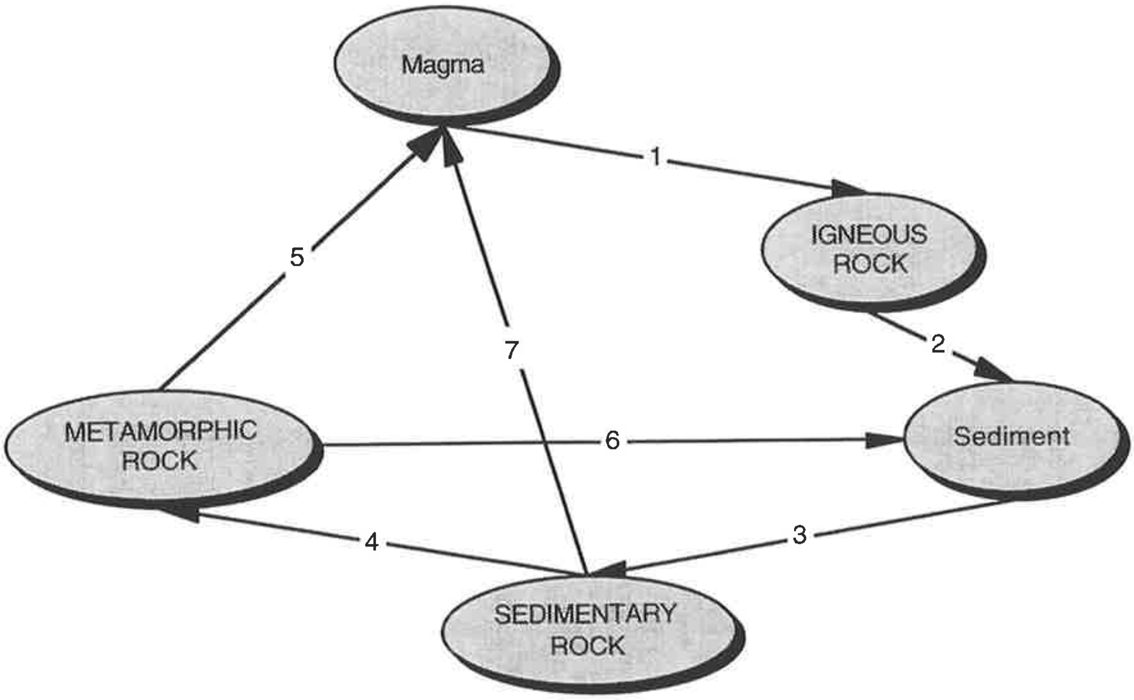
1. age of 4 500 million years	2. liquid surface water	3. weathering and erosion
4. dynamic outer surface	5. impact craters	6. age of 11 000 million years
7. gravity	8. silicate rocks	9. atmosphere

The answers to each of the following questions are provided in the numbered boxes above. Answer each question by selecting the box number(s) of the appropriate response(s). In some cases there will only be one appropriate response and others there will be more than one. Indicate as many numbers as you think are appropriate in the spaces provided.

Example: Which of the characteristics apply to Earth?	1, 2, 3, 4, 5, 7, 8, 9
1. Which of the characteristics is unique to Earth?	________
2. What is the age of the Earth?	________
3. What is the age of the Universe?	________
4. Which things act together to produce landforms?	________
5. Which of the characteristics relate to the Earth's moon?	________
6. Which things are common to the Earth and the moon?	________

Figure 4.1 Grid-square question used in the orientation survey

The second question tested beginning students' knowledge and was designed to be the basis for assessing changes in concepts held before and after the teaching. It was a version of the rock cycle diagram which required students to identify from a list the processes that connect the main concepts. This was included to see if there was a difference between the knowledge of students who had studied geoscience at senior secondary school and those who had not. It was also included to look for misconceptions and to see if there was any relationship between those students who held misconceptions and those who did not. This question is shown in Figure 4.2.



The diagram above shows a number of terms which are related to each other; the numbered arrows show the related terms. Listed below are the processes which link the terms in the boxes. Against each of the processes listed put the number(s) of the arrow(s) that you think represents this process.

Crystallisation ------------------------------

Weathering & Erosion ------------------------------

Deposition ------------------------------

Heat & Pressure ------------------------------

Melting ------------------------------

Figure 4.2. The second question from the orientation survey.

The third part contained two questions that were similar in appearance, but which required different types of knowledge to answer them. Both questions related to a diagram which required students to determine the order or sequence of events depicted by the diagram. The first was a simple drawing of "pick-up-sticks" and required the students to describe the order in which they would pick up the sticks one at a time without disturbing any of the remaining sticks. Although this relatively simple exercise required no prior knowledge of geoscience, it was included because in determining the answer, students needed to use the same principles as basic laboratory exercises in stratigraphy and the laws of superposition where students have to work out the order of events from cross-cutting relationships.

The last question, although similar in appearance, required a knowledge of igneous crystallisation processes to get the correct sequence of events. A diagram showing a microscope view of a thin section of an igneous rock was given and students were required to list the order in which the minerals crystallised. This question was included because it was felt that only those students who had done geoscience at senior secondary school would have the knowledge to answer it correctly. To help with this conclusion the students were asked to indicate from a list, how they obtained their answer. Because it was assumed that the students required prior special knowledge to answer the question, it could also be used for comparison between the beginning and the end of the subject to determine how well the concept had been learned by students.

4.22 Results Of The Orientation Study

The follow-up study was not carried out in 1991 because there was some difficulty in arranging for an appropriate time for it to be carried out. It was also felt that the questions, which had been hurriedly constructed, did not achieve exactly what was needed so it was decided to analyse the results of the prior knowledge part and to prepare a better instrument and procedure to be administered in the following year.

117 questionnaires were collected, 20 of which were from students who had studied geoscience at senior secondary school level. Analysis of the results did provide some insight into the different nature of prior knowledge of those students who had studied geoscience at senior secondary school and those who had not. The results are summarised in Table 4.2.

	Students who have studied Year 12 Geoscience		**Students who have not studied Year 12 Geoscience**	
	Percentage of cohort who scored		Percentage of cohort who scored	
Rock Cycle Question				
score = 7	55		20	
6	20		10	
5	25		20	
4			10	
3			20	
2			20	
1				
Pick-up-sticks	Correct	Incorrect	Correct	Incorrect
Percentage in each category	95	5	100	
Crystallisation of magma				
Percentage in each category	45	55	20	80

Table 4. 2 Summary of the results of the orientation study. Percentages in each category have been rounded to nearest 5%.

As was expected the students who had studied geoscience before did much better on the Rock Cycle question. For those who did make mistakes the links 4 and 6 were the most commonly mislabelled or mistakenly labelled links. Amongst those who had not studied geoscience, there was a fairly even spread of scores. Most students were able to correctly identify that 2 (weathering and erosion) was the link from igneous to sediment and many were able to correctly identify that 3 was the link from sediment to sedimentary rock and that 7 was the correct link between sedimentary rock and magma. The students who had not studied geoscience also commonly could not correctly label 4 (heat & pressure) as the link between sedimentary and metamorphic rock.

As was expected the majority of students in both groups was able to determine the order in which the sticks had to be picked-up in order not to disturb other sticks. The one student who did not get the correct order exactly reversed the order.

Only slightly less than half of the students who had studied geoscience at senior secondary school was able to correctly determine the order of crystallisation of the minerals depicted in the diagram of the igneous rock thin section whereas about 20% of those who had not studied geoscience at senior secondary school were able to correctly determine the order. Of this group, two guessed and the remainder (20) indicated that they had used the shape of the crystals to determine the order of crystallisation.

A small number of students who did not pick the correct order of crystallisation indicated that they used the principle of "overlapping" relationships as though the crystals had settled with the last to form settling to overlap those that had settled before. This relatively logical conclusion and the fact that most students could correctly determine the order for pick-up-sticks indicates that most beginning students would be able to correctly complete a simple stratigraphic sequence exercise.

4.23 Detailed Study Of Students' Prior Knowledge

Another instrument was designed to provide information to answer the research questions and was administered to students taking the introductory geology subject at the University of Adelaide at the beginning of 1992. The instrument again consisted of two parts, a questionnaire designed to obtain background information about the students and a second part which consisted of seven questions about geology.

The questionnaire was similar to the one used in the Orientation Survey except that respondents could remain anonymous because one of the concerns expressed by students participating in the orientation survey was that the results might be used to influence their overall assessment. In order to be able to match initial and follow-up responses, it was necessary to develop a matching code. The instructions for the matching code are given in Figure 4.3

Matching Code (this will not identify you. It will be used to match data from this survey with later data.)

First three letters of your Mother's Family name.

Your Mother's birthday. day month

Figure 4.3 The instructions for the matching code used to ensure that student responses remained anonymous

The other information obtained by the questionnaire related to the background of the students, including gender, nationality, whether English was their first language, details of their secondary education and information about their proposed university studies.

The geology questions were six multiple choice items chosen from a data bank of standardised questions prepared by the American Geological Institute and a seventh question which was the "pick-up-sticks" question from the previous study. All of the questions related to the concept of geological time because it was felt that more useful information could be gained by concentrating on one area. Another reason for concentrating on this concept, was that it is considered to be of fundamental importance to geology and one that is unique to geology. More pragmatically, it was chosen because the topic was to be taught later in the year so that any information gained from the analysis of the results could be incorporated in the teaching and because the staff member who was teaching that topic was most likely to support the research.

4.24 Results Of The Detailed Study

The detailed study did not quite match up to the anticipated outcome because it was not possible to properly administer the initial survey and it was not possible to develop a way of incorporating a satisfactory follow-up study into the program of the students.

Both of these problems were partly related to the fact that the researcher was a part-time student who could not be present at the times when the students were available, especially for the follow-up study. Another part of the problem was that the research was not highly valued by the people able to ensure that it was logistically possible because the purpose of the research was not properly explained or appreciated.

The initial study would have been most appropriately and conveniently administered to the whole group at one time either at the first lecture or during the preliminary lecture as had been the case with the orientation study. Unfortunately this was not possible because it was not possible to set aside 15-20 minutes during either of these lectures. It was therefore necessary to use the practical times, and again because of time constraints during the first week of classes, the questionnaire was not administered until week 2 of classes. In some classes the questionnaire was administered at the beginning of the 3 hour class, in some it was administered at the end, and in some it was distributed at the beginning of the class and collected from the students as they left. Thus there was a variation in the conditions under which the questions were answered. A further problem was that some students had had six lectures if their practical class was scheduled at the end of the week and others had had only four lectures if their class was scheduled a the beginning of the week. It was decided that there were too many possible variations for any analysis of the results to be meaningful.

With a view to beginning the study the following year, an abbreviated analysis of the data collected from 50 students enrolled in the Bachelor of Science degree was carried out. This group was chosen because they were the group who were most likely to be going on to study more geology. A summary of the analysis is given in Table 4.3.

Question Number	Percentage with correct answer All students	Percentage with correct answer Students who have studied Year 12 Geoscience
1	28	60
2	88	100
3	60	80
4	28	20
5	20	60
6	80	80
7	80	100

Table 4.3 Summary of the results of the detailed study of beginning geology students

For every question the students who had studied geoscience at senior secondary level performed better than those who had not. Only questions 1 and 5 showed a clear difference between those students who had studied geoscience at senior secondary level and those who had not. Question 5 clearly required specific geoscience knowledge to answer it. Question 1 also required specific geological knowldge as well as some experience in answering that particular type of question. It is a little surprising that as many of the non-experienced geoscience students were able to answer the question at all. It is possible that the number simply reflects the 1 in 4 chance that students who guess have. Question 4 was poorly answered by both groups and of the students who had studied geoscience at senior secondary level was only correctly answered by those who had scored 19/20 or 20/20 for geology at Year 12.

4.3 CONCLUSION

There is clearly a scope for this kind of study because there will always be students who have prior knowledge in introductory geology classes. While many people believe that this presents a problem, there is little known about the effect of prior knowledge. Before any strategies are implemented to deal with this perceived problem work needs to be done to delineate the true nature of the problem.

Although this study has not been entirely successful, it has shown that it is possible to gain the information needed. To gain worthwhile information the study needs to be carried-out over several years, or over several departments by someone who has unlimited access to the group of students and some control over their program of study in the introductory geology subject. Such a person will either be the subject coordinator, a research student of the coordinator, or a researcher who has been commissioned by the department to carry out the study. In other words, for this type of research to be made possible, the department or the subject coordinator needs to be fully supportive.

CHAPTER 5

IMPROVING THE QUALITY OF TEACHING AND LEARNING IN GEOLOGY EDUCATION

5.1 INTRODUCTION

This chapter and the following three relate to the investigation of quality teaching and learning at a more advanced level of the Tertiary geology curriculum (second year undergraduate structural geology). The study was prompted by the need to evaluate more carefully and rigorously the outcomes on student learning of modified teaching and delivery methods. Prior to and during the course of the study the methods involved in delivering information to students have changed and students have been encouraged to use different learning strategies.

The study was carried out with two different types of students: second year undergraduate science students at the University of Adelaide and second year undergraduate teacher education students at the University of South Australia. At the University of Adelaide the researcher was involved in the development of the modifications and helped during the classroom delivery. At the University of South Australia the same modified teaching methods were used by the researcher during the instruction of the students in the structural geology classes.

This chapter describes the way in which the delivery methods have changed and the different learning strategies which were introduced to the students. Chapter 6 describes the way in which the effects of the changes were evaluated, Chapter 7 describes the research questions and the quantitative and the qualitative methods which were used to answer them, and Chapter 8 is a discussion of the results.

5.11 Traditional Teaching Methods.

Structural geology is part of most undergraduate geology courses. Like most other sub-disciplines such as palaeontology, petrology or geophysics, it is a small part of introductory courses and is not treated in more detail until subsequent years when it becomes an individual subject within a geology major. Structural geology involves the study of the morphological features of rocks that have been deformed by forces in the Earth, the nature of the forces that drove the deformation and controlled their evolution and the mechanical properties of the rocks that determined the way they deformed. Structural geology provides a fundamental building-block for a career in petroleum or mineral exploration. Traditionally structural geology and the other subjects in undergraduate geology courses have been taught by a combination of lectures, practical or laboratory classes and fieldwork. In this combination lectures were used to convey the expert knowledge required to understand the subject from the expert to the students. Usually lectures are of 50 minutes duration and in the traditional model, involve little interaction between the lecturer and the students. Practical or laboratory classes are where students develop and practice skills, and fieldwork is where they observe examples of many of the topics which were presented in lectures, as well as an opportunity to develop many of the skills needed to become a professional geologist.

5.2 TEACHING ENVIRONMENT

The teaching of structural geology involved in this study has changed progressively throughout the study as new technologies became available and as the result of the analysis of student evaluations of the subject. The remainder of this chapter describes the early methods of teaching and discusses their perceived shortcomings and goes on to describe the types of modification which were made to the teaching: the staged introduction of the electronic classroom and the use of concept maps to help students learn.

5.21 Lectures

Lectures are a common way of transmitting information from the teacher to a group of students. '...most geoscience departments place considerable reliance on lectures to transmit essential knowledge and understanding to their students' (Gill 1994, p97) Lectures tend to be teacher-centred rather than student-centred, with most of the responsibility for the content and structure of the curriculum resting with the teaching staff. However there is plenty of evidence to suggest that these traditional, didactic approaches are giving way to more interactive, problem-based, and independent approaches which support students while they grapple with the difficult problem of assuming personal responsibility for their own learning (Ramsden 1992; Laurillard 1993).

At the tertiary level, geology lectures usually consist of the presentation of a series of factual statements, frequently illustrated with quantitative data displayed as graphs, tables or figures. These data are used to erect models of natural behaviour and to substantiate reasoned assertions or "scientific hypotheses". Analogue models and demonstrations are sometimes used to illustrate abstract ideas and to enable students to relate new information to their experiences. The style of individual lecturers varies and for an individual lecturer the format may vary from one lecture to the next according to the nature of the topic. Often this involves the use of questions and answer segments. This process is referred by Laurillard as a way of involving the 'discursive mode that gives the lecturer an insight into how they [the students] are thinking about the topic (Laurillard 1993; Gill 1994)

In structural geology, most lectures are illustrated using a variety of methods. A fundamental problem which has consistently hampered the lecturer's delivery of a professional presentation has been the poor quality of display material. The quality of the display or illustration of the scientific data has varied historically depending on the currently available technology and the individual whim of the presenter. Blackboard and chalk (or whiteboard and pen) thumbnail sketches with associated, often illegible, text have been the most common display method, with illustration added by 35mm transparencies. Overhead projectors which have allowed enlargement of written text and figures, and photocopies onto overhead transparencies from reference books and other publications, have gradually improved the overall quality of technical presentation material. This improvement in the presentation technology is in itself a trap because students feel compelled to copy as much into their notes as they possibly can. In many cases however, there is too much detail included on the transparencies and it is impossible for students to copy their content during the lecture. Complicated, pre-prepared overhead or 35mm transparencies can be very frustrating for students because they do not have time to copy the information which they perceive to be important. This is a common comment contained in student evaluations of teaching.

It is well known that the optimum concentration span of most of the students during a scientific (and probably any other type) of lecture presentation deteriorates rapidly from early in a lecture and reaches a very low level after about 20 minutes (Gibbs, Habeshaw et al. 1984). The standard 50 minute lecture, illustrated with poor quality visual images, is thus neither an ideal mechanism for the distribution of scientific information nor for the promotion of student learning. This is supported by Candy (1994, p4) who says that 'it is patently clear that lectures - especially poorly presented lectures - do little to develop in students a "deep" approach to learning, and an abiding love of learning or of their subject...'

As well as improving illustration quality, other strategies are commonly used to break-up the standard lecture, for example short question and answer sessions, active demonstrations, slide shows, film clips, and video are used.

Another problem which students have is the restriction of access to lecture material out-of- the normal lecture period. The best way for students to have access to lecture material out-of the normal lecture period is by having the lecture video-taped. In most situations this is not practical. To provide some help in this area, some teachers provide extensive hand-outs and notes but these seldom include the visual material which was part of the lecture.

A third problem for students during lectures is the difficulty in distinguishing between peripheral detail and important concepts. They are often confused and left unclear about learning and assessment directions by too much detail. This concern was raised by students during consultations and in written submissions to the Working Party on Quality in Teaching and Learning of the University of Adelaide (Working Party on Quality in Teaching and Learning 1992). Typically, during a lecture, students spend the whole 50 minutes writing as much of what the lecturer says as they can. The result is a set of notes with little or no structure. In their submission students suggested that lectures should be structured so that students can attend to central principles, and fit necessary details into a knowledge framework. It is very difficult in a lecture situation, to stop students from trying to write everything they hear. The result is that they seldom have time to think about what is being said, and thus they have little chance of putting the new information into a hierarchy of concepts and connecting these to their existing knowledge framework.

5.22 Practical classes

Practical classes are the place where students traditionally learn and practice the skills that they will need to apply after they graduate. In structural geology these include: identification and description of rocks and other earth materials; working with and interpreting topographical and geological maps, aerial photographs, satellite images and other forms of remote sensing data; manipulation of and interpretation of structural data which includes geometrical methods and stereographic projection methods; analysis of rock-deformation data; construction and balancing geological cross-sections; and analysis of strain (Marshak and Mitra 1988). The format of practical sessions varies according to the type of activity which is occurring. Some sessions involve students following step-by-step instructions in a cookbook-like fashion. The instructions may be in the form of written material or may be presented to the whole class by the lecturer in a lock-step fashion. Alternatively practical activities may be investigative where students are provided with information and must choose the appropriate methods to arrive at a solution to a problem.

Like many other fields of study the time available is too short for students to become proficient in all of the skills that they will need after graduation. There is a very strong temptation to include more and more into the practical curriculum in order to adequately prepare graduates to practise, and to be "up-to-date". However, this practice often leaves students with a fragmented and disjointed view of the field rather than an understanding of the essentials (Candy, Crebert et al. 1994).

Laboratory classes have always been regarded as the place where students learn the process of 'doing science'. But summaries of research on the value of the laboratory for learning science do not favour laboratory classes over lecture-demonstration. Studies at Cornell University, reported in (Novak 1988), show that most students in laboratory classes gain little insight about the key science concepts involved and are helped little in the process of knowledge construction. These aspects have been addressed, as will be described later, by changing the nature of laboratory activities

5.13 Fieldwork

Work outside of the classroom is generally described as fieldwork. In geology it can be conveniently described as short excursions which involve one or two days, and field camps which occupy students for a week or more. Fieldwork is commonly recognised as one of the most important contributing elements to a complete geological education (Kern and Carpenter 1984a; Kern and Carpenter 1984b; Locke 1989). Field excursions used as an aid to geology teaching vary through a range of fully guided instructional tours to individual mapping projects and a multitude of intermediate combinations. Fieldwork is important because it provides students with the opportunity to be guided in a "real world" situation where natural conditions of scale and imperfections must be considered. The observations and measurements are made in context so that their relevance and relation to other features can be taken into account.

Short excursions for structural geology are usually when students are taught the skills that they will need during field camps. They are also opportunities to show students examples of geological features which have been introduced in the classroom either during lectures or practical classes.

More often than not, field camps have a single purpose, such as the preparation of a geological map. This activity involves identification of rocks, identification of structures and interpretation of their three-dimensional form. Such activities usually involve the implementation by students of the skills that they have learned in the classroom and in the shorter excursions which have preceded the camp. Geological mapping is undoubtedly the most challenging, rigorous and stimulating field-based activity, and its correct use as an adjunct to other modes of geological instruction can be a powerful method for enhancing the learning process (including most importantly the enjoyment and satisfaction of learning), especially at the introductory level (James and Clark 1993).

5.23 Texts and References

In most institutions within this traditional approach (lectures, practicals, and fieldwork) there is usually some attempt to relate the content between the three areas, although there are parts of the discipline that are more naturally taught in the laboratory or field rather than in the lecture theatre. Taking this natural division into account the development of the curriculum has been such that separate theory and practical strands have been developed. This is exemplified by looking at the content and presentation of textbooks which are commonly recommended for such courses. Although there are many books which have been written to give students practical activities to elaborate the theory, they are seldom recommended for student purchase and rarely recommended as the sole purchase. Those recommended treat the theory of structural geology, often using excellent examples, but rarely include practical activities that will give students the chance to integrate theory with ability to learn practical skills. This practice is exacerbated when theory is presented in more or less formal lectures. The lecture room effectively separates the teacher from the students. In the worst situation, the pace of presentation prevents the students from relating the content to anything that they have previously learned or experienced.

5.3 MODIFIED TEACHING ENVIRONMENT

During the past few years there has been an increase in interest in evaluating the effectiveness of teaching in higher education. This has come partly from the need for University teachers to demonstrate their effectiveness and efficiency and partly as a result of the need to maintain academic quality as Australian universities move towards internationalisation and more open access (Ramsden 1992). More pertinently, the modifications to the teaching methods which are central to this study have resulted from the understanding that the incorporation of new technologies, a variety of teaching methodologies, and the implementation of different learning strategies will result in more effective learning.

A combination of factors suggested that traditional teaching methods were not as effective or suitable in the new environment. It is clear that students in the present university classroom are much different to their predecessors. As a result of the greater access to tertiary education there is more variation in ability, experience and academic background (Candy, Crebert et al. 1994). The majority of students in tertiary courses have been brought up with television as the main form of entertainment and are therefore used to a presentation format which involves frequently changing short segments designed to maintain interest.

Close scrutiny of end of subject assessments in the structural geology course indicated that only a small group of students were successfully developing an understanding of the higher order concepts and how they are related one to another. This was most obvious in the more open-ended long response examination questions where students had to recognise and make the relevant links between the various concepts that had been introduced during the teaching of the subject. Although the majority of students were able to successfully complete the subject many did so by rote learning and as a result did not carry the knowledge into subsequent subjects. This observation resulted from the use of pre-tests administered to students before they commenced their third year structural geology subject.

Taking these things into account, the first change that was made to the teaching methods was a modification of the way information was presented. The traditional teaching approach using lectures and practicals to introduce new information, and fieldwork to apply the newly acquired skills, was changed to a more integrated and interactive approach.

Year	Summary of changes	Description of changes	Reason for change
Prior to 1989	Refinement of curriculum and delivery technique		
1989	Use of Powerpoint to prepare masters for OHP transparencies		Higher quality illustrations
1990	Direct-delivery of B&W computer images		Better lecture sequencing, ability to build-up slides and ability to move forward and backward through the lecture reduced cost of modifying lecture illustrations
1991	Minor modifications to slides		
1992	Introduction of colour PP slides Availability of lectures in read only form for revision Introduction of Concept Maps		
1993	Refinement of 1992 materials Introduction of journals		Reflective journals showed students' learning progression
1994	Re-ordering of the topics to start off with concrete concepts Introduction of student activities in lectures		Increase student involvement
1995	More interactive lectures Friday 'lectorials'	Groups of students prepare & present a topic to the rest of the class	Promote deep learning

Table 5.1 Summary of the changes to the teaching of structural geology.

The modifications from the traditional teaching approach described above evolved over a number of years. Table 5.1 summarises the changes. The modifications were made by studying the teaching methodologies and their learning outcomes, making and implementing changes and studying and comparing their effects. Each year during the study two classes were taught, one at the University of Adelaide and one at the University of South Australia, using the same curriculum. This enabled the modification of materials and methodologies from one class to the other within the same year, effectively doubling the rate of change.

As the positive benefits of the changes to most students became more obvious the new methodologies were embraced more enthusiastically. The following section describes the path of this evolution. It is expected that, as has happened so far, each subsequent period of subject evaluation will result in a refinement of the previous methods and each planning session will produce new ideas for activities, demonstrations and delivery strategies. Another factor which has had a significant role in the changes is the rapidly evolving technology, both software and hardware that is becoming available to the modern classroom.

5.31 Introduction of Computer Delivery

Stage 1 Preparation of overhead projection transparencies using presentation software

The initial development and use of software programs to prepare visual material for lecture illustration began following the purchase of an Apple Mac Plus and the Microsoft Powerpoint™ Presentation and image management software. Powerpoint™ was designed to produce professional style overhead projection transparencies (and/or 35mm slides) which may be copied from a high-quality encapsulated postscript black-and-white laser printer output. Powerpoint™ allows the production and mixing of text titles and bulleted or paragraph text with a range of fonts and formats to produce excellent quality transparencies. In-house graphics ranging from simple figures or diagrams to complex tables and graphs, or imported graphic images, may be used to enhance the visual impression of the transparencies. Layout is aided by a significant range of professionally prepared templates which are provided. The program is cheap, simple to learn and rapid to use.

Initially overhead projector transparencies for a series of second and third year undergraduate introductory structural geology lectures were produced. Some of the text for the transparencies was transferred from an earlier DOS system using a file transfer program and thence into Powerpoint™. However, it proved faster in most cases to retype text and reproduce new transparency images for most presentations. The text facilities allowed the complete range of Macintosh fonts and styles (**bold**, *italic*, <u>underline</u> etc), while a sophisticated text ruler provided a range of paragraph alignments and graphic bullets. Of further important benefit to the lectures were the greek symbol fonts which allowed the presentation of complex mathematical algorithms. The graphic drawing tools in the simple Powerpoint™ palette (line, square box/rounded box, circle/ellipse) allowed the preparation of many unsophisticated figures showing for example the range of structures found in most introductory structural texts (Figure 5.1).
For most of the 20-30 lectures (50 minutes each) presented during the teaching of the subject, about 10-15 overhead projector transparencies was found to be sufficient to illustrate individual structural topics. As usual, most lectures were further illustrated with 35mm field photographs together with transparencies photocopied from reference papers. The Powerpoint™ transparencies were produced at some cost. Additional costs included replacement transparencies where errors were found or changes required. The overall inflexibility of the transparency "hard copy" once produced, proved a negative inducement to produce more transparencies or alter those already copied.

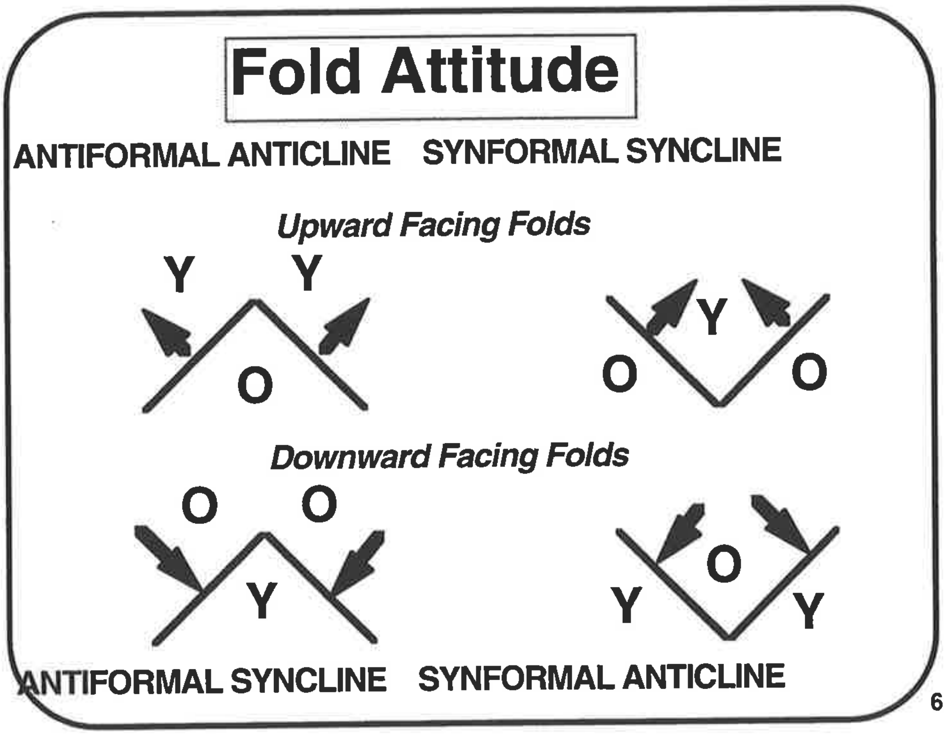


Figure 5.1 An example of a slide master prepared using Powerpoint™.

The transparencies could be coloured for visual effect, altered to provide more in-depth explanations or further annotated, using marker pens, though this effectively reduced the lifetime of each transparency to a single lecture. The need to modify lecture content annually also severely reduced the likely lifetime of each individual transparency. Students were particularly keen on the availability of reduced size photocopies of all of the most pertinent transparencies which could be prepared to a professional standard by the software and distributed as a student hand-out for each lecture (Figure 5.2). Evaluation of teaching surveys showed that students were significantly in favour of the improved quality of transparencies.

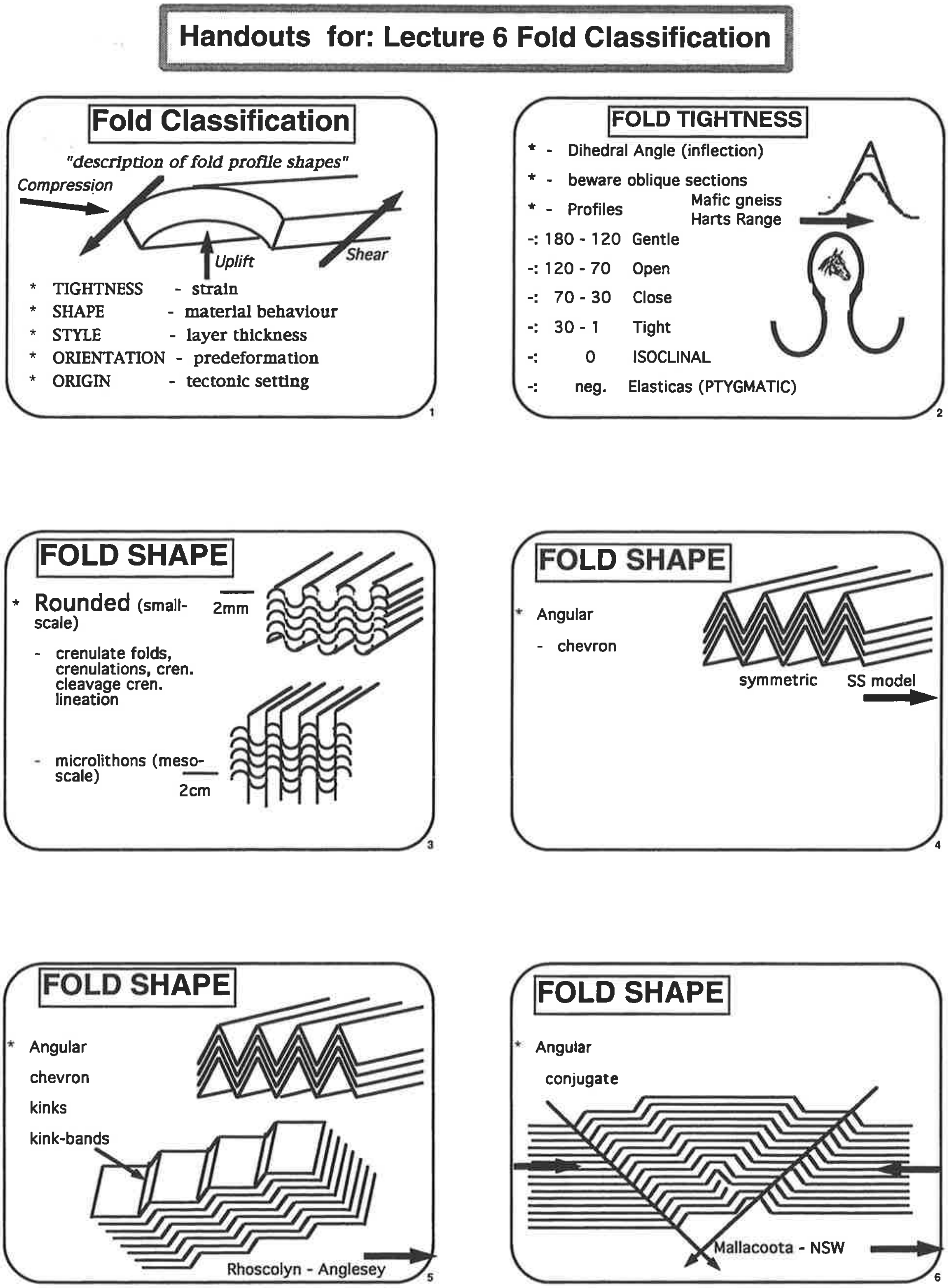


Figure 5.2 An example of the summary screens prepared by Powerpoint which were given to students as a lecture summary.

Stage 2 The direct display of computer generated presentation software images

A major new development in the teaching programme began with the acquisition of grants to purchase a Kodak Datashow, portable computer image projector. Other equipment acquisitions included a faster and more powerful Apple Mac SE30 with 4 Mb RAM (allowing concomitant multiple software use under Multifinder), a 40 Mb. hard disc storage, a flat-bed black and white scanner, and a site licence for Powerpoint™. The inexpensive multiple-copy site licence provided a significant additional advantage in that it allowed access to the program by other staff and by students for the preparation of lecture and seminar material for delivery via microcomputer teaching suites.

The ability to directly project computer images provided a number of significant improvements to the presentation of lectures. These were mostly enabled by the features of portions of the Powerpoint™ program's slide/transparency lecture manipulation facilities, which could not be previously used. Powerpoint™ contains a sophisticated series of ways to store, arrange, rearrange and view slides in each individual computer file, which thus becomes an individual lecture or presentation. Multiple slides can be viewed at a reduced size, in sequential order as either small slide images or as a list of titles. Either way, single images or groups of images can be moved, cut, copied, pasted or deleted via single instructions or keystrokes.

The Powerpoint™ program also allows the sequence of images designed to be displayed in order via single instructions as a manual "slide show" or as an automatic (time-variable) "slide show". All of these features were ideal to produce full length (50 minute) fully illustrated lecture presentations. These features were also ideal for the alteration of the order or sequence of slides in a presentation with great ease and speed. The full sequence of slide images produced in the computer by the program were delivered in the lecture theatre directly to the lecture screen using the Datashow device and a standard overhead projector. The aim of this stage was therefore the elimination of the preparation and presentation of hard-copy overhead transparencies thus reducing the cost of their production, together with an increase in the flexibility of the lecture illustration system.

Each lecture consisting of a series of transparencies was stored as a computer file. Those produced as originals for the preparation of OHP transparencies were re-edited and developed for direct presentation using the Kodak Datashow.

The advantages of this technology

The particularly advantageous features of the lecture preparation and delivery using this procedure included the following points.

a) Sequential display of text and graphic images

Bulletted text may often be used to greatest effect if individual bulleted statements are revealed sequentially to illustrate the development of a time variable concept or a set of increasingly more complex statements. Standard lecturing practice is to use an opaque overlay mask (paper or card) as a simple solution while complex annotated figures may be similarly exposed using complex cut-out opaque paper overlays. The Powerpoint™ program proved to be an ideal vehicle for this type of display using the multiple slide copy facility. Each single complex slide or figure from the previous array was copied typically 6-10 times (taking 1-2 seconds of preparation time). The sequence of identical slides were then progressively edited by removing less and less information from each sequential slide. So for example with bulleted text the first slide contained the first bulleted statement, the second contained the first and second statements and so on. A similar process was carried out for figures containing complex and multiple components (see Figure 5.3). Powerpoint™ also allows all but the last bulletted point to be dimmed, thus enabling the audience to clearly identify the new point. Turning a single complex image into a sequence of slides each containing gradually more information took from 5-10 minutes.

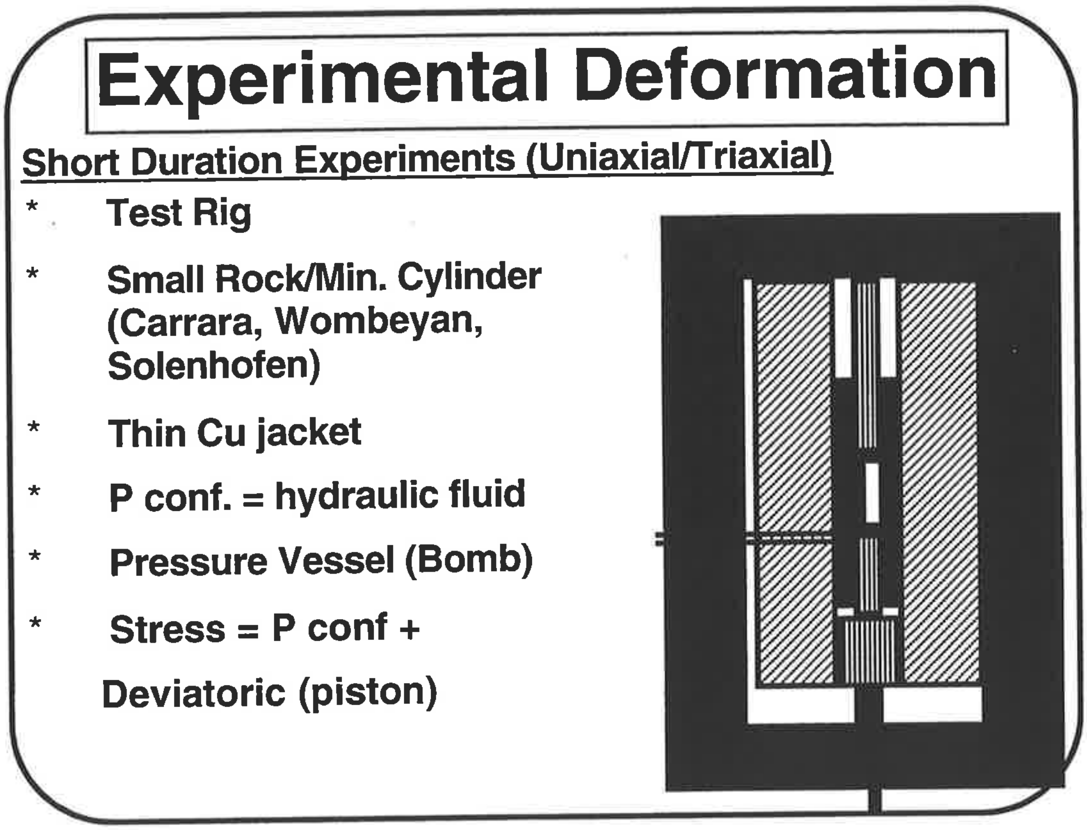


Figure 5.3 An example of a complicated Powerpoint slide which has been built sequentially to show complex multiple components.

b) kinematic modelling of time-dependant processes (animation)

Many scientific (repeatable quantitative-experimental) studies analyse physical parameters which operate on materials over time to change states of matter. Such changes are observed and described in a variety of parametric ways illustrated by models, graphical representations, algorithms etc. Typically, such procedures are illustrated in lectures with single (or occasionally multiple) images revealing one instant in time of the process under study, or as graphs showing how different parameters vary with time. Animation as a display technique, especially where the rate of progress may be varied (slowed, halted, reversed etc), has the ability both to increase audience understanding of how such processes operate in real-time, and also to significantly enhance the ability of the lecturer to demonstrate this in a visually enhanced way.

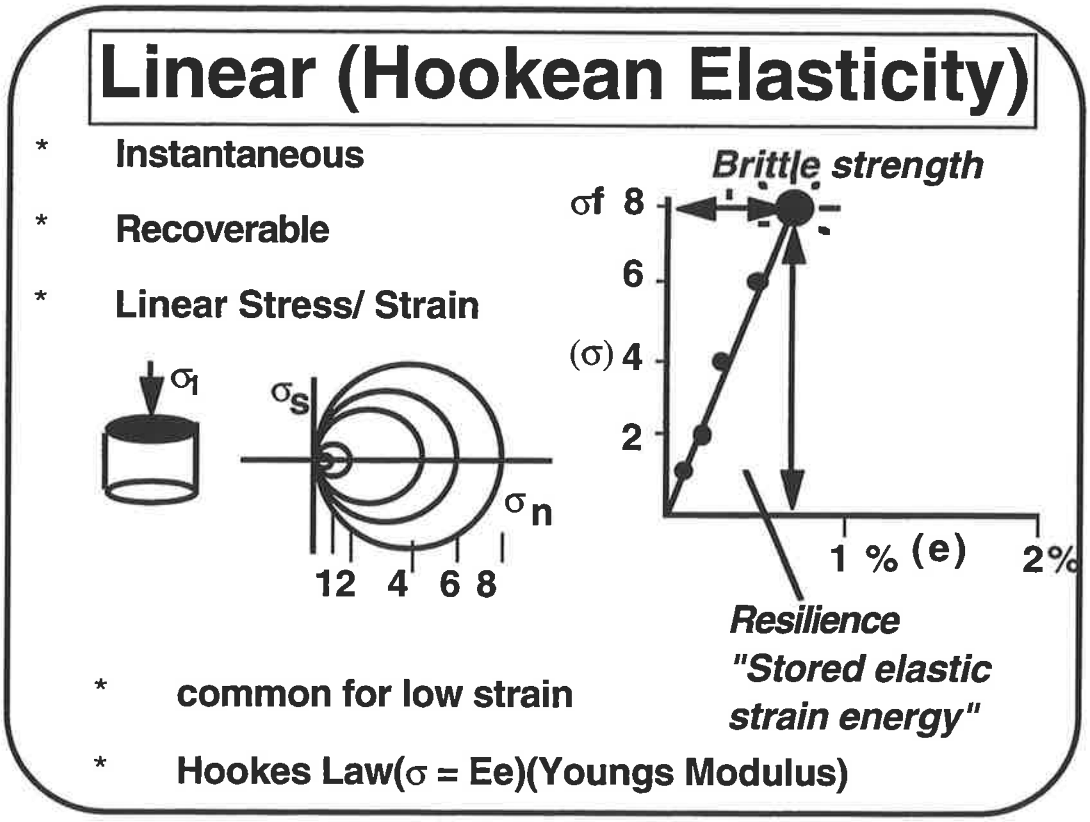


Figure 5.4 An example of a complicated Powerpoint which has been built sequentially to show elastic-brittle behaviour

The Powerpoint™ program with direct display of computer slides was used as a crude animator of a variety of structural processes. As an example, the experimental deformation of an elastic-brittle theoretical rock analog (which is a typical behavioural response of rock at low temperatures and pressures) proved to be an excellent illustrator of the process (Figure 5.4). Such an empirical deformation process may be demonstrated in a number of ways in a lecture environment. A simple 2D figure with a shaded box representing the material, arrows representing deviatoric stresses and lines representing resultant fractures is a simple illustration of sophisticated experiments carried out in high-pressure material testing laboratories. The time-variable response may be indicated by arrows of different size (for increased stress), varying the dimensions of the box (for strain or dilation) and the presence or absence of fractures. The typical rheological analog to the process is a coiled spring stressed with varying weights and showing variable extension or shortening. Quantitative parametric relationships may be displayed on orthogonal graphical axes of stress versus strain magnitudes or for stress variation using the Mohr Circle representation.

Slides to illustrate these processes were prepared as a series showing the progressive behavioural change during the deformation. Thus a complete visual representation of the experiment was carried out by showing the sequence of about 6-8 slides. As will be discussed briefly later, this technique is the forerunner for the further development of more sophisticated animations using more powerful software.

c) Modelling of kinematic processes

Another time-dependant process important in structural geology is the gross incremental change in mechanical state of rocks during ductile deformation. Such variations are observed as changes of position, shape, size and orientation, which are quantitatively specified as translations, distortions or strains, dilations and rotations, respectively (Bjornerud 1991). With the ability to draw simple or complex 3-dimensional models of undeformed rock bodies containing identifiable original features (eg. clasts, fossils, layers or earlier tectonic structures) using the graphic tools available in Powerpoint™, the effects of the different types of deformation on such bodies can be illustrated in real-time visual experiments. All of the different styles of deformation mentioned above are beyond the transformation capabilities of Powerpoint™, but these may alternatively be carried out using other software drawing packages and transferred as graphic images to Powerpoint™ for display.

d) Electronic-file storage and lecture linking

Scientific lectures should ideally stand independently as complete presentations. However, in a series of lectures with a uniform theme, later lectures often depend on concepts and data introduced in earlier lectures. Remembering to bring along overhead transparencies or slides from earlier lectures often leads to weighty manilla folders and slide boxes ready to burst onto the floor of the lecture theatre. The advantages of the electronic storage and retrieval of a whole series of lectures on a single floppy disc reduces the risk of such embarrassing and inefficient occupational hazards.

Using Apple's Multifinder it is further possible not only to open and interrogate earlier presented lectures at will and at random, but also to immediately access other software (eg the drawing program with all of the kinematic transformations just described) for demonstration.

These techniques thus indicate the clear advantages of the direct delivery method in the presentation of text and graphic illustrations in formal lectures. Within each lecture the addition of further slides including introduction, revision, linking, reference, and summary material, has led to the creation of presentations/lectures comprising 70-120+ slides. Each of these Powerpoint™ presentations/lectures, together with 35mm field illustrations, other figures etc. comprised a series of lectures which were delivered to classes of about 50 undergraduate students.

Student responses to the system were excellent. Students commented favourably on all aspects from clarity of the text, to availability of summary handouts of slide images (Figure 5.2). The student comments are described more fully in Chapter 7 where the results of the quantitative evaluation are presented.

The Disadvantages

The main disadvantage of the system used in 1990 was the need to transport and set up the Datashow and computer in a lecture theatre for every lecture. This portability allowed the flexibility to use the system in whichever room was available (or even transport it to other institutions or even interstate). However, risk of damage in transit or theft was a constant concern. Few lecture rooms had permanently installed computer projection facilities, which would have reduced such problems. The black and white image although clear suffered from the lack of colour for visual impact, and the dullness of the image required severely dimmed lecture room lights (conducive to audience drowsiness but conversely not to note taking).

Continued Refinement of Presentation Methods 1992-1995

In 1991 there was only a slight modification to the teaching which involved the refinement of the computer generated images and the addition of some scanned 35mm transparency photographs into the individual lectures. At the completion of the teaching of the subject, student evaluations were either strongly positive or strongly negative, the majority being positive (See Chapter 7 for details). The negative responses suggested that too much information was being transmitted and that students were unable to keep-up with the delivery pace. It was also clear that students had trouble sorting the important from the less important concepts.

The addition of a computer teaching suite in the building during late 1991 allowed complete after-hours availability of the lectures to students. Each set of lecture slides was down-loaded onto the server and was available to students who were encouraged to use the lecture slides for revision, to supplement their lecture notes and to direct their reading. In 1995 the lecture material was available during the week before the lecture was delivered and students were encouraged to read the material prior to the lecture. With the availability of a read only facility in the Powerpoint™ software program students were also able to copy all or parts of the lecture program to view on their own personal computers. Several copies of the lecture series were also made available on disc for student borrowing. Both of these developments were the target of favourable comments in student evaluations.

Another development which improved the quality of presentations was the installation of colour projection equipment in the main lecture theatre used at the University of Adelaide. This enabled the projection of larger and brighter images and also allowed video-clips to be incorporated into the presentations. Later versions of the Powerpoint™ software had improved presentation features including the ability to simulate simple animation and improved layout and drawing capabilities made presentations more attractive and more stimulating.

5.32 Introduction of Concept Maps

In planning for 1992 it was decided that the use of the computer for direct delivery of lectures was worthwhile, and that, to address student concerns about the difficulty in determining the important concepts, concept maps would be used in the teaching.

Objectives.

The objectives of the modified teaching methods adopted were to:

- present new information in a way that relates to knowledge that students already have;
- offer students an alternative to rote learning by more clearly demonstrating the relationships between concepts;
- encourage students to recognise the hierarchy of concepts;
- help students gain an overview of structural geology earlier in their career.

It was decided to introduce the technique of concept-mapping into the teaching of structural geology to help students develop a better understanding of the topic area. It was felt that concept maps would allow students to recognise the major concepts and the links between them and would help them develop a hierarchical knowledge structure which would lead to more meaningful learning and less rote learning, which in turn would promote better application of concepts and skills.

5.33 Developing Understanding

Concept mapping was introduced to promote better understanding. Before describing the way in which concept mapping was incorporated into the teaching it is necessary to describe what is meant by "better understanding". Most people agree that understanding is too complex a concept to define in a single sentence or a simple definition. White and Gunstone (1992) suggest that the 'first step in describing understanding is to sort out the targets we talk about, and see what lies behind understanding of each' (p 3). They specify six targets of understanding and describe the forms of knowledge which underlie each. The six targets are understanding of: concepts; whole disciplines; single elements of knowledge; extensive communications; situations ; and people. Understanding is a function of the number of elements of knowledge that a person has about a target and of the mixture of different types of element and of the pattern of associations that the person perceives among them. Understanding is thus a continuum and it is difficult to say that a person has a complete understanding of a particular topic or to say that one person's understanding is better than another's.

In teaching to improve understanding it is necessary to acknowledge that an important aspect of a person's understanding is the pattern of associations that the person perceives among the different types of elements of knowledge that they possess. This relates to the cognitive and constructivist theories of learning (Ausubel 1968; Wittrock 1974; Anderson 1985; White 1988) described in Chapter 2. Essentially these theories are that *learners construct their own meanings from the knowledge they acquire.* White and Gunstone (1992, p 13) extend this stating:

> *understanding develops as new elements are acquired and linked with the existing pattern of associations between elements of knowledge. Addition of new elements will often stimulate reorganisation of the pattern as the person reflects on the new knowledge and sees how it puts the older knowledge in a different light.*

Ausubel (1978) in the assimilation theory for learning suggests that there are four key considerations: cognitive structure; subsumption; integrative reconciliation and progressive differentiation. Cognitive structure in this sense describes the organisational stability and clarity of knowledge of a particular subject matter field in an individual's mind at any time. The learner's cognitive structure is organised in an hierarchical fashion so that ideas and concepts are held in such a way that broad overall concepts have linked to them several subservient ideas. These in turn have their related subservient ideas and so on. When a learner is presented with a new concept it may be received into the cognitive structure and related to the concepts already there. If there is not a related concept already there, the new concept attaches to nothing and will only be retained for a short time. Ausubel et al (1978) called the relating concept a subsumer and the process of linking new information to pre-existing segments of the cognitive structure is referred to as subsumption.

If a new concept is introduced to a learner and a subsumer for the concept is already in place in the cognitive structure, the new concept will be linked in by the subsumer and is likely to be integrated into the cognitive structure. In other words if new concepts can be related to ideas which the learner already knows, there is more likelihood that the learner will retain the new concepts.

If a new concept is introduced to a learner and a subsumer for the concept is not already in place the new concept will be retained for a short time and then lost, unless additional ideas are subsequently introduced which allow the new concept to be linked in. The process whereby new ideas are related to previously acquired ideas and one, or the other, or both are modified is called integrative reconciliation (Ausubel, Novak et al. 1978). A new incoming idea linked to the cognitive structure by a subsumer will over a period of time fit into the hierarchy of ideas or modify them. This takes place when the learner thinks about the new idea. Progressive differentiation describes the hierarchical arrangement of subject matter in the cognitive structure; the most general concept of a subject will be at the top and the other related concepts will be progressively differentiated into less general concepts down to the very specific concepts.

Thus the process of meaningful learning is facilitated when new material presented by the teacher can be linked into the existing cognitive structure of the students. During the teaching process, as the students mull over a new idea, for example by doing exercises, the new idea may be categorised under a broader overall concept, or may itself be broad enough to organise several subsumers under it. It may be linked under a broad concept and interlinked with several other equal concepts or it may be ranked under a concept and be somewhat independent of other equal concepts. The idea is massaged until it fits into the progressively differentiated structure in the logical place, linked to a broader concept above it and perhaps having several narrower concepts linked below it.

In the initial study of structural geology many new concepts are introduced and their overall relationships with each other can not become apparent until they have all been introduced. What may appear to be the logical sequence for the presentation of new ideas may in fact not take into account what the students already know. Therefore it is important to consider the prior knowledge and experiences of students when determining the order of presentation. Perhaps the initial stages should consist of concrete-empirical experiences that are carefully selected to relate to the abstract idea that the teacher wants the student to grasp at some later stage. Another difficulty with introductory courses is that students can not see the overall framework into which the individual parts (concepts) fit.

With all of these things in mind a new approach to teaching was planned. Planning took place during a number of discussions and, as is outlined in Table 5.1 and is described in the following sections, continued during the preparation and teaching in each subsequent year. The purpose was to encourage meaningful learning by modifying the teaching methods to include the use of concept maps to visually demonstrate the relationships between the concepts which were being introduced. The modifications also involved the continued use of and integration of the computer direct-delivery method and the introduction of pre-testing to determine students' prior knowledge. Other changes which are described later involved more student involvement in lectures and changes to the practical and fieldwork.

5.4 MODIFYING THE TEACHING TO ACHIEVE MEANINGFUL LEARNING

5.41 Presentation of the Unit

From 1991 until 1994 the same subject was taught to science students at the University of Adelaide and separately to teacher education students at the University of South Australia. At Adelaide the lectures were mostly presented by one person (PRJ) and both (PRJ and IFC) were present at practicals and were assisted by demonstrators (post-graduate students). One person (IFC) spent some time in practicals teaching concept mapping and also spent time with individual students (see later) outside of scheduled class time helping them to prepare concept maps from their lecture notes. At the University of South Australia, all aspects of the subject (lectures, practicals and tutorials) were presented by one person (IFC).

5.42 Modifications to the Teaching Procedure

5.421 Pre-testing

Pre-testing was used to determine students' existing knowledge prior to the start of teaching. There was concern that the traditional starting point may have assumed knowledge that the students did not already have. It was also considered likely that some students would have come to the class with misconceptions that needed to be addressed and also that individual differences existed between students' experiences which would be important in choosing a starting point for teaching.

The lecture outlines for the structural geology subject which had been distributed to students in the previous year were used to determine the concepts to be tested in the pre-test. These consisted of summary screens (Figure 5.2) and numbered about 12-15 per lecture. Each set was analysed to determine the pre-requisite knowledge required to understand the new information. A check was also made to ensure that such knowledge was part of the introductory subjects which preceded the subject.

Most of the pre-requisite knowledge needed was terminology, so a simple multiple choice test which included mostly recall questions was designed. Some interpretive items were included (plunging fold block diagrams). The tests were marked and the results were analysed. Items where a large number of students chose the same wrong answer were considered important as it was thought that this would indicate misconceptions which needed to be corrected. By presenting the pre-test to students in the first class, without warning, it was considered that the results would be more likely to reflect students' knowledge, rather than recall. For this reason it was decided to set a pre-test instead of analysing students' results from examinations held at the completion of the introductory course which was initially considered as a way of determining prior knowledge and misconceptions. It was felt that a student's ability to remember (recall) the correct response in end of course exams (Thompson, 1990; Schoenfeld, 1989; Novak & Gowin, 1984; Gunstone and White, 1981) may overshadow lack of understanding and may hide any patterns which would indicate common misconceptions.

The analysis of the pre-test result confirmed the belief that most students were familiar with the terminology but could not always recall correct meaning. The test did not detect any common misconceptions related to structural geology and the results of those questions which required interpretation showed a higher number of incorrect answers.

Consequently it was decided to briefly review appropriate assumed knowledge during the introduction of new concepts and content at the time when it was necessary. In some cases this was done by using demonstrations (see later section, eg. breaking plastic ruler)

For the University of South Australia class the pre-test gave very similar results and it was decided to provide the students with a list of the pre-requisite (assumed) knowledge during the first session of the subject and make it their responsibility to decide whether or not revision was necessary.

5.422 Introduction of concept maps

Although structural geology is included in introductory courses, its treatment in second year involves many new concepts. In an attempt to present these concepts most effectively, concept maps were used as both a teaching tool and a learning tool. As a teaching tool they were constructed by the teacher and presented to students during lectures to introduce new topics, as summaries and to show relationships between parts of the curriculum. As a learning tool students were taught to construct their own concept maps (see later).

A concept map is a way of representing concepts and the organisation of subject matter. Concept maps help students see the subject matter more meaningfully. A concept map is a two-dimensional representation of a discipline or a part of a discipline (Stewart, Van Kirk et al. 1979) that shows the relationships between concepts. This method gives students a much different perspective to the traditional note-taking which is one-dimensional and illustrates no relationships between concepts. The concept map not only identifies the major points of interest (concepts), but also shows the relationships between them in much the same way that a road map shows the links between cities.

Concept maps can also be used to show the hierarchy of concepts. In most cases some concepts are more important than others. These more important concepts tend to be more inclusive than others. Traditionally concept maps have the most inclusive concept at the top and progress down through to the least inclusive, more specific concepts.

The purpose for using concept maps was to achieve meaningful learning rather than rote learning. In the process of meaningful learning, the new knowledge is incorporated into the existing knowledge of the learner. On the other hand, rote learning is characterised as learning in which the information is arbitrarily stored because the learner does not have the relevant concepts required to incorporate the knowledge in any other manner. It is generally accepted that meaningful learning is much more effective and desirable.

5.423 The lectures

Lectures were delivered in a normal lecture room equipped with white-board, 35 mm projector, video-projector and overhead-projector. All lectures were illustrated using direct delivery hardware to project computer generated images as has already been described (James and Clark 1991).

In 1992 concept maps were incorporated into the sets of images presented during most lectures. Lecture summaries were presented at the end of each lecture or at the beginning of the following lecture by developing concept maps; that is the concept maps were developed on the screen by first showing the concepts and then showing the linkages. In some cases the same maps were developed on the white-board to reiterate their content and also to help students learn to develop their own. During lectures, very little instruction was given to students about the construction of concept maps. (Instruction to students was given in the practical sessions.)

During lectures major concepts were highlighted on the screen using a common format and in some cases these concepts were linked in the form of 'mini-concept maps' during the lecture. Hard copies of the mini-concept maps and the summary maps were provided to students as part of the lecture course hand-outs. From 1991-1993 hand-outs were provided to students in sets after each section of the lecture course was completed. This was done because previous experience indicated that hand-outs given prior to lectures often distracted students and reduced the quality of their own notes. In 1994 and 1995 the complete set of lecture summaries was given to students in the first lecture. This was done to give students the opportunity to read the content of a lecture before it was presented. Since a complete set of computer images for the lectures was available to students in the computer suite in both IBM and Apple formats it was felt that students could use this facility to improve their notes. It was also felt that students would be more comfortable participating in demonstrations and activities where note-taking time was reduced if they were provided with summary sheets in advance.

Another major modification to the traditional lecture style was the use of demonstrations during lectures. In as many lectures as possible the presentation was broken by the inclusion of a demonstration which was relevant to the topic. The demonstrations were simple and involved the use of common materials to demonstrate concepts. For example to demonstrate the concept of homogeneity and isotropy the different directional properties were compared by the cutting of celery sticks and melons. In another demonstration, a common clay house brick was used to show the difference between force and stress. The effects of temperature on the way materials deform was demonstrated by using liquid air to cool different kinds of balls, and silicone putty was used to demonstrate the effect of different strain rates. In 1995 demonstrations were still used in lectures but some of the analogue model demonstrations were used in the lectorial sessions which were introduced (see section 5.53 for a descriptions of lectorials).

5.424 The practicals.

Practicals were conducted in the normal way except that time was set aside throughout the course of the subject to introduce the technique of concept mapping and to help students develop this skill so that they could produce their own concept maps. The procedures used followed those of Novak (1990) and are described in detail later in this chapter. There was no compulsion for the students to participate, but they were encouraged to do so. Initially the instructor developed maps for the concepts introduced in lectures.

However as the teaching proceeded the students were encouraged to develop their own concept maps and to choose the concepts to include in them.

5.425 Tutorials

No formal tutorials were scheduled but in 1992, volunteer students were encouraged to meet with me to further develop their skills in constructing concept maps. Meetings took place during the last six of the ten week period that the subject was taught. From 1993 individual instruction became less formal, however individual students were encouraged to seek help whenever they wanted it.

5.43 Teaching Students to Construct Concept Maps

The development of concept mapping skills in students took place in a number of steps: (I) the introduction to the concept map; (ii) use of teacher prepared maps for lecture summaries; (iii) formal teaching of students to construct maps; (iv) jointly developed maps in class; (v) student prepared maps from provided concepts; (vi) student prepared maps from lecture notes. Some of these steps took place at the same time. For example the use of teacher prepared maps for lecture summaries took place from the very first lecture and continued throughout the teaching. In some cases teacher prepared maps were not provided until after the students had completed the exercise of developing their own maps. The concept maps which were prepared were all related to the content of the lecture course although in some practical classes in 1995 students were encouraged to use concept maps to help solve problems which involved application of already learned skills to a new problem.

5.431 Introducing the technique to students

Students were introduced to concept maps in the first practical session. They had already seen a concept map summary of the first lecture and were advised of their use during the introductory lecture. The value of concept mapping as a learning aid/tool was described in the context of meaningful learning and constructivist theory. Concept maps were described as a simple tool for summarising knowledge and showing the relationships between the parts of the subject in a way that was necessary to gain a good overview. At this time students were made aware of the learning objectives of the subject.

The first exercise involved the preparation of a concept map showing the relationship between concepts which were already familiar to the students. Small groups of students were given a large sheet of blank paper and a number of small cards each printed with a concept label. The labels were common concepts from the introductory geology subject (Figure 5.5). They were then guided through the preparation of a concept map using the following instructions which were displayed on the OHP screen:

- *put the cards on the sheet of paper, and arrange them in a way that makes sense to you. Terms you see as related should be kept close together, leaving space to write between the closest cards;*
- *draw lines between the terms that you think are related;*
- *write a phrase on each line which shows the relationship between the two terms (include an arrow to show the direction in which the relationship should be read;* (modified from White and Gunstone, 1992, p17)

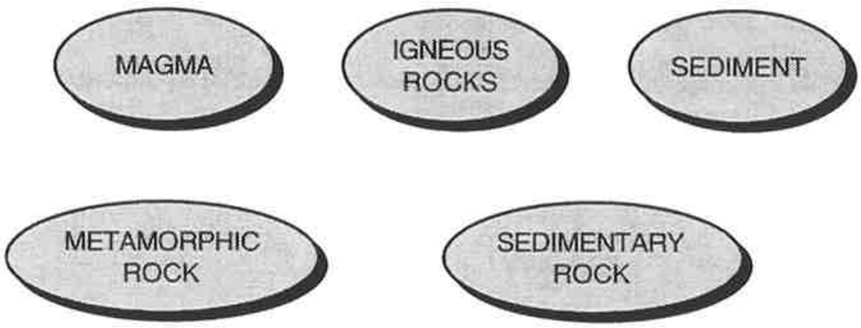


Figure 5. 5 The concept labels that were used in the first preparation of the first concept map

Once the groups were happy with their concept map, one group was chosen to draw their map on the board. The arrangement and the linking phrases were discussed by the class and any missing linkages were suggested. Since the concepts chosen were from a diagram which is part of nearly every introductory text (Figure 5.6), the students were all familiar with the outcome and there was little variation in the individual group results. This set of concepts was deliberately chosen because it was from a form of concept map with which the students were already familiar and for which its usefulness as a summary tool had already been demonstrated.

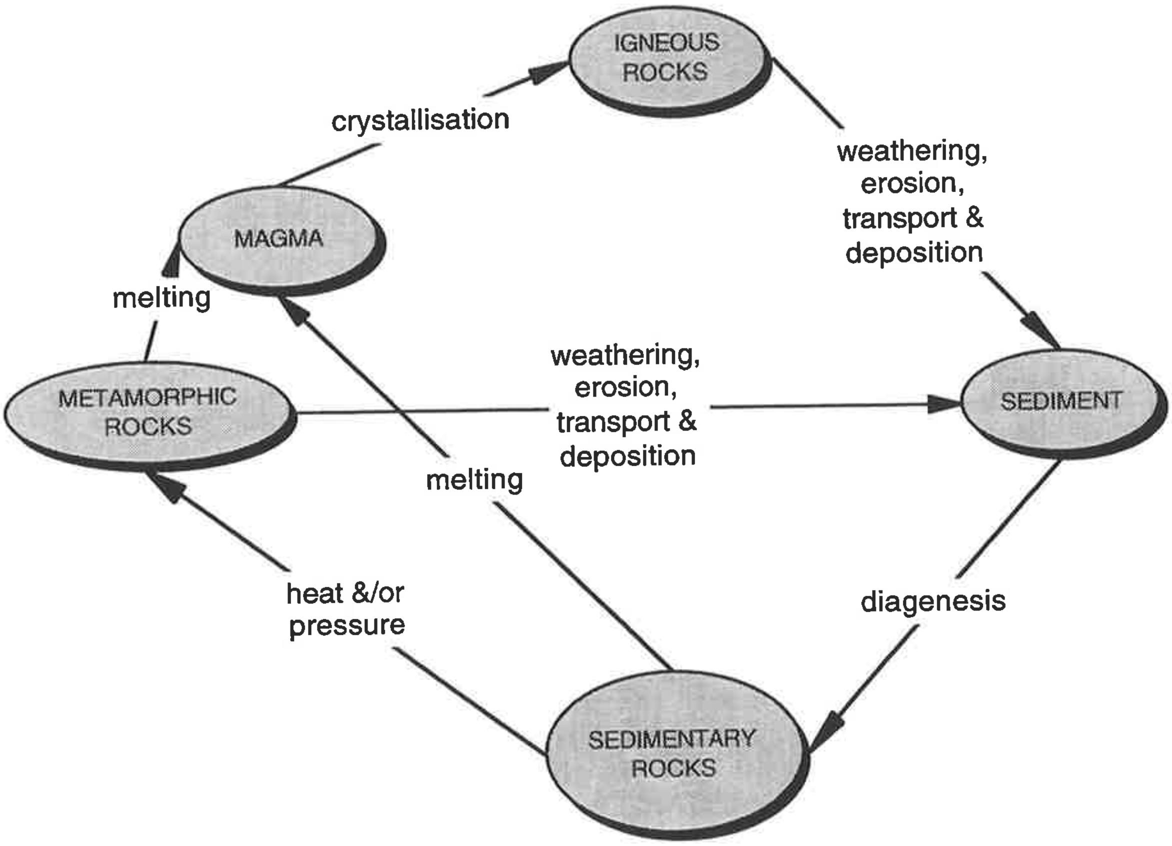


Figure 5. 6 The Rock Cycle: a common concept map found in most introductory geology texts

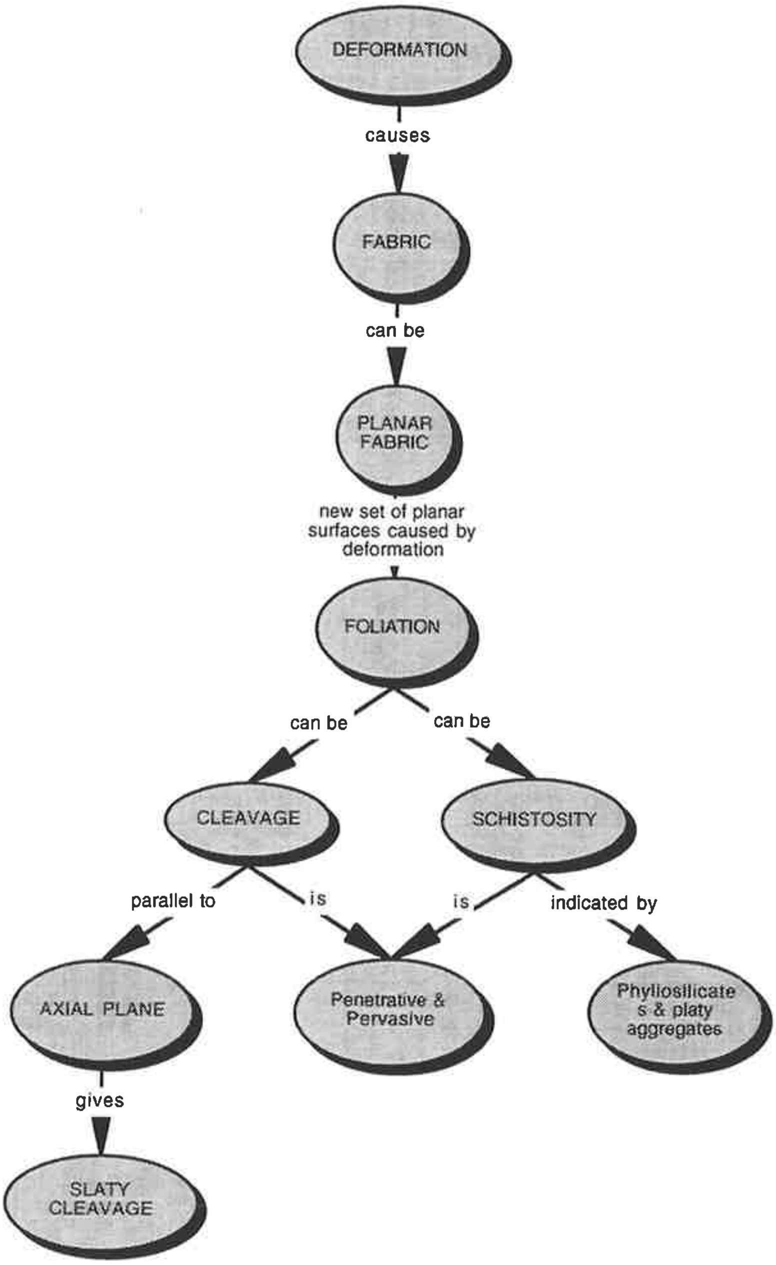
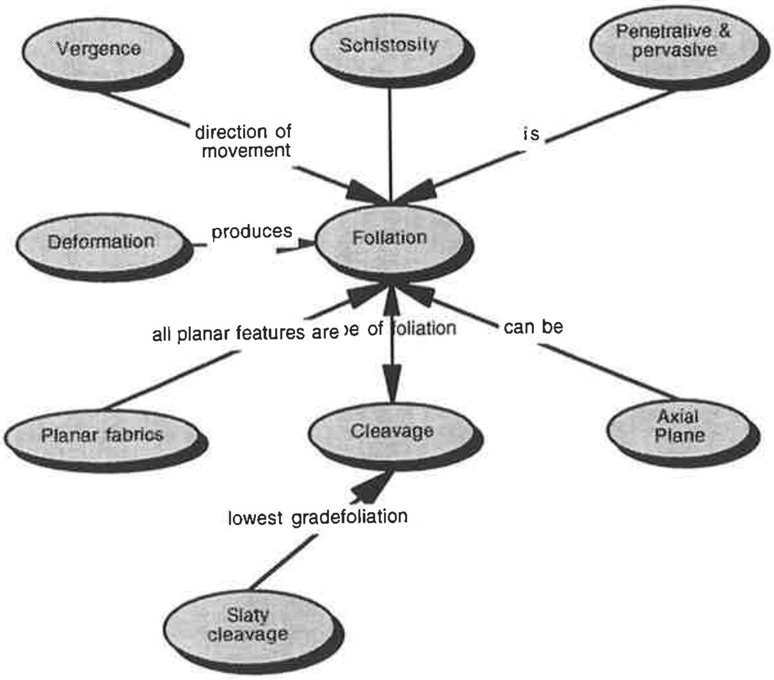


Figure 5.7 Examples of concept maps constructed by students



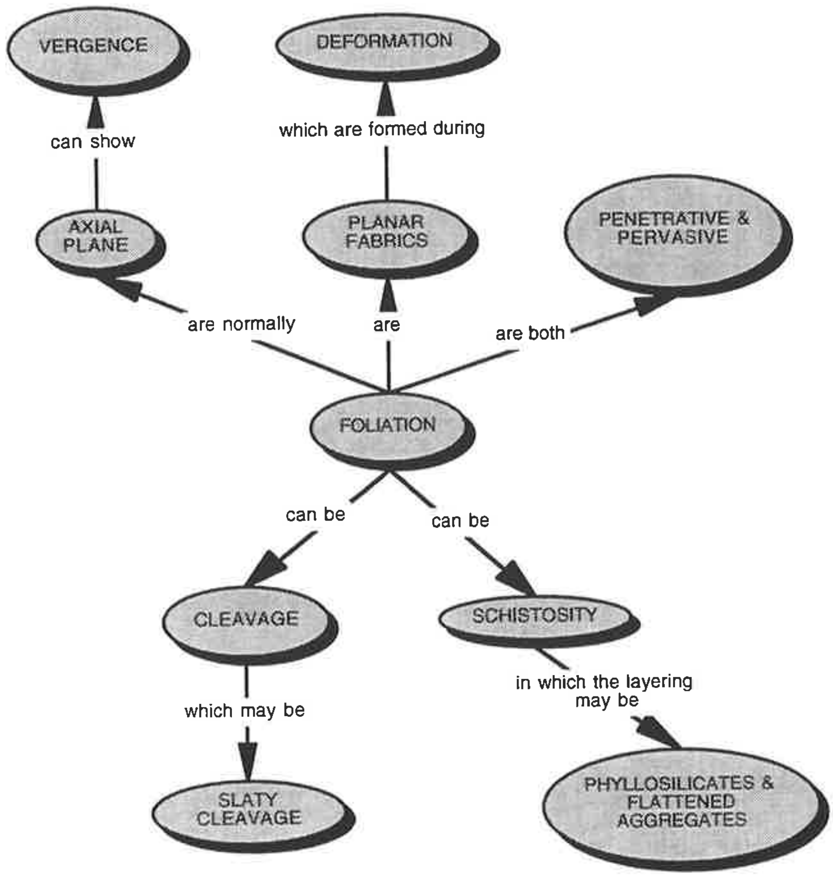


Figure 5.7 (cont) Examples of concept maps constructed by students

During the next two weeks exercises in concept mapping involved groups preparing maps from a list of concepts prepared from the lecture sessions. The list was taken from a glossary of new terms presented with each lecture. In these exercises students worked in pairs or small groups to prepare the maps which were then discussed by the whole class from which a consensus map was prepared. A teacher prepared map was also provided to the students and the differences were noted. It was pointed out that although it is possible to have minor variations in maps, most maps will have a similar ranking of concepts and will have similar linkages. "Expert" maps tend to have more linkages.

The next stage in the development of student concept mapping was the preparation of maps by individuals. These were done as out-of-class exercises, initially from the glossary list of terms. The maps produced varied from very simple maps with few linkages to maps which showed most of the linkages and closely resembled the teacher-drawn map (Figure 5.7). To help students the following list of steps was provided:

Step 1. ***Select*** *the concepts from a test, lecture notes or other source. Do not choose too many concepts, somewhere between 6-20 should be about right. Choose a focus concept.*

Step 2. ***Rank*** *the list of concepts from the most abstract and inclusive to the most concrete and specific. Normally there will be fewer abstract than concrete concepts. Several concepts may share the same level in this ranking.*

Step 3. ***Cluster*** *the concepts according to two criteria: concepts that are of similar rank and concepts that inter-relate closely (each defined in terms of the other for instance).*

Step 4. ***Arrange** the concepts in a two dimensional array analogous to a road map in which the clusters would represent regions and the concepts towns in the regions.*

Step 5. ***Link** related concepts with lines and label each line with a phrase which completes a meaningful statement between the two concepts. Work on one pair of concepts at a time. Concepts can be linked to more than one other concept and it is possible to form closed cells.* (Ault 1985, p520).

An example of the implementation of these steps is given in the following sequence which shows the development of a concept map from a lecture on rock fabrics.

Step 1 ***Select***

Fabric, planar, linear, creep, stress on rocks, isotropic, anisotropic, foliation, lineation.

Focus concept = fabric

Step 2 ***Rank***

Fabric

isotropic, anisotropic

planar, linear, foliation, lineation, stress on rocks, creep

Step 3 Cluster

Fabric

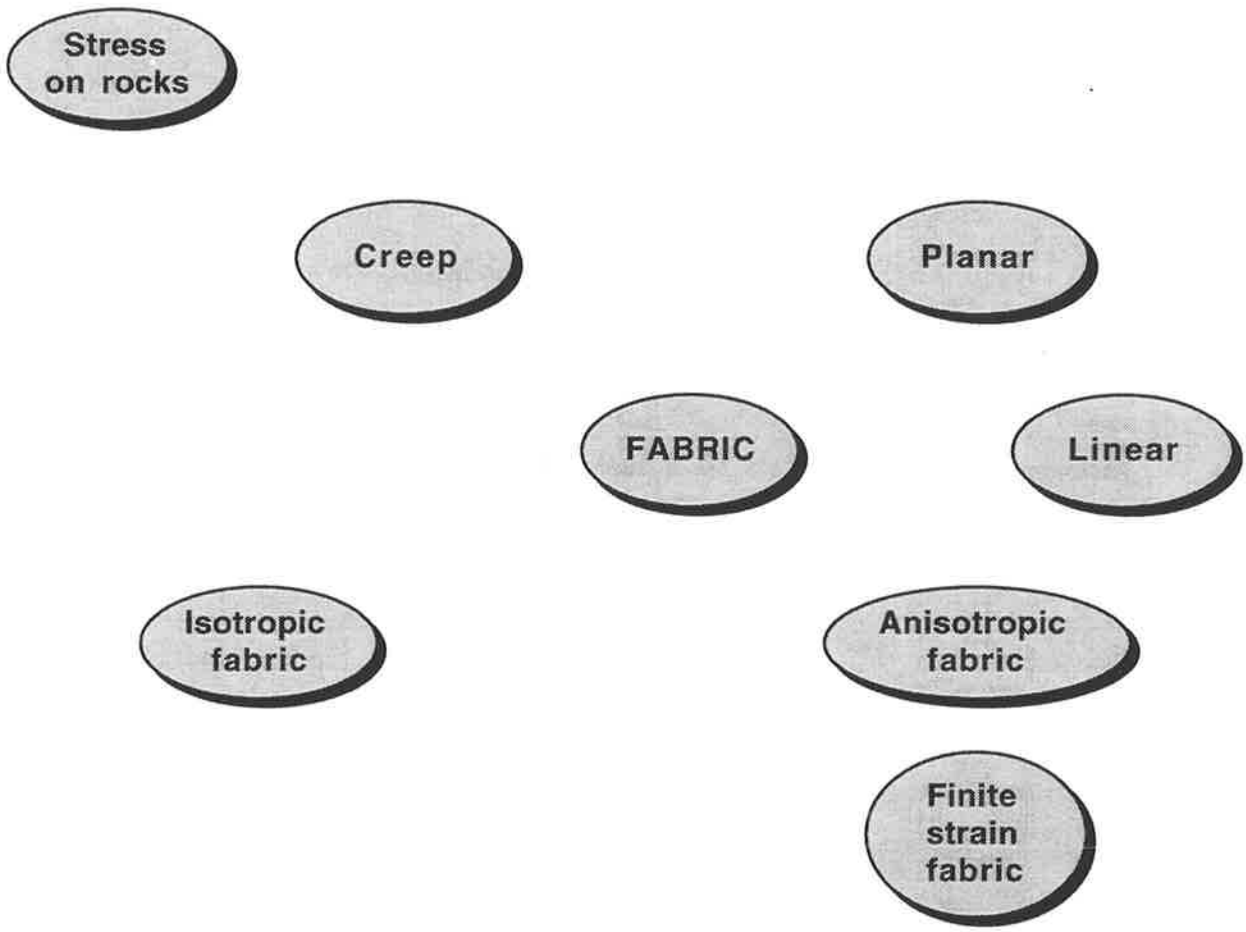
isotropic, anisotropic

planar, linear

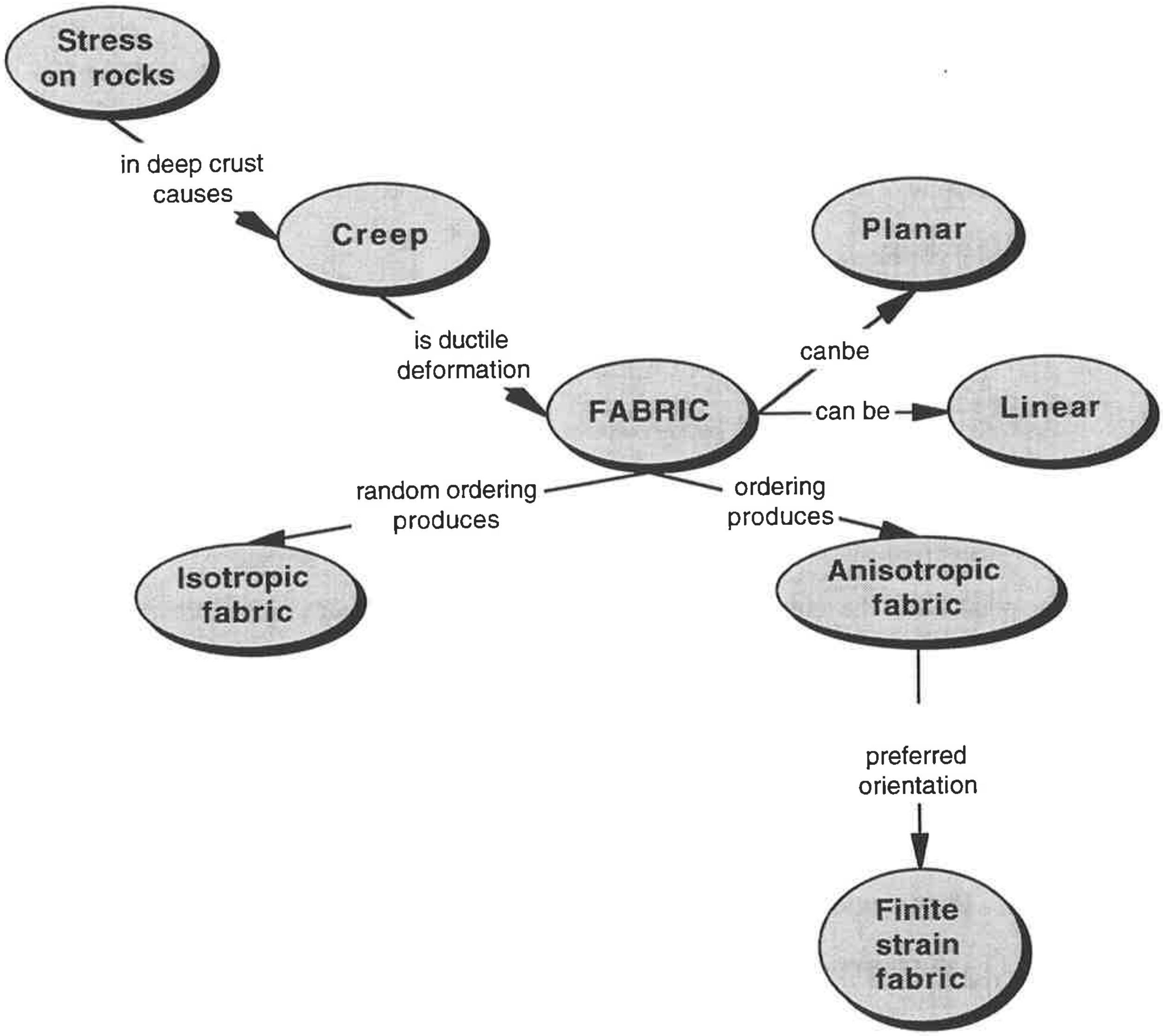
foliation, lineation

stress on rocks, creep

Step 4 ***Arrange***



Step 5 ***Link***



After this stage no more formal instruction in the construction of concept maps was given, however students were encouraged to continue using them to summarise their understanding of each lecture. Most lecture presentations included at least one summary map and summary maps were completed as class exercises during practical classes to show the overall relationships between lectures within each segment of the subject and between segments. Students were also encouraged to consult with the staff if they wanted help to construct summary maps or specific maps.

In each year and in each group of students (University of Adelaide & University of South Australia), some students sought assistance and conscientiously continued to compile concept maps. No attempt was made in this research to draw any quantitative conclusions about the possible relationships that existed between those students who persisted with concept mapping and overall success in the subject. However there is some comment in the student reflective journals related to this which will be reported and discussed later.

5.5 CONCEPT MAPS IN COURSE PLANNING

As well as using concept maps to promote more meaningful learning in students, concept maps were used to plan the curriculum, especially the sequence of topic presentations. The use of concept maps for this purpose was not planned but one which evolved during the planning of the content and while choosing the best sequence for the presentation of the chosen topics. During this process, concept maps were developed in three different environments: from pre-existing lecture content outlines; during discussions between the two lecturers; and during lecture presentations as a summary.

5.51 Preparation of Concept Maps

5.511 Using pre-existing lecture content outlines

In 1992, when it was decided to incorporate concept maps into the presentation of the lectures, it was necessary to develop a set of concept maps that represented the topics to be covered. The source of the concepts to be incorporated into the maps for this phase was pre-existing lecture outlines. At this time, the lecture course had been presented several times before using the Powerpoint™ constructed images, so for each lecture, a comprehensive set of hard copy lecture summary hand-outs was available as well as the complete set of images used in the lecture.

For each lecture it was possible to prepare a relatively simple concept map which was used as the basis for the concept maps which were eventually incorporated into the lecture and used with students in the teaching. It was also possible to develop concept maps which showed the links between consecutive lectures and others which provided a summary of the major topics. It was this latter type of map which was developed to give students an overview of the subject.

5.512 Using discussions between experts

The maps which had been prepared from lecture outlines were used as the basis for the concept maps which were incorporated into the lectures and used with students in the teaching. The modification of these maps was done during discussions between the two lecturers involved. Modifications occurred to both overall layout and to the specific content. Changes to the specific content involved inclusion and deletion of concepts and changes to the linking phrases. Changes to the layout involved re-ordering and re-arranging the hierarchy and addition of extra links and in some cases deletion of links. Although the modifications were mostly minor, the need for modification indicated that it was not always possible to interpret the desired meaning and emphasis from the lecture hand-outs alone. This implies that if students were to use only these materials alone without interaction with the lecturer, they would in all likelihood mis-interpret emphasis and relationships. The incorporation of concept maps into the images provided to students goes some way towards showing the desired emphasis and relationships.

5.513 During lecture presentations

The maps which were developed as a result of the processes described in sections 5.51 and 5.52 were incorporated into the lecture presentations in 1992. During the lectures I constructed another set of concept maps which represented my interpretation of the desired relationships between the concepts presented and the relative importance of concepts. Relative importance of concepts was determined by presence or absence in a concept map and position in the hierarchical structure of the map.

When these maps were compared to those constructed using the processes described in sections 5.51 and 5.52 they were closer to those prepared using the method described in 5.52. There were, however, differences which reflected the emphasis given by the lecturer during the presentation. The concept maps prepared during the lecture were the ones which were most acceptable to the lecturer and were the ones incorporated into the subsequent teaching, and the ones which guided the planning of subsequent years.

5.52 Outcomes of Preparing Concept Maps During Subject Planning

The two-dimensional nature of concept maps makes them especially useful in curriculum planning. Fairly abstract ideas or inclusive generalisations are placed above subordinate ideas. Concepts are listed vertically according to their level of generality within the particular conceptual system. This arrangement provides a visual representation of the relationship between the different parts of the subject and helps determine the best sequence for its presentation. These diagrams are also helpful for students who can use them to develop their own concept organisation (Moreira 1979). Students who have been taught by this method report that the technique is very helpful (Cliburn 1986).

5.521 Topic sequence

An apparently logical sequence for the presentation of topics in this subject was changed as the result of this use of concept maps. The subject at second year level consists of two major parts: the theory and application of continuum mechanics to the behaviour of materials; and classical descriptive or morphological structural geology. Continuum mechanics describes the way in which rocks respond to applied forces and explains the variation in deformation features which result from differences in rock properties and the environment in which the processes are taking place. Descriptive structural geology describes the outcomes of the deformation processes.

It seems logical, therefore, to start the subject by teaching continuum mechanics and to conclude by describing the outcomes. However, when concept maps were developed for the individual parts of the subject it became apparent that the students did not have the existing conceptual framework into which they could incorporate the new continuum mechanics knowledge. Most students studying structural geology at this level do not have the background in mathematics and mechanics to handle a detailed continuum mechanics treatment of the subject. When this situation occurs the new knowledge is more likely to be forgotten after a short time. Cognitive research clearly shows that young people can learn most readily about things that are tangible and readily accessible to their senses. With experience, they grow in their ability to understand abstract concepts, these skills develop slowly however and the dependence of most people on concrete examples of new ideas persists throughout life (Project 2061 1989).

As a result of these observations the sequence of topics was changed so that the first section to be treated was the descriptive structural geology section and the more abstract rock mechanics section was treated last. Twiss and Moores (1992) in the preface to their text support this approach:

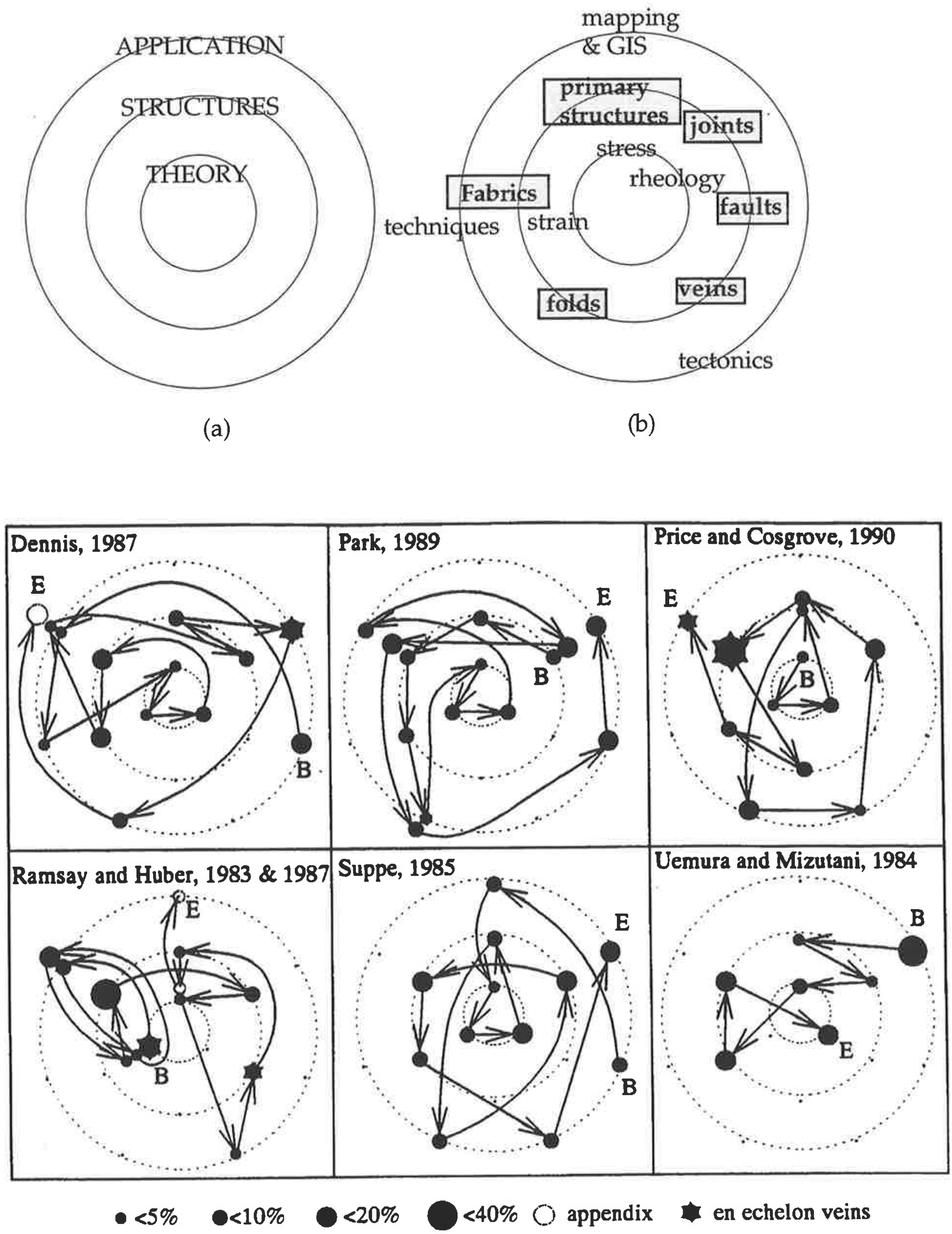
> *As a result of many years of teaching this material (structural geology at an introductory level) we have adopted a somewhat novel organisation for the book. Our aim is to introduce observations about the Earth first, followed by the relevant mechanics and experimental results that are needed to understand the observations. Thus we introduce the concepts of stress and fracture mechanics only after we have described fractures and faults as they are observed in the Earth....the relevance of... [the theory] is then clear, and its application to understanding structures rests on an established foundation of knowledge about the Earth.*

The new and the old topic sequences for the subject are shown in Table 5.2 and are compared using a concentric topic level diagram (Smith 1992). In this study Smith clearly showed that the approach taken by most common texts in structural geology is to describe the theoretical concepts first and to treat the more traditional descriptive topics later even though they are much more tangible to students. This is shown diagrammatically in Figures 5.8.

Smith (1992) suggests that it is possible to represent topics in structural geology by three concentric levels with the most abstract at the centre and the most concrete as the outer ring (Figure 5.8b). The most abstract topics in his scheme are stress, strain and rheology . These equate to the continuum mechanics section of the second year course described here. The more concrete ideas relate to the geological structures themselves. These are shown on the middle concentric ring in Figure 5.8b and the application and integration ideas are shown on the outermost ring.

Smith uses these diagrams to plot the sequence of topics as they are treated in common texts (Figure 5.8c). Dennis (1987), Price and Cosgrove (1990) and Ramsay and Huber (1987), start in the most abstract area and do not treat the more concrete ideas until the theoretical basis has been laid. Suppe (1985) starts with application but then moves straight to abstract theory and Uemura and Mizutani (1984) take a more haphazard path starting with application and ending with the abstract. Only Park (1989) completes the concrete ideas before visiting the abstract theory. It can be seen that there is no consistent starting position but the majority of commonly used texts treat the abstract theoretical

Figure 5.8 (next Page) (a) Concentric levels of topics in Structural Geology. (b) Concentric base-map of structural geology topics. (c) Diagrams showing the sequence of topics from beginning (B) to end (E) for six structural geology texts (after Smith, 1992).


APPLICATION
STRUCTURES
THEORY
(a)
mapping & GIS
primary structures
joints
stress
rheology
Fabrics
faults
techniques
strain
folds
veins
tectonics
(b)
Dennis, 1987
Park, 1989
Price and Cosgrove, 1990
Ramsay and Huber, 1983 & 1987
Suppe, 1985
Uemura and Mizutani, 1984
E
B
<5%
<10%
<20%
<40%
appendix
en echelon veins

(c)

basis for rock deformation before they describe the resulting structures . Although the sequence that should be used for teaching a subject does not necessarily follow the order of topics in a text it is more convenient for students if it does.

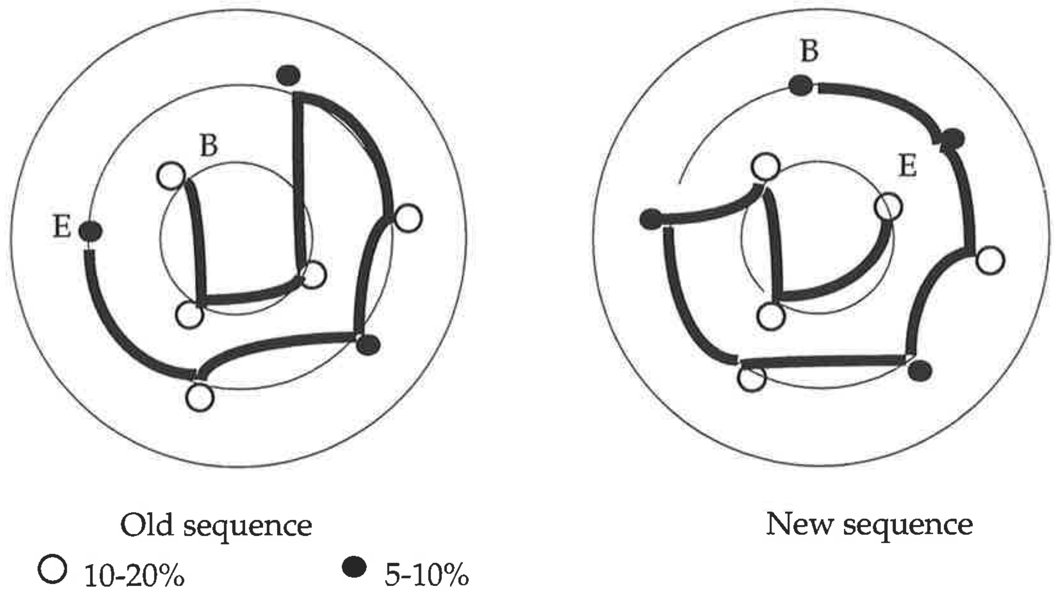


Figure 5.9. Diagrams comparing the new with the old topic sequences for the subject structural geology. The positions on the "map" are those named on Figure 5.8(b). Percentages shown are the amount of time spent on each topic.

Figure 5.9 uses Smith's diagram as a base to compare the old and the new topic sequences for the introductory structural geology subject. In the new sequence the first topic is Joints. As well as being familiar with this topic from the introductory course, students recognise that joints are a common structure found in most rocks. Joints are part of the larger topic, brittle deformation. The phenomenon of materials breaking when they are subjected to large forces is relatively familiar to most people. To reinforce this, an interactive activity of brittle behaviour is part of the first session (breaking a plastic ruler). The purpose is to start with something familiar. From this activity the first simple concept map is constructed using descriptive terms provided by the class. This clearly links the new information to the ideas which the students already have. The development of the subject then proceeds using concept maps to show the way in which each new piece of information is linked to that which has come before.

5.522 Concept overload

Another outcome of using concept maps during the planning of the subject has been the reduction in the overall number of concepts which are introduced at any one time and a reduction in the amount of detail that students are expected to retain. Ideas and thinking skills are emphasised at the expense of specialised vocabulary and memorised procedures such as mathematical proofs. Sets of ideas are chosen that not only make satisfying sense in relation to students' prior experience, but which also provide a lasting foundation for learning more. Despite the overall reduction in detail, students do not exit the subject any less competent in structural geology than students of previous years. In fact they are more likely to retain the knowledge that they have acquired and be better prepared for lifelong learning.

Support for the rationale behind these changes can be found in the NBEET Report on *Developing Lifelong Learners through Undergraduate Education* (Candy, 1994) which lists 'overloading the curriculum' and 'imposing too much detail at too advanced a level' as two kinds of problem with undergraduate curricula. There is a temptation to load more and more into the curriculum in the belief that it will adequately prepare graduates to practise, and to maintain currency. In fact, heavily loaded curricula often leave students with a fragmented and disjointed view of the field rather than an understanding of the essentials.

5.6 OTHER TEACHING INNOVATIONS

In addition to the use of concept maps and multi-media presentations, the teaching methods were modified in other ways. The traditional lectures were replaced by more interactive sessions which included demonstrations and activities which involved student participation. Traditional practical classes were changed to more actively engage students and the important fieldwork component of structural geology was also varied with the introduction of a grid-mapping exercise on a small area of totally exposed, highly deformed rocks. The grid-mapping exercise was introduced to engage students more actively in the mapping exercise in a way that they could quickly see the results of their mapping.

5.61 Demonstrations and Interactive Lectures

Almost every lecture included some kind of demonstration or activity. There were two principal reasons for these. Firstly, many of the concepts that were being introduced were abstract, but could be easily explained by the use of analogue models. Secondly, the demonstrations were used to break the lecture to restore the concentration of the students (Gibbs, Habeshaw et al. 1984). The methods used varied from demonstrations performed by the lecturer to activities which involved participation of the whole class.

The process of interactive lectures began in the second lecture with an activity which involved the whole class. The lecturer asked the students to carefully observe while a plastic ruler was slowly bent and broken. The students were asked to write on a card three words which described what they observed during the process. The cards were then collected and the words were listed on the board. The list of words was then used to compile a simple concept map which related the various concepts of deformation involved in the breaking of the ruler. This concept map was referred to at various times throughout the semester as each new concept was introduced.

Some of the activities involved simple demonstrations which were used to explain the behaviour or properties of rocks by using common materials as analogues. For example the variation in directional properties of materials was demonstrated using different kinds of fruit and vegetables and wooden blocks. The relationship between force and stress was demonstrated by showing the difference in stress on the faces of a common clay house brick. This was then related to the impression made on floor surfaces by stiletto heels compared with broader heels.

A banana was used in a demonstration which involved the whole class. Each student was given a banana and was asked to carefully observe what happened when compressional and extensional forces were applied.

The demonstrations were simple and always involved the use of common materials to demonstrate concepts. For example to demonstrate the concept of homogeneity and isotropy, fruit and vegetables were used. In another demonstration liquid air was used to show the effects of temperature on the way materials deform. Different kinds of balls, such as tennis balls and golf balls, were cooled by immersion in the liquid air making their behaviour brittle rather than elastic. Silicone putty was used to demonstrate the effect of different strain rates and the phenomenon of creep. In 1995 demonstrations were still used in lectures but some of the analogue model demonstrations were used in the lectorial sessions which were introduced (see section 5.63 for a descriptions of lectorials).

5.62 Rock Descriptions

Observation and description of rock structures, textures, and fabrics are important skills that geology students should acquire. Usually attention to these skills is left to petrology subjects where the emphasis is often more on the petrological character of the rock than the overall features including structural features. One of the teaching modifications which was introduced to the practical component of the second year structural geology subject was the use of rock descriptions to encourage students to more closely observe features of rocks and to give students practice in recording their observations. At the beginning of each practical session each student was given a hand specimen of a rock and asked to describe it with the aid of a detailed three dimensional sketch. After about 15-20 minutes their descriptions were collected for marking and the instructor demonstrated a full description on the board. Students were expected to include in their description details of the mineralogy, texture and fabric of the rock. The first rock used was a relatively simple quartz sandstone with a heavy mineral delineated cross-bedding sedimentary structure. As the semester progressed the rocks became more complicated and an attempt was made to choose rocks which exhibited the structures being described in the lectures.

Thus during the first part of the semester rocks showing brittle deformation features were used and rocks showing foliations and lineations were used later when ductile structures were being treated in the lecture program.

These exercises were also used to introduce the use of descriptive terminology (S_0, S_1, S_2, etc. for foliations and L_1, L_2, etc. for lineations).

In 1995 the procedure for the rock description exercise at the beginning of each practical was changed. Prior to 1995 students carried-out the exercise individually and their effort was marked and counted towards assessment. In 1995 the students were encouraged to work together in developing their individual records. This change was made to try to reduce some of the apprehension which previous year groups had for the exercise (see "Analysis of Qualitative Results' in Chapter 7). Each student was still required to make an individual description in the same way as in previous years, but these were not collected and marked for assessment.

5.63 Lectorials

Lectorials were introduced in 1995. They were an extension of the interactive lecture in which the students worked in groups to prepare a presentation to the rest of the class. The time-slot used was the last (third) lecture time of the week which fell at noon on Friday: not a particularly good time for introducing new material in a traditional lecture session. The rationale for the lectorials was partly to overcome the disadvantage of the time-slot, but mostly to try to make the students become more involved in their own learning.

The schedule for each week was arranged so that the new material to be introduced in the lectorial session was that which would in previous years have involved a demonstration. The lecture material was prepared in the same way using the computer, was described in the summary hand-out and was also put onto the computer network. Students were encouraged to view the lecture images prior to the lectorial session.

Each lectorial involved the use of materials for a demonstration. Students worked in groups of 4 or 5 and were set the task of using the materials to demonstrate a new concept. For example in one of the lectorial sessions one group of students was set the task of explaining how platy minerals align to produce a foliation. They were given a block of cream cheese and some round, flat cracker biscuits and were referred to the lecture hand-out booklet which contained a summary of the relevant computer screen images. Most of the students would have viewed the entire sequence of images on a computer in the network prior to this lectorial. The screen images are shown in Figure 5.10. At the same time the other groups in the class were each given a block of cream cheese and some round flat cracker biscuits or some pretzels and asked to explain other aspects of rock fabric development. After about twenty minutes each group in turn presented their demonstration to the rest of the class.

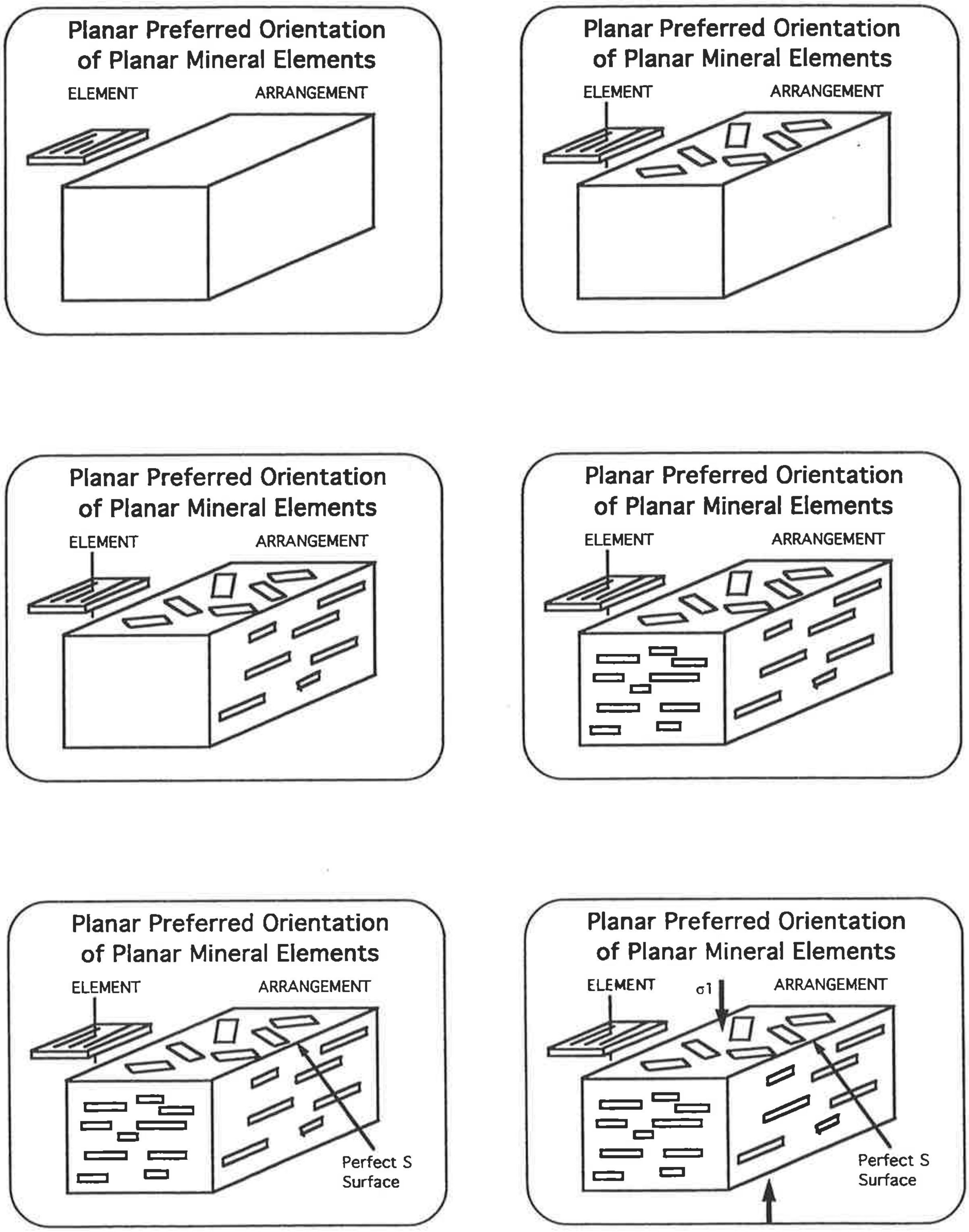


Figure 5.10 An example of a hand-out page prepared for students using powerpoint

5.64 Grid Mapping

The use of grid mapping was introduced into the fieldwork component to actively engage students at an early stage. It was felt that by enabling students to rapidly achieve a product they would be more likely to see the relevance of the mapping process and be able to see the relationship to classroom exercises.

This innovation involves the use of grid sketching to aid teaching geological mapping in an area of complex polydeformation. The method was developed initially to introduce to beginning students the skills involved in constructing geological maps. Fieldwork is commonly recognised as one of the most important contributing elements to a complete geological education (Kern and Carpenter 1984a; Kern and Carpenter 1984b; Locke 1989). Field excursions used as an aid to geology teaching vary through a range of fully guided instructional tours to individual mapping projects and a multitude of intermediate combinations. Geological mapping is undoubtedly the most challenging, rigorous and stimulating field-based activity, and its correct use as an adjunct to other modes of geological instruction can be a powerful method of enhancing the learning process (including most importantly the enjoyment and satisfaction of learning), especially at the introductory level.

There are many texts available outlining the variety of field techniques which need to be mastered in learning geological mapping (Simpson 1977; Barnes 1981; Compton 1985; Lisle 1988). Although many of these texts refer to "large scale mapping" as an essential adjunct to geological interpretation of a field area, most provide only the briefest comment on the technique of detailed mapping or its application as a learning instructional tool.

Ahmed and Almond(1983) indicate that, contrary to the popular opinion of many students, large scale mapping (up to scales of 1:200 for "very detailed mapping in and around active mines"), is less difficult than small-scale reconnaissance mapping. They also stress the importance of field sketches as an adjunct to photographs of structural and lithological complexity stating that accurate sketches are more valuable than any but the best photographs, as drawing encourages the observer to look at the rocks carefully. Moseley (1981) also supports the idea that detailed surveys are often required in areas of metamorphic rocks which usually include structurally complex areas and McClay (1987) mentions baseline, grid and planetable mapping as essential in establishing detailed relationships in one outcrop and to illustrate "key structural relationships".

Few publications, however, describe in detail a method of grid mapping or sketching, or especially how such a technique can be used as an aid to geology teaching. A method of rough grid mapping for particularly large and complex outcrops is described by Compton (1985 p.33), who also emphasises the need to keep the scaled drawing as simple as possible, so that important features will stand out clearly. Barnes (1981, p48) also briefly describes a method of producing a sketch map of an exposure in detail by the construction of a pegged-out orthogonal grid of ropes or tapes, with field data plotted on squared (graph) paper by estimation.

Therefore, although detailed grid mapping of well exposed terrains on a variety of scales is very well known and cited as a standard mapping tool and as an aid to more conventional geological mapping techniques (Hobbs, Means et al. 1976; McClay 1987), it has not received the thorough investigation and recognition it deserves as a basic geological learning method.

The method which has been developed is an extension of this technique and has been used to assist the teaching of mapping skills to introductory geoscience students as well as a method of introducing senior students to the complexities of areas that have undergone multiple periods of deformation. Over many years of introducing students to geological mapping, it has been found that:

a) students invariably take a considerable time to gain sufficient confidence to "put (mapping) pen to paper" as they are introduced to the rigour of producing a geological map from a blank sheet of paper, topographic base map or aerial photograph, and

b) once even the earliest mapping technique has been learned, students will tend to resist changing that technique even if it is not correct or sloppy ("bad habits die hard").

This method eases the introduction of geological mapping because students can produce an accurate, detailed sketch map of a very small area of complex geology in a couple of hours. It has proved to be an ideal way to bring students to accept that they are able to succeed in the often difficult task of producing their first geological map. With senior students it is an ideal way to introduce the complexities of areas that have undergone multiple periods of deformation. It also, as a complementary reward, teaches valuable geological principles and develops in students an appreciation that fieldwork is the basis of most geological study.

To make best use of the technique there are a number of requirements which appear to be important for success. The area chosen must be fully (100%) or almost fully exposed. As each eventual mapping area is no more than 3 metres by 3 metres, it is not a common difficulty to find appropriate areas. Essentially flat, horizontal and clean rock sheets are ideal for both marking out of the grid and for mapping. The technique involves a combination of form surface (Hobbs et al, 1976, p.366) and lithostratigraphic mapping/sketching and has been used with undergraduate students from the Universities of South Australia and Adelaide (first and third year levels) and also on senior school students in their final year of secondary school (see later Student Evaluation).

5.641 Method

To retain the interest and enthusiasm of the students the mapping exercise was designed to take between 60-90 minutes depending on prevailing weather conditions and the complexity of the outcrop. Students worked in small groups and produced their own individual sketch map. Given the small size of the area the maximum number of students that could fit comfortably around the area was between 5 and 7. In most cases the group size was more than this so it was necessary to lay out more than one grid square. Initially the grid was measured using tape measures and a compass and marked with chalk, however this is quite consuming and does not always result in the selection of the best area for the map. An alternative method was developed which made use of a 3 metre by 3 metre grid made out of nylon chord with rigid plastic tubing making each of the outer right angle corners. This aid made marking-out of the grid for mapping much quicker and also made it possible to easily adjust the position of the grid to cover the most appropriate features of the outcrop. Once selected the area is marked-out with chalk lines.

Once the grid was set out the complexity of the geology revealed in the outcrop was introduced to the group by outlining the variety of lithologies, fabrics, structures, intrusives etc. The instructor then demonstrated a preferred method of accurately sketching the area within the central square metre onto a sheet of graph paper.

It has been found that a scale of 1:20 is a convenient one and makes it possible to compile a sketch map of the gridded area on a sheet of A4 graph paper. This scale allows the representation of geological features (beds, layers, veins etc) down to 2-4 cm on the ground (1-2 mm on the map). A discussion with the students of map scales and the relationships between *ratio scales* and *graphic scales* was carried out at this time, firstly as an introduction to an often difficult concept, and secondly as way of helping them to get a feel of the relationship between their chosen area of rock and the graph paper on their board. Students were asked to write/draw both types of scales on their maps at this time.

Normal representations of bed/vein boundaries, faults, folds and fabrics etc as solid or dashed lines, with appropriate shading to reflect lithotype, were used to construct the sketch. Hard pencils and erasers were found to be the best at this stage, and mapping pens or fine felt-tipped pens were used to prepare the final map. At each stage as the geological maps were sketched an accompanying legend with appropriate symbols for geological boundaries, lithologies, foliations, etc was constructed on the graph paper next to the map. A discussion of the variety of other features such as cracks and joints, loose rocks, rock pools, guano etc, which might be useful, or likely to constitute an individuals legend usually occurred at this time and in cases where the area was not flat there was usually some concern about how to represent the physiography or topography of the area. It was found best to choose a flat area and if this was not possible to assume that it was flat.

Usually the initial square took some time to complete (25-45 minutes), as the students grappled with what was often their first attempt at an accurate scale-drawing field exercise. The instructor helped identify the lithologies using such variations as colour, heterogeneity, field petrography etc. and boundaries were marked according to whether they were sharp, transitional, discordant, or lensoid. During the beginning stages it was important to closely supervise the students work, however as the students became confident with the process they required less help.

5.642 Student Evaluation of Grid-Mapping

This technique was initially trialed with a large group of first year undergraduate students from the University of Adelaide in the fifth or sixth week of their introductory geology course. This was their first opportunity to see "hard" rocks in the field, and certainly their first attempt at geological mapping. With four or five demonstrators, classes of 100 students undertook this exercise over a 1-2 hour period. Follow-up laboratory and class exercises were also incorporated to extend the teaching scheme to include topics such as drafting fair copies of the maps, describing the petrology of samples collected during the mapping and outlining the structural/metamorphic evolution of the area. It was also used with first year undergraduate students from the University of South Australia during their first field exercise as an introduction to laboratory based mapping exercises.

Evaluations questionnaires were used to ascertain the views of participating students on the value and productivity of the grid mapping method. Perceptions were generally very positive and students were seen to have retained and improved their attitude to, and competence in, field mapping through later subjects.

The technique has also been used with groups of third and fourth year undergraduate students who are taking a geology major in a Bachelor of Education degree at the University of South Australia. The students had already completed a five-day mapping camp in an area of simply folded sedimentary rocks and were practised in the basic techniques of transferring field observations onto an air-photo basemap.

The two-day field exercise in an area of complexly deformed Precambrian crystalline basement rocks at Corny Point included the detailed "grid-mapping" exercise as an introduction to a five day mapping exercise to be held later in the term at Broken Hill in a complex middle Proterozoic metamorphic terrain. In the first part of the exercise students laid out a rectangular grid using 50 metre tapes and mapped an area of almost totally exposed wave-cut platform at the scale of 1:500. Within the area mapped there was a closure of a major fold with a number of smaller parasitic folds on the limbs. The lithology varied between biotite-rich and biotite-poor grey gneisses and pegmatites both cross-cutting and conformable with the folded layering. Graph paper was used as the base for the map. Even at this scale there were areas of uncertainty, particularly where the outcrop was obscured by loose boulders. There were also subtle variations in lithology which were not apparent until after mapping had commenced and this caused uncertainty in the students which affected their confidence.

The students spent one and a half days mapping the area at this scale and it took most of this time for them to become confident about the process. The fieldwork exercise was completed by grid-mapping part of the area at the 1:20 scale using the procedure already described. The important outcome was the response of the students. All agreed that the method contributed greatly to their understanding of the overall geology of the area. The fact that they were able to see the result of their work (in the form of a map) in a very short time helped to maintain their interest. The students also agreed that the detailed grid mapping would have been more beneficial had they completed it before embarking on the larger scale mapping. In other

words, the students felt that detailed grid mapping should be used as an introduction to mapping in more complicated areas because it was possible to achieve a result in a relatively short period of time.
Grid mapping was used later in the year when the same students began a five day mapping project at Broken Hill. The students agreed that the technique was an instructive introduction which was exemplified by the higher than usual confidence the students had in the early stages of the project. As a result they were able to accomplish more in the five days than preceding groups.

Subsequent exercises with first year students and with more advanced students have confirmed that this method of introducing the process of geological mapping is efficient and results in better learning of the basic skills at an early stage of the student's course.

5.7 CONCLUSION

This chapter has described the rationale for the methods adopted in modifying the teaching of structural geology at second year undergraduate level. Two important modifications are described in detail: the modified delivery method using direct projection of computer generated images; and the introduction and use of concept maps to summarise concepts and develop an understanding of the relationships that exist between them.

In the course of the development of these modifications other related changes were made to the way in which the subject has been traditionally taught. These include the use of demonstrations and development of more interactive lectures, the use of lectorials and the introduction of grid-mapping to help students develop their mapping skills.

All of these modifications have been made to improve student learning. The way in which this has been evaluated is described in the next chapter and the results of the evaluation are discussed in chapter 7.

CHAPTER 6

EVALUATION OF TEACHING AND LEARNING

6.1 INTRODUCTION

Evaluation is the process of gathering information which enables interested individuals and groups to discuss and debate what counts as quality teaching and learning. It is a process which is now a common part of tertiary education and in some cases a compulsory process which must be undertaken for every subject taught. For example in the UK the higher Education Funding Council for England is currently assessing the quality of geoscience teaching in all higher education institutions in England that offer courses in geology or earth science. A parallel process is taking place in Wales (Gill, 1994). Evaluation is a way of understanding the effects of teaching on students' learning. It involves collecting information about teaching and interpreting that information and making judgements about which actions should be taken to improve the teaching.

The purpose of this chapter is to explain the background of the evaluation processes that were used to determine the effectiveness of the modifications made to the teaching methods. Evaluation of teaching is also used to demonstrate accountability. In a relatively recent development Australian universities have to give a formal account of themselves to the Government which pays for them. The nature of evaluation in this context and its relationship to evaluation as a means of gauging the extent to which effective teaching is going on, and to use the results to help improve the quality of instruction, is discussed by Ramsden (1992) at length. His conclusion is that the effectiveness of evaluation:

> *...depends on the way in which academic staff interpret it. ...[The] aim should be the development of a self-critical, reflective academic community which constantly*

seeks internal and external comment on the quality of its teaching. (Ramsden 1992, p247)

The purposes of evaluation vary as do the processes used to gather the information. Evaluation of teaching is commonly undertaken using student evaluation questionnaires, however notwithstanding the importance of student opinion, many other factors are taken into account when teachers and administrators make judgements about courses, subjects and teaching approaches. These include:

- gathering information, ideas and arguments relevant to the subject under consideration;
- thinking about current ideas and practices in the context of the teaching environment;
- making decisions about what to maintain and what to change of our current ideas and practices in the interests of student learning.

Although the formal process of evaluation of teaching and learning may be a recent one, the practice of it has been carried out by experienced teachers for a very long time. Moore (1994) stresses the importance of reflective practice as part of evaluation and describes three aspects:

- reflection on ideas
- reflection on action
- reflection of ideas in action

Reflection on Ideas

This is the process by which the experienced teacher makes decisions about classroom practices, content, teaching techniques, etc based on ideas which come from a variety of activities and events. Activities such as reading journals, following new advances and research outcomes affect the content and the way in which it is arranged in the curriculum. Information gained from attendance at professional association meetings, seminars, and conferences also influence and may prompt changes to the content of subjects and courses or the teaching techniques employed in them.

Reflection on Action

This involves decisions about teaching skills such as engaging students more meaningfully, arranging the sequence of topics appropriately, motivating marginal achievers etc. Information about these aspects comes from interaction with students in laboratory classes, fieldwork or even in the lecture room. Reflection on action involves recognising problems and finding practical solutions to them.

Reflection on Ideas in Action

This is a form of evaluation which deals with the moral/political aspects and is more likely to be undertaken during course planning by a team of people rather than for single subjects by individual teachers.

Each of these activities cause teachers to reflect on what helps students to understand a concept or argument, and to apply the results to teaching.

> *To experiment with a new way of assessing students, and to monitor its effects on the quality of their learning is to engage in evaluation. To listen to a student describing his or her approach to learning is to engage in evaluation.* (Ramsden 1992, p217)

The evaluation undertaken during this project had the specific purpose of determining whether the modifications to the teaching affected student learning. The project was a form of action research (Zuber-Skerritt 1992) in that the methods were monitored each year and modified in response to the feedback received from the various forms of evaluation and reflective practice undertaken. Feedback from students was gathered by three separate means: evaluation questionnaires; interviews; and from reflective journals.

Each of these methods was used at the completion of the teaching of the subject; in two of the methods the information was collected anonymously.

6.2 EVALUATION QUESTIONNAIRES

Student evaluation questionnaires were used at the completion of the teaching each year, usually at the end of the last lecture session. It was recognised that the student evaluation questionnaire is 'only one technique that may help evaluation - it is not evaluation itself' (Ramsden & Dodds, 1989, p 34). However it was felt that this was an easy method by which to gather information from students since they are used widely and the students are familiar with them. Such questionnaires are probably the most widely used method for obtaining student feedback in university education today (Moore and Smith 1994)

The student evaluation questionnaires used consisted of two parts:

> **summative/ratings part** which was designed to *sum up* the overall quality of the subject by asking students to *rate* the worth of its various features, using a 5 point Likert-type scale.
>
> The summative evaluation part of the questionnaire was used to collect information in order to judge the effectiveness of the teaching and the content of the subject.
>
> **formative/diagnostic part** which was designed to help *diagnose* what particular practices, materials, activities etc. needed to be retained or modified by asking students to *write discursive responses* to formal and generally open-ended questions.
>
> The formative evaluation part was diagnostic. The intention of this part of the questionnaire was to collect information in order to make decisions about what to

maintain and what to change in order to improve the quality of teaching and learning in the following year.

6.21 Summative/ratings questionnaires

This form of evaluation is used extensively and can provide helpful information when taken in the context of the teaching/learning environment. Their use as the only method of evaluation, however, is not recommended as Ramsden (1992, p.229) points out, one needs to be aware of the 'strange lure of the student rating instrument'. Consequently it is worthwhile spending some time here describing the value and potential inadequacies of them.

The value of the student summative/ratings questionnaire is its capacity to capture the scope of a course or subject succinctly in a series of statements that can be rated, ranked or weighted quickly by students.

The student summative/ratings questionnaire is generally used because individual student's experiences in a subject can be reasonably captured in a series of responses to closed questions. Accepting this, the challenge is to construct questions that tap into the experiences of students that will provide an insight into their perception of the subject and the way that it was taught. In this research questions were framed to evaluate specific parts of the subject, the teaching methods and the technology that was used to deliver it. Thus, the efficacy of this part of the evaluation rests on the ability to include 'purpose built' questions. This is supported by Moore who in describing the value of student summative/ratings questionnaires states:

> *in the development of a ratings questionnaire, the teacher needs to design questions that will account for the uniqueness of the course's subject matter, the location (home study, lecture room, studio, laboratory etc), mode (face-to-face or distance) and the profile of the student group (year level, gender distribution, cultural spread etc).* (Moore and Smith 1994, p74)

Using student summative/ratings to provide an overall achievement score (or scores) for particular aspects of the subject - relevance, quality of teaching, assessment requirements etc. in this way assumes that the cumulative experience of students enrolled in the subject can be represented by the aggregated and averaged scores. For this to be true the questions must be carefully constructed (Gardner 1995).

The use of rating scales in this way also assumes that the most important elements in the development and delivery of subjects can be quantified. This is another contested assumption. This view that research findings only have meaning if something can be measured arises from a once dominant and now discredited opinion that tries to reduce social realities to precisely defined, observable and measurable quantities (Fensham 1989).

There is evidence (Theall and Franklin 1991) to show that, depending on the procedures by which questionnaires are administered, students have a tendency to give the sort of feedback they think is wanted. This is called the 'halo effect'.

It is possible that the results of questionnaires could change the nature of the subject and the way that it is taught in ways that will maximise scores but not necessarily effect learning positively:

> *Will teachers who test only recall of lecture material or who give 'hints' about the forthcoming examinations, get better ratings from their students than other teachers who may expect students to do a lot of independent work or who set searching examinations aimed at measuring students' real understandings of the key aspects of the subject? If so, what are the consequences for the quality of teaching and learning?* (ERADU, 1990, p 6).

When students are asked to rate a university teacher from their experience in a range of subjects and by comparison with other university teachers, their ratings are invariably relative to time and place. Absolute or normative criteria defining 'good' teaching do not exist. Overall ratings from a particular group of students may be *exceptional* but they may be relative to frustrating experiences with other university teachers in other subjects. Exactly the same teaching performance to another group in another place or at another time may result in only an *average* or *above average* rating.

Recognising all of these possible limitations of student ratings of teaching and subjects it was still considered worthwhile to use them. This is supported by Ramsden who points out that 'students are in an excellent position to provide information about the quality of instruction. Valid methods of collecting such data exist [however] it is wise to be circumspect about using student ratings to make judgements'. (Ramsden 1992, p229)

In addition the student ratings could be combined and compared with other forms of evaluative data (eg reflective journals, examination results, student interview data etc) in order to illustrate the consistency with which evaluations were being made and to ensure that interpretations were supported by a number of different sources. It was also possible to combine the summaries of ratings from previous years so that 'trends' could be demonstrated over time. When aggregated over time the validity and reliability of ratings seems to improve (Morton 1987)

6.22 Formative/diagnostic Questionnaires

Summative/questionnaires ratings have a very limited capacity for providing any meaningful diagnostic (or formative) feedback. It is the form of the questions asked and the responses demanded that determine whether student ratings are helpful in making decisions about what to maintain and what to change in order to improve the quality of teaching.

Formative evaluation is so called because it attempts to gain feedback which is descriptive and provides an explanation for the particular opinion expressed. This type of evaluation enables students to spell out what seems to enhance or constrain the quality of their participation and learning and hence is more readily interpreted and can be used more easily to make changes that will improve the quality of teaching.

Formative questionnaires are more diagnostic because they consist of open-ended questions which invite students:

- to describe their experience (eg. of the workshop sessions)
- to evaluate the consequences (in terms of the effects of the workshops on what they learned)
- to explain their evaluation (by exploring discursively what they perceive has contributed to such an outcome)

The assumptions that the students make about what makes for quality teaching and learning are important in analysing the results. In most cases formative/diagnostic questionnaires alone cannot adequately bring such assumptions to the surface. However it is possible to use the information gained when interviewing students to elaborate their ideas and so better inform the evaluation.

Open-ended questions, then, are far superior to ratings questions for eliciting formative feedback. They are less effective than reflective conversations or interviews but reflective conversations and interviews can only be carried out with small groups and take much more time for both the teacher and the students involved. The power of formative/diagnostic questionnaires, then, is in their reach (they can be administered to large numbers) as well as in their disposition to elicit rich explanatory detail about the experience of being taught.

Thus, the student evaluation questionnaires which best meet the need for diagnostic feedback are those which target particular facets of the way in which a subject was taught and which ask students to write discursive answers to open-ended questions about those facets.

Ramsden and Dodds (1989, p42-46) present the following as a general checklist to guide the construction of open-ended student evaluation questionnaires.

- Do not use questionnaires to collect student data unless you intend to do something with the results to make things better.
- Use questionnaire items that are relevant to your concerns and those of your students.
- Use questionnaire items that are likely to provide information that is useful.
- Be aware that open-ended questions provide the most revealing data about your teaching.
- Administer your forms correctly and at the right time in the course.
- Remember that student evaluation is affected by the context in which it is collected.
- Adopt a professional approach in considering the results from student questionnaires.
- Correlate evidence, wherever possible, with results from other sources of evaluation.
- Inform students about what you have done and what you intend to do to change your teaching as a result of their comments.

To get the most value out of questionnaires two things are critical. Firstly, the students must be given time to fill them out in a considered way and secondly they must be returned by the majority of the class. Moore (1994, page 80) suggests that when using formative/diagnostic questionnaires it is crucial that adequate class time is provided during which students can complete the questionnaire. Only by using class time can there be a reasonable certainty of getting the rate of return that is necessary to ensure that the responses are reasonably representative of the cohort of students. Adequate time is necessary if students are to provide thoughtful responses.

6.222 Interpretation of formative/diagnostic questionnaire responses

There are many ways of interpreting the responses to formative/diagnostic questionnaires. The interpretation may appear mysterious, imprecise and time consuming, especially when compared with the apparent precision and efficiency of quantitative/ratings analyses, however this is a misreading of qualitative analysis. In general terms the interpretation of diagnostic feedback is done by:

- reading the responses;
- organising them into categories (ie finding patterns of similar responses, sentiments or suggestions and summarising them under distinctive headings);
- deducing from these categories what are the overall perceptions and experiences of students, how they are evaluated, and what suggestions are proposed or implied.

There are two ways of interpreting students' diagnostic feedback: the first is to use predetermined categories for grouping individual responses and the second is to use the responses to determine categories (ie. interpretation shaped by students' voices) (Moore, 1994, p 81).

Interpretation within predetermined categories

This method is used for questionnaires which contain carefully framed questions about specific facets of a subject. These are often grouped under sub-headings which are in fact the categories to be used for interpretation. To analyse and interpret the discursive responses to these questions simply requires summaries of the responses for each category.

Interpretation shaped by students' voices

When questionnaires are constructed with broad ranging or general open-ended questions, students are more likely to provide insights about their experiences which are not shaped by focused questions arising from the assumptions of teachers about what is effective teaching. In the absence of predetermined objectives that provide specific categories for interpretation, the challenge in interpreting these broadly framed questions is to 'let the data speak for itself; that is, to create categories grounded in the realities of students' voices' (Moore, 1994 #171, p 82). This approach is more likely to provide unexpected insights.

Thus considering the strengths and weaknesses of questionnaires for evaluation it was decided to use a single questionnaire which contained a summative part and a formative part. The summative part was used to evaluate aspects of the teaching which could be rated on a Likert-type scale. The questions were carefully constructed and grouped so that the results were meaningful. The questions for the formative part were constructed using the guidelines provided by Ramsden and Dodds (Ramsden and Dodds 1989, p42-46)

6.3 STUDENT INTERVIEWS

Interviews are another way of obtaining information from students, either in groups or individually, which can be used to evaluate the success of teaching and learning from the students' perspectives.

Interviews have been used for a number of evaluation purposes in the past. They are a valuable precursor to student evaluation questionnaire construction. Talking to a selection of students about their experiences can be invaluable in identifying the sorts of topics that some students are finding valuable/confusing. Interviews can be used in their own right as a way of obtaining formative feedback. They are a very good way of obtaining formative evaluation and can be conducted with individuals or with groups of students.

The purpose of the interview is primarily to gather feedback which will improve the learning outcomes for all students in the subject. In the evaluation interview the students are being invited, in effect, to reflect on their personal experiences and to provide feedback which they believe might help future students.

The strength of the individual interview is that it provides a unique opportunity to probe with the student, the specific features of the subject and the teaching which are facilitating or inhibiting learning and to gain insights into how those features actually operate to achieve such outcomes. Interviews have the advantage over the questionnaire method in that they allow answers to be followed-up which provides the opportunity to probe more deeply. Interviews also allow more advantage to be taken of single or one-off opinions expressed by only one student. Laurillard (1993) supports the use of interviews because they allow students to be coaxed towards an awareness of what it is they fail to grasp, thus illuminating problems for the teacher that would not be apparent if the students were left only to frame their own questions.

A possible criticism of individual interviews is that they are used to generalise on the basis of a response by a single student, or even on the basis of a small sample. Thus, the interpretation of interview records should be approached in the same way as that described earlier for formative/diagnostic questionnaire responses with either the use of pre-determined categories or deciding on the summary headings based on what the students have said. Pre-determined categories would normally be used when the interviews are structured by a common set of questions whereas the other method would be used for situations where the interviews were unstructured.

6.4 REFLECTIVE JOURNALS

The reflective journal was the third method which was used to obtain information from students about the impact of the modified teaching methods. Students were asked to keep a journal in which they were encouraged to record their reactions to each session of contact teaching as well as their reactions to any other periods, for example revision sessions or library research sessions. Advice was provided at the start of the semester about the nature of the record which should have been made. The journals were collected at the end of the semester in such a way that the writer remained anonymous. The use of a reflective journal is not uncommon as an assessment requirement in a subject and/or, more importantly, as an aid to learning for students. Reflective journal entries (eg. based on clinical practice experiences in Nurse Education) can be found in many courses across schools and faculties and are used as a tool for linking required course readings to tutorial sessions, or as an aid to introspection about one's developing personal and professional competencies (Batts and Wilkes 1993). Such journals are a potentially rich source of insights for formative evaluation purposes.

Access to students' journals can provide a unique view of the impact of an event or a particular episode of teaching on students' learning. Reflective journals were introduced into this program particularly to try to see if there were common times or events which led to “break-throughs” in the students' understanding. The instructions for keeping the journal which were given to the students emphasised this aspect.

The use of journals also encourages students to actively reflect on their learning in relation to their experiences of teaching. This encourages them to change from their dominantly passive role in the conventional university lecture and is a way for the teacher to devolve to students a degree of power and responsibility in effecting the quality of teaching and learning.

The value of the journal as an evaluation tool is that it provides an on-going commentary of the student's perspective of the teaching situations and how they either facilitate or frustrate learning.

6.41 Practice Relating To Reflective Journals

Reflective journal writing does not come easily and naturally to students in higher education, especially those in the science and related disciplines. Students are not commonly encouraged to reflect on ideas, themes, concepts, theories etc. dealt with in the course in a way which sets up a discussion with the lecturer. It is even more uncommon for students to reflect on the design of a subject and the teaching materials, presentation methods and strategies in order to open up discussion on factors which may be facilitating or obstructing effective learning. To achieve such reflective writing, which would also contain significant evaluation data it is necessary to draw up guidelines for students and be prepared to teach them how to construct such a journal.

Heinrich (1992) has suggested that there is a tendency in journals for students to give the teacher what they think the teacher wants. To avoid this Heinrich suggests that students be encouraged to link their classroom observations and experiences with their own professional knowledge and the stated aims of the course.

No matter which way teachers facilitate reflective journal writing, it is crucial that students are reassured that they will not be penalised for any critical evaluations they provide. Stated reassurances need to be included in the instructions and repeated during the teaching. It is also necessary to remind students to make records in their journals and where possible class-time should be set aside for making journal records.

The interpretation of journal records for evaluation of teaching and learning is done in the same way as formative/diagnostic questionnaires and individual or group interviews are interpreted.

6.5 STUDENT ASSIGNMENTS

It is common practice for lecturers to use student responses to assignments (essays, portfolios, reports, journals etc) and examination scripts as data on which to make judgements about their teaching. Some types of assignments, for example, reflective journals, contain greater scope for more direct evaluative feedback than others such as essays and examinations. However analysis of students' work of this type still provides a valuable teaching and learning evaluation opportunity and can be used in association with the other forms very effectively.

6.5.1 Assignments/examinations

Ramsden and Dodds (1989, p 13) have argued that the success of teaching in a course or subject must be judged ultimately in terms of student learning. The main measure of student learning that is commonly used is student assessment in the form of set assignments (essays, field reports, practical exercises and reports etc) and formal examinations. Normally these assessments are used to make judgements about the quality and extent of student knowledge, skills and understandings.

After assessment, lecturers generally get an idea of the learnings in a cohort of students based on the evidence in assignments and examination scripts. They sense, as a result of such summaries, that a particular concept, for example, is not well understood or a crucial skill has not been adequately acquired. On the basis of such judgements they may make minor or major adjustments to the subject and/or their teaching.

Fundamentally, assignments and examinations indicate what students know and can do. They tell very little about what contributed to or constrained their acquisition of such knowledge and skills. Assignments may indicate whether there is cause for concern and thus whether other forms of student evaluation should be conducted to find out more precisely what it is that may be causing the problem.

Assignment and examination results should thus be used only as a very general indicator of the quality and appropriateness of courses, subjects and teaching. Moore (1994, p 88) points out that although the potential of assignments and examinations for evaluation of courses and teaching is limited, there are steps that can be taken to increase their reliability as evaluation data.

An obvious but sometimes not considered way of increasing reliability is to ensure that the aims and objectives of the subject are considered when the content of assignment tasks or examination questions are set. For this to be helpful it is also important that the teaching reflects the aims and objectives of the subject. Invalidity results when examination questions, for example, reflect neither the detail nor the spirit of subject objectives. 'If examination questions are designed with the benefit of a careful analysis of objectives, then they will be capable of eliciting misconceptions more clearly than if they require only the parroting of bookwork, or display of standard procedures.' (Laurillard, 1993, p 191) Gronlund (1985) provides guidelines which can be used to make more reliable evaluative judgements based on student assignments and examinations.

Criterion referencing is a way to gather more precise evaluation information from students' assignments and examination scripts. Setting out clear and comprehensive criteria helps students understand more clearly what is expected of them. More importantly, criterion referencing helps make the teacher's expectations more explicit and provides a ready way of checking assignment expectations against subject content and aims. Moore (1994, p 89) suggests that by using a criterion referencing pro-forma and by keeping records of student achievements in assignments or examinations, it becomes possible to identify specific aspects where students, as a whole, have done significantly well or poorly. Such information can be useful in making decisions about what to retain or change in the subject.

Whether or not devices like criterion referencing are used to assist in gathering evaluative data from student assignments and examination scripts, it is important that a sense of where students are succeeding well and where they may be experiencing difficulties is documented. For this to be most useful it is important that it is done both during and immediately after an assessment activity.

6.6 INCIDENTAL INTERACTIONS

There are many occasions when interactions take place both between teachers and students and between students and students. These occur in the classroom, during practicals and especially during fieldwork. Such incidental interactions can provide useful information about teaching performances or course experiences. By their very nature, however, they cannot provide conclusive insights into the appropriateness or effectiveness of courses, subjects, teaching materials or teaching strategies. They are, however, valuable opportunities to obtain information which can be used in association with all of the other data collected by the other means described in this section to provide insights of student opinion about the subject and the teaching and learning that has occurred.

6.61 Teacher-Student Interactions

One major advantage of using incidental interactions as sources of evaluative data is that it does not involve any extra work. Such interactions can contain direct or indirect evaluative information. A student may speak directly about how a particular lecture or tutorial style has facilitated her/his learning. A student request for clarification of a point during or after a class may alert teachers to the need to consider changes to content or teaching strategies.

Although this kind of interaction is not provided in an anonymous way, it is still important to use it judiciously. Should the information be used to make subject changes it is important that the anonymity of the student who provided it is fiercely protected (Moore, 1994, p 92). In interpreting evaluation information obtained in this way it is important to remember that it represents the experience and opinion of an individual student. Such insights should not be discredited. The insight of just one student can sometimes lead to changes which will enhance the effectiveness of teaching considerably. The ideas of individuals need to be taken seriously. One effective way of doing so is to use other forms of evaluation in conjunction with such interactions.

6.62 Student-Student Interactions

In the context of evaluation, student-student interactions are not as easy to handle for they result from overhearing discussion not meant for the person who is interpreting it for its evaluative value.

Overhearing comments is a daily event and not the result of deception. There are, however, ethical dilemmas in collecting unsolicited commentaries for evaluation purposes. As with all evaluation initiatives, university teachers are in a powerful position to effect the educational outcomes for students positively or negatively. They are therefore obliged to use evaluation information in the interests of students' learning.

As with casual teacher-student interactions, it is important that information derived from student-student interactions is used in association with other evaluation data.

The way in which incidental student-student interactions are interpreted should be guided by the principle of using the information to make changes to the content or teaching strategies which will enhance student learning. To achieve this it will be necessary to use other forms of student evaluation to corroborate the experiences and opinions which have been overheard. It is unwise to assume that what has been overheard is all that the students have had to say about one's teaching. Their comments may be taken out of context. It is always unwise to assume that what was said was seriously intended. The information obtained through overhearing student conversation is of little value unless it is combined with more disciplined forms of evaluation.

6.7 CONCLUSION

Although there is uncertainty about the validity of individual evaluation methods it is clear that they provide useful feedback to the university teacher about teaching methods and subject content. It is also clear from this discussion that the information received from student evaluation is most valuable to the university teacher involved in the presentation of the subject and must be interpreted circumspectly with respect to situation/circumstances. It is also clear that the results of a combination of methods is likely to be more valuable than using only the results of a single method and that trends elucidated from the data aggregated over time are likely to provide more valid and reliable insights into the quality of teaching and learning.

Thus, since the purpose this research was to gauge the effectiveness of modifications to the teaching and delivery methods in an action research process, it seems reasonable to use the feedback from a variety of student evaluation methods to do so. As will be described in the next chapter, the student evaluation data is also used in association with quantitative data obtained from students' examination results to draw conclusions about the success of the modifications to the teaching and delivery methods.

CHAPTER 7

RESULTS

7.1 INTRODUCTION

This chapter describes the nature of the research into the teaching and learning of geology at the tertiary level. Two different curricula were used: the introductory geology curriculum and the second year undergraduate structural geology curriculum. It also describes the way that the research was designed, the two types of study instruments that were used, the data that was collected, and the way in which that data was collected. In particular it is a study of the effectiveness of modifications to the teaching and learning methodologies and their effect on the way students learn. Thus the data collected have been analysed to elucidate these effects.

7.11 Assessment of the changed methodology

The outcomes of the changed teaching and learning methodologies already described in Chapter 5 were assessed in a number of ways using both qualitative and quantitative methods. As has already been described the teaching methodology changed progressively from 1989 with the introduction of computer-prepared overhead transparencies and continued to evolve as the result of the availability of new technology and the incorporation of different teaching strategies. The modified teaching and learning methodologies were used at both first year and second year undergraduate level. Data collection to assess the outcomes of these changes for the second year structural geology students began in 1992 and continued until 1995. Data to assess the effectiveness of the method for the first year students was only collected in 1993. The results of the analysis of these data are described in this chapter. A discussion of the results of these analyses is given in the next chapter.

Although there are similarities between the teaching methods, the data collected and the way it was analysed, the differences between the groups are such that each group will be described separately here. Both qualitative and quantitative data have been collected to answer eight research questions. The research questions are divided into two groups: those related to the second year structural geology subject and those related to the first year introductory geology class.

7.12 Research Questions

The first five questions relate to the second year structural geology subject.

1. Was students' attainment in structural geology and geophysics equal prior to the modification of teaching methods in structural geology?
2. Has the modification of teaching methods improved students' attainment in structural geology?
3. Is there a gender related difference in students' attainment in structural geology and geophysics after the modification of teaching methods?
4. Is there any difference in attainment between the 1993 and the 1994 cohort?
5. Are first year results a good predictor of success in second year?

The second group of questions relate to the differences in mean exam scores for two differently taught groups in the first year introductory geology class. To evaluate these questions quantitatively, a null hypothesis was established for each.

6. Was the teaching modification incorporating the use of concept maps successful in improving achievement by students in the first year introductory geology subject?
7. Was there a gender related difference in students' attainment?
8. Are Year 12 results a good predictor of success in introductory geology?

7.13 Student groups

Three distinctly different groups of students were used during this study: Groups A and B were second year undergraduate students studying structural geology and were both taught using the combination of modifications described in detail in Chapter 5. In summary the modifications involved the delivery of lectures using the computer.

Lectures became more interactive and involved demonstrations. Students had access to the computer developed materials outside of normal class time and students were taught and encouraged to use concept maps to aid their learning.
Group C was a group of first year undergraduate students about half of whom were taught to construct concept maps as the only modification to traditional teaching methods.

Group A
This group consisted of second year B Sc. students from the Department of Geology and Geophysics, University of Adelaide most of whom were studying geology as a major and were studying at least one other subject in geology and at least one from another science. In 1992, 1993 and 1994 there were about 35 students in the class. In 1995 there were only 16 students.

Structural Geology, the topic for which the teaching methodology was modified made-up about 50% of a semester long subject, the other part of which was Exploration Geophysics. The subject was taught using three one-hour lectures and one three-hour practical per week plus fieldwork consisting of one half-day and two full-day excursions and a six-day field camp. For practicals the larger classes (1992-1994) were divided into two approximately equal groups. The 1995 class was not split. All but one or two of the structural geology lectures were given by one person. This person was also present during all practical classes and presented the majority of the information to students. There was also a graduate-student demonstrator at all practical classes

Group B
This group comprised eight to ten second year B Ed. students from the School of Human and Environmental Sciences, University of South Australia who were studying geology as one of their majors and who were also studying another science subject and a subject from the School of Education at the same time.

The subject was taught for nine weeks of the second semester for 1992-1994. It was taught using two one-hour lectures and one three-hour practical class per week. All of the lectures were given by one person who also taught all of the practical classes. There was also fieldwork consisting of a 10 day field camp and two single day fieldtrips.

Group C

Group C was a class of 71 students from the School of Human and Environmental Sciences, University of South Australia who were studying an introductory geology subject in Semester 2, 1993. 35 were in the Bachelor of Applied Science (B. App. Sc.) (Conservation & Park Management) course and 36 were from the B. Education (B. Ed.) (Secondary Science) course.

The introductory geology subject was taught for 14 weeks using two one-hour lectures and one two-hour practical class per week and two single-day field trips. All students attended the same lecture course which was presented by three different lecturers each of whom presented approximately one third of the lectures. For practicals the B Ed. students were in one of three groups and the B. App. Sc. students were in one of two others. Each of the five practical classes was supervised by one of the lecturers who remained with the class for the whole semester. The content of practical classes each week was closely related to the material covered in lectures and was exactly the same for each group. Part of teaching in each practical session involved revision/reinforcement of this material. Each of the two B. App. Sc. practical groups was taken by the same lecturer who used concept maps to summarise information from the lectures and who also, during the practical classes, taught the students to construct concept maps throughout the semester. The B. Ed. students were not taught to construct concept maps during practical classes.

7..2 QUANTITATIVE STUDY INSTRUMENTS AND DESIGN

Quantitative methods could only be used on groups A and C because Group B was too small.

7.21 Group A-Second Year Structural Geology at Adelaide University

7.211 Orientation Study 1985-1992

To determine whether there was an improvement in the students' attainment in structural geology (Research Question 2) final examination marks were used. Since the modification to the teaching only applied to the structural geology part of the subject it was decided to compare students' attainment in structural geology with that in geophysics assuming that these two topics were equivalent. Before the main research question could be addressed it was therefore necessary to answer the question related to the equivalence of these two parts (Research Question 1)

For each of the years 1992 -1995 the structural geology topic in second year was part of the same subject as the geophysics topic. Both topics are similar in a number of ways:

- they build on a very brief introduction to the topic in the first year introductory subject;
- many new concepts are introduced;
- they involve and build on more mathematics than most other second year geology topics (Dentith and Trench 1992);
- they are more concerned with the physical properties of materials than the chemical or biological properties;
- they are seen by students as being equally demanding.

These similarities are part of the basis for the statistical comparisons which were used to evaluate the success of the teaching modifications which were introduced to the teaching of the structural geology topic. During the period of the study, the geophysics topic was taught by traditional methods. The attractiveness of this comparison is that a number of variables that might otherwise arise are able to be controlled. The same students are involved so variation in ability is controlled. The period of comparison is the same so external influences both physical and emotional are the same for each individual student. The examination from which the marks are used for the comparison is the same one held at the same time and in the same place. Thus all factors which influence an individual student's exam performance are the same for each student.

It is assumed that, since the two topics are so similar, students should achieve equally in them. Therefore any difference in student performance in this case can be attributed to the changed teaching methods.

To test the assumption that students' achievement in the two subjects is equal prior to modification, students' examination scores for the two subjects were analysed for each year from 1985 to 1990. Two analyses were done: the mean exam scores for geophysics and structural geology for the class were compared; and the correlation between the individual student's scores for geophysics and structural geology was also calculated. It was also possible to obtain the individual students' examination scores for the first year introductory geology subject which preceded the structural geology-geophysics subject. This enabled the correlation between the individual student's scores at the end of first year with their performance in second year. All of these data are shown in Tables 7.1, 7.2 and 7.3

7.212 Detailed study - analysis of 1992-1995 data

A more detailed comparison of structural geology and geophysics examination scores was made for the period 1992-1995 during which the modifications to the teaching method were being implemented. Although the methods for the comparisons were similar to those described in the previous section, the scores compared were slightly different. The structural geology (SG) part remained the same but the geophysics topic was divided into two parts, mineral geophysics (GP1) and petroleum geophysics (GP2). Each of these three parts was taught by a different lecturer. The two geophysics parts were taught using fairly traditional teaching methods and the structural geology part was taught using the modified methods already described.

Figure 7.1 clearly shows that the class mean examination score for structural geology is higher than that for geophysics so research question 2 was reframed to be:
Is the higher mean examination score for structural geology the result of the modified teaching method?

The following analyses were made for each year cohort of students using the SAS Statistical Package:

- one sample t-test on the difference between matched pairs;
- Pearson's Product-Moment Correlation of matched pairs;
- independent t-test to determine gender influence.

The purpose of the first two of these procedures was to determine whether the differences observed between the mean exam score for each of the parts was statistically significant (modified Research Question 2.). The third procedure was to determine whether gender had any influence on student achievement (Research Question 3.).

The raw data for the 1993 and 1994 cohorts were combined and compared to determine whether there was any significant difference between the achievement of the two cohorts. The following analyses were made using the SAS Statistical Package:

- Pearson's Product-Moment Correlation of matched pairs;
- a two-way Analysis of Variance (ANOVA) to determine the effect of gender
- a two-way Analysis of Co-variance (ANCOVA) to compare the two cohorts

7.22 Group C - First Year Introductory Geology at University of South Australia

Approximately half (35/71) of the class in this first year introductory geology class were taught using a modified method which mainly involved the use of concept maps. During the 14 weeks that the subject was taught, students were taught to construct concept maps to summarise their knowledge and to help them better recognise the relationships between the different parts of the subject. To evaluate the success of this method their final examination results were compared with the other half of the class (36/71) who were taught by traditional methods and were not taught to construct concept maps. Five sets of data were collected for each of the 71 students:

university entrance score	ENTR
pre-test score	TEST1
examination score (part 1)	TEST2
examination score (part 2)	TEST3
examination score (total)	TOT

The university entrance score is a score out of 100 which is provided to the universities by an independent authority in each of the states of Australia. It is used to select students and is calculated from: the Year 12 assessment results for school leavers; a grade-point average for students transferring between tertiary courses; and a Special Tertiary Aptitude Test (STAT) for applicants who do not otherwise qualify for selection.

The pre-test score was the score for a test in the first session of the subject. It consisted of a number of multiple choice questions selected from a set of standardized questions prepared by the American Geological Institute. The questions were chosen to represent the main topics covered in the introductory subject.

The examination score (part 1) was the score for the first section of the examination which consisted of 20 multiple choice questions which had been tested for over three years using 180 students (they showed a reliability of 0.504 based on the Kuder-Richardson reliability index) (Kuder and Richardson 1937).

The examination score (part 2) was the score for the second part of the examination which comprised short response questions requiring interpretation of information.

The examination score (total) was the sum of parts 1 and 2.

The following analyses were made using the SAS Statistical Package:

- Pearson's Product-Moment Correlation to determine the correlation between students scores in the five different tests;
- a two-way fixed ANOVA to determine the significance of the differences in performances between the groups and genders on the five tests;
- a two-way fixed ANCOVA using the entrance score as the fixed variable.

7.3 QUALITATIVE STUDY INSTRUMENTS AND DESIGN

The qualitative data which is described here was only collected from the two different groups of students who studied the second year structural geology subject at the University of Adelaide or the University of South Australia. The purpose of collecting the information was to evaluate the response of students to the modified teaching methods which were being introduced into the subject. Although a large amount of quantitative data was available to evaluate the success of the teaching it was felt that the students were in a unique position to comment on the impact of the modifications, especially the impact on student learning. It is recognised that the validity of student feedback is disputed in the evaluation literature (Marsh 1987; Martin 1987; Jones 1988; Ramsden and Dodds 1989; Entwistle and Tait 1990; De Neve 1992; Ramsden 1992) because student views are partial and are affected by context and their approaches to learning, but it was felt that these limitations could be taken into account. Not only one form of evaluation was being used so the different forms could support each other, and other sources of information that were available or were likely to be available could help to validate the conclusions that would be drawn.

The primary purpose of the modifications to the teaching was to promote student learning (the concept of *quality teaching* discussed earlier). The various forms of evaluation that were used were designed to elicit *what promoted and what hindered learning*. The methods which were used were the same for both university groups.

7.31 Subject Evaluation Questionnaires.

All students were required to anonymously answer a subject evaluation questionnaire which was completed in the last formal teaching session of the subject. These contained a summative/ratings form of evaluation which was designed to sum up the overall quality of the subject by asking students to rate the worth of its various features on a five point Likert scale. A second part of the questionnaire was a formative/diagnostic form of evaluation in which students were asked to write discursive responses to formal and open-ended questions. The purpose of this part was to help diagnose the particular practices, materials, activities, etc. needed to be retained, modified or removed from the subject in order to improve the quality of teaching and learning.

The numerical responses to the summative/ratings part were tallied, summed and converted to a percentage for each question. The comments in the formative section of the questionnaire were transribed onto a summary sheet, on which they were organised into categories which were similar in sentiment or suggestions. The summaries which also contained the average scores for the summative/ratings part were then used to deduce the overall perceptions and experiences of the students. Particular note was taken of comments which related to the modified teaching methods.

At the University of Adelaide this evaluation process was carried out by an independent person who prepared the summary of the results. At the University of South Australia the entire evaluation process, including the preparation of the summary, was carried-out by the lecturer who taught the subject.

7.32 Reflective Journals.

In 1993, 1994 and 1995 students were asked to keep a journal in which they were encouraged to record their reactions to each session as well as their reactions to any other periods, for example revision sessions or library research sessions. Advice was provided at the start of the semester about the nature of the record which should have been made. The journals were collected at the end of the semester in such a way that the writer remained anonymous.

Analysis of the journal comments were collated in a similar way to the formative section of the questionnaires. Since the journals contained a sequence of comments which spanned the semester, the analysis sought patterns within the class and evidence for changing attitudes within individual students.

7.33 Interviews.

In 1995 the class members at the University of Adelaide were interviewed individually by a member of the Advisory Centre for University Education. A list of topics to be covered in the interviews was prepared in consultation with the researcher who was involved in the development of the modified teaching method. Notes from the interview were transcribed and collated into categories under a number of selected headings.

7.34 Observation Diary

Part of the evaluation of both groups of students resulted from informal discussions with the researcher during practicals, field trips and at other times during the teaching of the subject. In some cases students who had been involved in the class in previous years commented on the process as it applied to their experience either during or subsequent to their taking the subject. A record of these discussions was kept in a diary along with other observations about the progress of class activities. These records were collated summarised and matched to the formative information from the other evaluation processes.

7.4 ANALYSIS OF QUANTITATIVE RESULTS

7.41 Group A-Second Year Structural Geology at Adelaide University

7.411 Research question 1

7.4111 Comparison of Mean Examination Scores 1985-1995

The graph in Figure 7.1 shows the result of the comparison and the correlation coefficient between individual's scores for each year. It was not possible to obtain separate scores for geophysics and structural geology in 1989 and 1990, so the score shown on the graph is the average total examination score for the two topics.

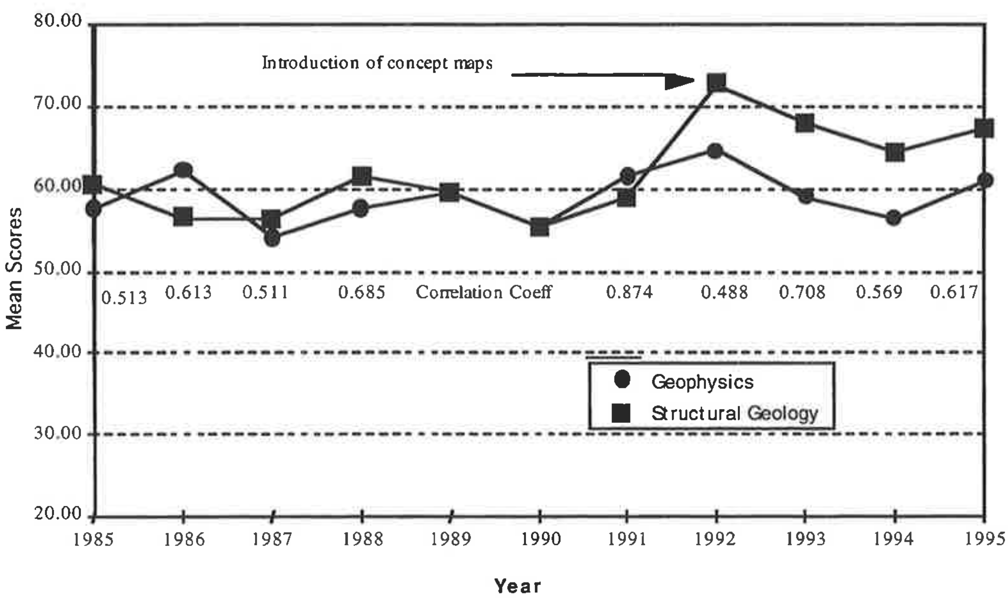


Figure 7.1 Result of the comparison and the correlation coefficient between individual's scores for each year

The graphs shows that prior to the introduction of concept maps in 1992 the mean examination score for the class was similar for both subjects and that it remained close to 60%. After 1992 the mean examination score for structural geology increased and the mean examination score for the geophysics remained unchanged at about the same score as previous years. This is interpreted to show that it is reasonable to assume that before modification of the teaching, students achieved equally in geophysics and structural geology.

7.4112 Pearson Product-Moment Correlation Coefficient 1985-1995

The correlation between students' performance in structural geology and geophysics was also measured. It was hypothesised that, since the subjects were similar, there would be a strong correlation. Thus the null hypothesis is that there would be no correlation between structural geology scores and geophysics scores (Rho=0). The Pearson Product-Moment Correlation Coefficient was calculated for each of the years 1985-1995. The results are shown in Table 7.1. They show that there is a strong correlation which is statistically significant at $\alpha = 0.05$ for each year. This reinforces the idea that the similar mean score for the two subjects from 1985-1991 and the change from 1992-1995 reflect the change in teaching methodology.

The correlation between the students' geophysics and structural geology scores with their first year score was also calculated (Table 7.3). There is a statistically significant correlation at $\alpha = 0.05$ between structural geology and the first year score for each year except 1985, 1991 and 1992. For geophysics there is a statistically significant correlation at $\alpha = 0.05$ for each year except 1986, 1987 and 1992.

	Structural Geology		Geop hysics		Correla-tion Coeff	Stat. Sig at $\alpha = 0.05$
	Mean	Std Dev	Mean	Std Dev	Geop/SG	
1985	60.4	17.0	57.5	8.9	0.513	Yes
1986	56.5	11.7	62.3	10.5	0.613	Yes
1987	56.3	14.5	54.1	13.3	0.511	Yes
1988	61.5	16.2	58.4	11.1	0.685	Yes
1989	59.5	8.4	59.5	8.4	1	Not relevant
1990	55.4	11.1	55.4	11.1	1	Not relevant
1991	58.5	16.9	61.5	13.6	0.874	Yes
1992	72.7	12.2	64.6	12.6	0.424	Yes
1993	68.0	15.1	59.2	15.9	0.708	Yes
1994	63.6	17.5	56.8	12.3	0.569	Yes
1995	67.2	14.8	60.9	13.4	0.617	Yes

Table 7.1 1985-1995 exam score data for structural geology and geophysics.

Another way of analysing the individual student scores was to look at the differences in exam scores between the matched pairs for structural geology and geophysics. For this comparison the null hypothesis is that the mean of the difference between matched pairs of examination scores is zero. If there was no difference the mean of the resultant figure labelled DGPSG should be zero. The results of a one sample T-test for this data is shown in Table 7.2. This data shows that prior to 1992 the mean of the difference is closer to zero than that from 1992 onwards. The probability that this difference would happen by chance (shown in the last column of Table 7.2) is high prior to 1992 and extremely low after. Thus for the years 1985-1991 the null hypothesis is not rejected, but for 1992-1995 the null hypothesis is rejected. Therefore the conclusion drawn from this analysis is that the modification to the teaching introduced in 1992 has had a positive effect on the students' achievement.

	DF	Sample Mean	t Value	Probability (2-tail)
1985	30	-2.8	-.895	.3779
1986	28	5.9	3.186	.0035
1987	25	-2.2	-.936	.3583
1988	24	-3.1	-1.158	.2582
1991	41	2.5	1.785	.0816
1992	38	-12.1	-5.82	.0001
1993	34	-8.759	-4.109	.0002
1994	32	-6.8	-2.665	.0119
1995	15	-6.3	-2.03	0.0599

Table 7.2 1985-1995 t-test data for the difference between student achievement in geophysics and structural geology (DGPSG).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
SG	.159 not	.431 **sig**	.371 **sig**	.685 **sig**	.447 **sig**	.720 **sig**	.185 not	.021 not	.722 **sig**	.573 **sig**
GP	.385 **sig**	.282 not	.245 not	.692 **sig**	.447 **sig**	.720 **sig**	.243 **sig**	.238 not	.730 **sig**	.429 **sig**

Table 7.3 Correlation Coefficients for structural geology, geophysics and first year scores for 1985-1994 showing the statistical significance of the correlation at a= 0.05.

	Structural Geology SG	Mineral Geophysics GP1	Petroleum Geophysics GP2
1992	mean=72.7 SD = 12.2	mean=60.6 SD = 12.6	mean=68.6 SD = 15.3
1993	mean=68.0 SD = 15.1	mean=56.6 SD = 16.8	mean=61.8 SD = 18.9
1994	mean=65.6 SD = 13.6	mean=56.2 SD = 11.9	mean=57.5 SD = 19.4
1995	mean=67.2 SD = 14.8	mean=60.9 SD = 13.4	mean=60.9 SD = 13.4

Table 7.4 Class mean and standard deviation for the three parts of the Structural Geology and Geophysics examination

7.412 Research Question 2

7.4121 One sample t-test, 1992-1995

The exam score for each student in each of the three parts of the Structural Geology and Geophysics examination was tabulated separately for each of the years 1992-1994. In 1995 the geophysics component of the subject was not subdivided, so only one comparison was made. For each year the class mean for structural geology was higher than for either of the two geophysics sections (Table 7.4). The difference between the scores of matched pairs was calculated and a one sample t-test statistic was used to determine significance. The results are shown in Table 7.5. The difference between student attainment is significant at $\alpha = 0.05$ in:

- structural geology and mineral geophysics for each year 1992-1994;
- structural geology and petroleum geophysics for 1993 and 1994 and between;
- mineral geophysics and petroleum geophysics for 1992 only.

	DGP1SG	**DGP2SG**	**DGP1GP2**
1992	p=0.0001 **significant**	p=0.0918 not significant	p=0.0063 **significant**
1993	p=0.0002 **significant**	p=0.0134 **significant**	p=0.0681 not significant
1994	p=0.0004 **significant**	p=0.0321 **significant**	p=0.7256 not significant
1995*	p=0.0225 **significant**		

DGP1SG = difference between mineral geophysics and structural geology exam score
DGP2SG = difference between petroleum geophysics and structural geology exam score
DGP1GP2 = difference between mineral geophysics and petroleum geophysics exam score
* in 1995 the Geophysics component was not subdivided

Table 7.5 Results of one sample t-test on the differences between student exam scores.

7.4122 Correlation of matched pairs

The Pearson's Product-Moment Correlation was calculated for each of the pairs, GP1-SG, GP2-SG, GP1-GP2. The results are shown in Table 7.6. There is a statistically significant correlation between student scores in the structural geology component of the examination and both of the geophysics components for each year. Since the mean score for structural geology is higher than that for either of the geophysics components, it is concluded that this difference is also significant at $\alpha = 0.05$.

Table 7.7 shows the results of the analysis of the 1993 and 1994 results combined into one data set with the addition of the corresponding introductory geology examination score for each class member. The structural geology component has a higher mean than either of the mineral or petroleum geophysics components. The Pearson's Product-Moment Correlation for each of the pairs including the first year score are all significant at $\alpha = 0.05$.

	GP1-SG	GP2-SG	GP1-GP2
1992	r=.454 p=0.0102 **significant**	r=.439 p=0.0120 **significant**	r=.251 p=0.1785 not significant
1993	r=.504 p=0.0020 **significant**	r=.680 p=.0001 **significant**	r=.581 p=.0003 **significant**
1994	r=.438 p=0.0122 **significant**	r=.432 p=0.0135 **significant**	r=.194 p=0.2785 not significant
1995*	r=.617 p=not calc. **significant**		

SG = structural geology exam score
GP1= mineral geophysics exam score
GP2 = petroleum geophysics exam score
* in 1995 the Geophysics component was not subdivided

Table 7.6 Pearson's Product-Moment Correlation coefficient between matched pairs

	GP1	SG	GP2	FIRSTYR
GP1	Mean=56.4 SD=16.7			
SG	r=.4432 p=0.0002 **significant**	Mean=66.9 SD=14.3		
GP2	r=.4222 p=0.0003 **significant**	r=.5722 p=0.0001 **significant**	Mean=59.7 SD=19.1	
FIRSTYR	r=.4608 p=0..0003 **significant**	r=.6465 p=0.0001 **significant**	r=.4169 p=0.0013 **significant**	Mean=67.1 SD=7.9

Table 7.7 Pearson's Product-Moment Correlation coefficient between matched pairs for combined 1993-1994 data.

7.413 Research question 3

7.4131 Independent t-test

Table 7.8 shows the results of the t-tests to determine the influence of gender on attainment. They show that except for the mineral geophysics component in 1993 gender has no significant influence.

	Structural Geology (SG)	Mineral Geophysics(GP1)	Petroleum Geophysics(GP2)
1992	p=.9766 not significant M (f)= 72.8 M (m)= 72.7	p=.8987 not significant M (f)= 61.1 M (m)= 60.5	p=.4243 not significant M (f)= 65.5 M (m)= 69.9
1993	p=.3429 not significant M (f)= 71.2 M (m)= 66.1	p=.0246 **significant** M (f)=64.7 M (m)= 51.7	p=.7654 not significant M (f)= 63.1 M (m)= 61.1
1994	p=.8669 not significant M (f)= 65.1 M (m)= 65.9	p=.3162 not significant M (f)= 58.8 M (m)= 54.5	p=.3099 not significant M (f)= 61.8 M (m)=54.7
1995	p=.6204 not significant M (f)= 70.6 M (m)= 66.1	p=.6582 not significant M (f)= 63.6 M (m)= 60.1	

Table 7.8 Independent t-test results to determine influence of gender on attainment

7.4132 Two-way ANOVA

An analysis of the combined 1993-1994 data showed no significant differences between the attainment of males or females in of the structural geology and petroleum geophysics examination components but there was a significant difference at $\alpha = 0.05$ for the mineral geophysics component. There was no significant difference between the attainment of males and females in the first year introductory geology examination.

7.414 Research question 4

7.4141 Two-way ANCOVA

This analysis showed that there was no significant difference between the attainment of the 1993 and the 1994 cohorts in the structural geology and the petroleum geology components of the examination, but there was a significant difference for the mineral geophysics component ($p=0.0001$).

7.415 Research question 5

Table 7.7 shows the results of the analysis of the combined 1993 and 1994 components with the addition of the corresponding introductory geology examination score for each class member. The Pearson's Product-Moment Correlation for each of the structural geology and geophysics components with the first year score are all significant at $\alpha = 0.05$.

7.42 Group C- First Year Introductory Geology at the University of South Australia

Group C was a group of 71 students taking Introductory Geology. Approximately half were Bachelor of Education students who were taught by traditional methods; the other half were Bachelor of Applied Science students who were taught to construct concept maps as a learning strategy during the practical sessions.

7.421 Research question 6

Figure 7.2 shows the relationship between the mean examination scores of the male and female students in the two groups. The Pearson Product-Moment Correlation between the entrance score (ENTR) and each of the exam components (TEST2, TEST3, TOT) is significant at $\alpha = 0.05$ (Table 7.9)

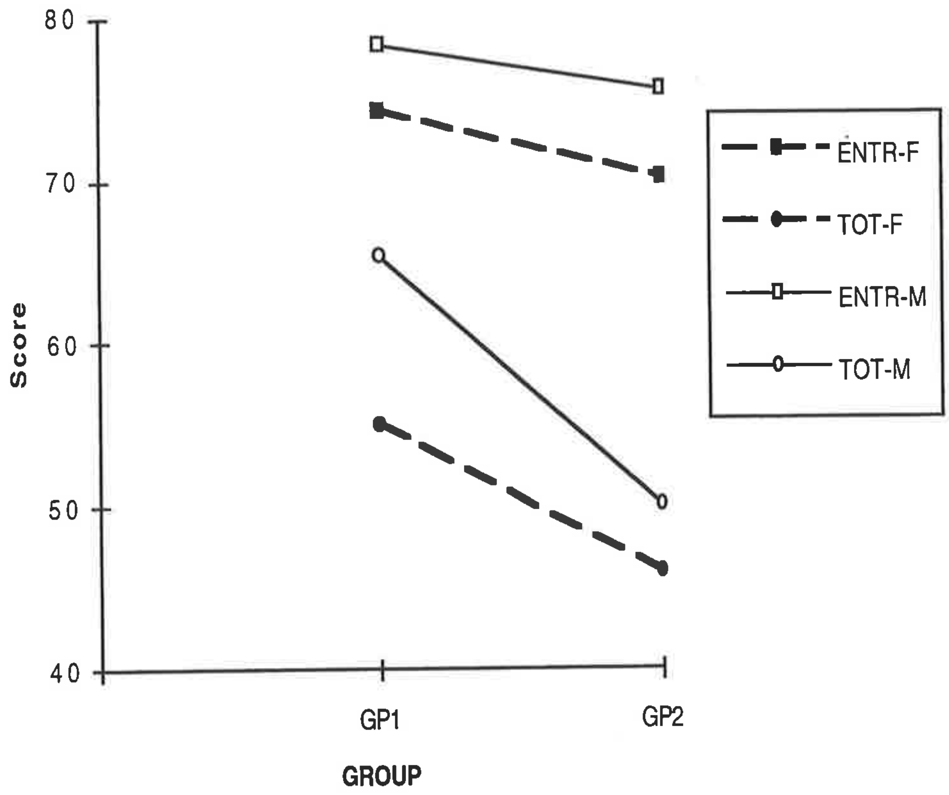


Figure 7.2 A graph showing the average examination scores for males and females in the two groups in the Introductory Geology subject at the University of South Australia.

The two-way fixed effects ANOVA shows that there is no statistically significant difference (at $\alpha = 0.05$) between the groups for the entrance score, but a statistically significant difference between the groups for each of the exam components (Table 7.10). Using the entrance score as the fixed variable in the ANCOVA analysis shows that the difference in examination scores between the two groups is significant. The results of the ANCOVA analysis are shown in Table 7.11. They show that there is a statistically significant difference (at $\alpha = 0.05$) between the attainment of the two groups of students for each of the exam components (TEST2, TEST3, TOT), but not for the pre-test.

	ENTR (uni entrance score)	**TEST1** (pre-test)	**TEST2**	**TEST3**	**TOT**
ENTR	Mean=73.9 SD=4.9				
TEST1	r=.1360 p=0.3175 not sig	Mean=48.9 SD=13.6			
TEST2	r=.2774 p=0.0403 **significant**	r=.3649 p=0.0022 **significant**	Mean=45.4 SD=18.4		
TEST3	r=.2732 p=0..0436 **significant**	r=.4078 p=0..0006 **significant**	r=.8564 p=0..0001 **significant**	Mean=55.6 SD=14.4	
TOT	r=.2879 p=0..0331 **significant**	r=.5534 p=0..0001 **significant**	r=.9549 p=0..0001 **significant**	r=.9484 p=0..0001 **significant**	Mean=53.6 SD=14.9

Table 7.9 Pearson's Product-Moment Correlation coefficient between entrance, pre-test and exam component scores for the first-year Introductory Geology subject.

7.422 Research question 7

For each of the tests the mean score for males is higher than that for females. This difference is true for the whole population and for each of the two sub-groups. Analysis of the difference using the two-way fixed effects ANOVA shows that there is no statistically significant difference (at $\alpha = 0.05$) between the attainment of males and females for the pre-test or for TEST3, but there is a statistically significant difference between the males and females for TEST2 and the total exam score (TOT) (Table 7.10). The results of the ANCOVA (Table 7.11) which takes into account the original difference between gender groups by using the university entrance score (ENTR) as the fixed variable also shows that there is a statistically significant difference (at $\alpha = 0.05$) between the attainment of males and females for each of the exam components (TEST2, TOT), but not for the pre-test or TEST3.

	ENTR (uni entrance score)	TEST1 (pre-test)	TEST2	TEST3	TOT
Group 1 Mean	76.3	49.9	51.1	61.8	60.1
Group 2 Mean	72.8	45.1	39.4	49.7	47.9
F test Probability significance	F=2.45 p=0.1238 not sig	F=1.56 p=0.32 not sig	F=8.14 p=0.0057 **significant**	F=15.11 p=0.0002 **significant**	F=14.12 p=0.0004 **significant**

Table 7.10A Results of the ANOVA between the two groups in the first-year Introductory Geology subject.

	ENTR (uni entrance score)	TEST1 (pre-test)	TEST2	TEST3	TOT
Males Mean	77.0	49.9	49.4	58.2	57.6
Females Mean	72.1	48.0	41.1	53.3	50.4
F test Probability significance	F=5.01 p=0.0295 **significant**	F=0.36 p=0.55 not sig	F=4.14 p=0.0459 **significant**	F=2.48 p=0.1199 not sig	F=4.97 p=0.029 **significant**

Table 7.10B Results of the ANOVA for gender in the first-year Introductory Geology subject.

7.423 Research question 8

There is a strong correlation between the university entrance score and the attainment in each of the exam components which are all significant at α=0.05 (Table 7.9).

7.424 Summary of 1993 First Year Analysis

The analysis of the 1993 First Year Introductory Geology study shows that

- for males and females, the group taught using concept maps obtained higher scores in the examination components;

- males obtained higher scores than females in both groups;
- the differences between the performance of males and females, and the difference in performance between the two groups are both statistically significant;
- the university entrance score was a good predictor of student achievement in the examinations and there was a strong correlation between the university entrance score and the attainment of the students in each of the examination components.

	TEST1 (pre-test)	TEST2	TEST3	TOT
GROUPS F test Probability significance	F=0.51 p=0.283 not sig	F=11.02 p=0.0017 **significant**	F=16.14 p=0.0002 **significant**	F=15.01 p=0.0003 **significant**
GENDER F test Probability significance	F=0.17 p=0.6848 not sig	F=7.61 p=0.0081 **significant**	F=3.47 p=0.0683 not sig	F=5.21 p=0.0268 **significant**

Table 7.11 Results of the ANCOVA using the entrance score as the fixed variable for the Introductory Geology subject.

7.5 ANALYSIS OF QUALITATIVE RESULTS

The qualitative data that were collected by each of the different methods were collated into categories that related to the purpose of evaluating the effects on student learning of the modified teaching methods. Four categories were chosen for the formative evaluation information. These were:

- the use of the computer for lecture delivery and preparation of hand-out material;
- the use of demonstrations to break-up lectures;
- the various ways that concept maps were used;
- other aspects of the learning environment;

The summative data which was collected by the subject evaluation questionnaires was collated and recorded as a percentage for the individual questions and an overall average calculated for all of the questions was also recorded as a percentage.

The same sort of qualitative data was collected from both the University of Adelaide and the University of South Australia students, however because they were different classes they will be treated separately here.

7.51 Subject Evaluation Questionnaires

7.511 University of Adelaide results

The summative data was reported in two parts, the subject characteristics and the teacher characteristics. Subject characteristics include curriculum design, preparation of subject materials, workload, pace of individual sessions and overall degree of difficulty. The average percentage of student satisfaction for 1992-1994 was 80% with the workload and the pace of individual sessions rating lowest and the preparation of teaching materials rating highest in each year. The average for the teacher characteristics for the period was 85%. This category included effectiveness of communication, clarity of explanations, availability of information, organisation of presentations and overall teaching quality, as well as some questions about the personal traits of the lecturer. All of these parts received about the same rating with enthusiasm for the subject by the lecturer rating highest in each year and organisation of presentations also rating higher than the average in each year. The overall teaching quality rated at or just below the average in each year.

Since these percentages are calculated from a 1-5 Likert rating scale, the implied precision of the numbers is not valid. It is however, significant to note that the students rated the various aspects of the subject between the highest and the second highest ratings for each of the three years. Because of the acknowledged limitations of this method of evaluation and the potential sensitivity of the results there has been no attempt to compare these numbers with those of the geophysics part of the subject which was taught using different methods.

The formative data is potentially more valuable for determining information about the learning environment as it is perceived by the students. Only the summary of the evaluation was available for analysis, so it is not possible to link the individual comments to the summative part of the evaluation. However, because all of the comments are provided it is possible to get a good overall impression for each year.

7.5111 Computer for lecture delivery and preparation of hand-out material

In 1992 more than half of the students who made comments in the evaluation commented on the use of the computer for lecture delivery. In 1993 there was only one out of 21 and in 1994 about half of the comments referred to the use of the computer. The 1992 students comments were positive about the use of the computer and were only critical of the pace at which they were delivered and the number of images that were included in some lectures. The following comments exemplify these points:

> "Computer screen - great, easy to read, but it does tend to move the lecture too quickly."

> "On the odd occasion it seemed that [the lecturer] had rather an affinity with the mouse button, and I would be hopeful that a world slide record (no. of slides in an hour) was set so that the cramp in my writing hand was not for nothing."

There were also several comments which suggested that the hand-outs which were of the summary screens should have been given out before the lecture. A couple of comments also suggested that the whiteboard should still be used to supplement the slides.

In 1993 the only comment about the use of the computer to deliver the lecture was that it "works well". In 1994 only one of the comments was critical of the use of the computer and this was part of a comment which was critical of all parts of the subject. All of the other comments were positive and many also commented on the usefulness of the hand-outs which were given to students before the lecture (in 1994 they were given out in two sets at the beginning and in the middle of the lecture series).

7.5112 Demonstrations in lectures

The majority of the comments about the demonstrations used during lectures were favourable and related to their usefulness in providing concrete examples for difficult somewhat abstract concepts (eg. using deformation of fruit as an analogue of the deformation of rocks). For example:

> "banana demo would have to be the best simple analogy to a geological concept that I have ever seen"

There were a number of comments about the demonstrations which did not give any indication about their usefulness. The following comment is related to the use of common materials, especially culinary items and exemplifies the non-judgemental nature of several comments:

> "[the lecturer] should be reported to RSPCV (Royal Society for the Prevention of Cruelty to Vegetables)"

7.5113 Concept maps

The most comments on the concept maps was in 1992. Most comments were favourable but requested more. A couple of students wanted concept map summaries to be prepared as a hand-out for every lecture in addition to those presented as images during the lecture. One student commented that they were good but that it was an "unrealistic demand to put on geology students." The same student went on to say that there should have been a requirement for students to complete concept map summaries each week. In 1993 and 1994 there were only a small number of comments about concept maps in the student evaluation questionnaires. These were favourable noting the value of concept maps as a learning aid and their transferrability to other subjects. In this vein, one student said

> "Concept mapping has been very useful I wish it was strongly recommended to other staff members."

Other comments included

> "Concept maps were good because they helped to show the relationships between the different parts"

> "I found the concept maps useful at the end of the subject when revising"

7.5114 Other aspects of the learning environment

Most of the comments other than those reported already were single comments about specific parts of the teaching or the course. There were several students who commented that the overall learning environment made a boring/difficult subject interesting; even some who said that their interest was stimulated enough to go on with further study in the subject. There were also several comments about the well organised nature of the presentations and several about the high quality of the overall teaching including the provision of a relaxed and enjoyable atmosphere.

7.512 University of South Australia results

The questionnaire that was used was similar to that used at the University of Adelaide. The first part was a summative evaluation which was divided into three parts, the subject characteristics, the teacher characteristics, and the learning environment. Subject characteristics include subject objectives, curriculum design, preparation of supporting materials, workload, and assignments. The average rating on the 5-point Likert scale for the period 1992-1994 was 3.9 with workload rating lowest while curriculum design and preparation of supporting materials rated highest. The average for teacher characteristics was 4.2. This category included preparation, presentation and communication skills, teaching methodology and variety, interest in and knowledge of the subject, and openess and availability to students outside scheduled class time. Preparation, presentation and communication skills, teaching methodology and variety, interest in and knowledge of the subject, and openess and freedom of students to ask questions rated consistently high, whereas availability of the lecturer to students outside of scheduled class time rated low and brought the overall average down. The learning environment part of the evaluation questionnaire included pace of individual sessions, appropriateness of sequence of topics, curriculum design and relevance, feedback on assignments, opportunity to monitor learning progress, and development of motivation and stimulation of interest in the subject. This category rated at 4.4 averaged over the period 1992-1994. In 1994 all 10 of the respondents rated appropriateness of sequence of topics, and curriculum design as 5.

The formative part of the evaluation was more structured than the instrument used at the University of Adelaide. Students were asked to specifically comment on the strengths and weaknesses of the use of the computer to deliver the lectures, the use of concept maps, the use of demonstrations in lectures and the overall subject. Data was collected from 1992-1994 when the subject was taught in semester 2 in each year. Because of the small number of students in each year the results are not subdivided into individual years. The results of the evaluation are summarised in Table 7.12.

	Strengths	Weaknesses
Computer delivery	easy to read; provide a good sequence; summary hand-outs are valuable; "being able to access the computer outside of the class times was valuable and should be done by other lecturers";	hard to write notes with so many slides; too much too fast
Concept maps	good way to show relationships between parts; helped me see the overall structure of the subject; good for revision; showed that they really are valuable, not just something from Ed. Theory; those handed out were good for revision, should have been more; best ones were those we did together with you.	should have spent more time doing our own in class; did not help me at all; we should be tested on them if they are important.
Demonstrations	excellent; made me think about things I could actually see; broke up the lectures-kept me awake; made the lectures more informal; made us think instead of just writing; Celebrity Heads was good, made us use the knowledge; gave me confidence that I could actually understand structure.	not enough; we should have done more of these instead of the mapping practs.
Overall subject	Well prepared and presented; good to see a lecturer prepared to do what we are told about in Ed Theory; most of the learning was done in the class instead of afterwards; relaxed informal class.	Too many concepts in too short a time, should have been spread across the whole semester; pracs did not relate closely to the lectures.

Table 7.12 Summary of formative comments from University of South Australia Students

7.52 Reflective Journals

In 1993 an additional qualitative method for information collection was introduced. Students at both universities were encouraged to keep journals which recorded their sequential reflections about the progress of their learning and the environment in which it was happening. Analysis of the journal comments were collated in a similar way to the formative section of the questionnaires with the comments being categorised under the same headings. Since the journals contained a sequence of comments which spanned the semester the analysis sought evidence for changing attitudes within individual students and, where the number of responses permitted, sought patterns within the class.

7.521 University of Adelaide results

In 1993 only four students (10% of the class) completed a journal, in 1994 there were 15 (38%) and in 1995 there were seven(44%). Not all of the journals had a complete record of the whole semester but there were enough to elicit some patterns which could represent the class.

The individual comments in the 1993 and 1994 journals reflected the comments from the formative part of the questionnaire evaluation as well as raising some other spects which were of interest.

7.5211 Computer for lecture delivery and preparation of hand-out material

Each of the journals in 1993 referred to the use of the computer and all were happy with it. For example one journal entry recorded the following comment:

> "The computer is an excellent method of structuring lectures and was quite effective in itself.... a vast improvement on other more disorganised lecturers who without computer aid tend to ramble."

The only criticism of the use of the computer related to the amount of material and the speed at which it was delivered. This was more common in the early entries and was not present in the later entries. Two other aspects of the use of the computer were common: the acknowledgement of the usefulness of the hand-out prepared from the computer images; and the ability to review the lecture material on the computers in the Faculty computer suite. The majority of the 1994 journals commented favourably on the value of the computer and the associated aspects. Only one of the comments referred to the speed of the presentation and this suggested that it was "by no means too slow - but very comfortable." The following extract typifies the tone of the journals for 1994.

> "I really think that the computer projection during the lecture is effective. Accompanied by the hand-outs with graphs and drawings the system seems to save the student spending a lot of time rapidly writing notes. The computer display is very clear which eradicates any problems related

> to not being able to read a lecturer's writing. Personally I find the computer displays are better for grabbing and holding my attention during lectures. Simple things such as different colours and moving cursors keep me from letting my attention drift elsewhere."

The 1995 journal entries rarely referred to the computer presentations, but there were several comments about the benefit of being able to annotate the hand-outs during the lectures instead of having to write detailed notes. There were also several comments about the benefit of being able to use the lecture slides in the Faculty computing suite or at home, especially for revision prior to the exams.

7.5212 Demonstrations in lectures

A major modification to the traditional lecturing style was the use of demonstrations during lectures. Each lecture included at least one demonstration or other activity to break-up the time. Analogue models using familiar materials were used to demonstrate particular abstract concepts eg. common materials such as honey, vegemite, tomato sauce, plasticene, clay and blue tack were used to analogue elastic, viscous and plastic behaviour during a lecture on rheology and ductile behaviour. Other demonstrations and activities are described in more detail in Chapter 5, sections 5.51, 5.523 and 5.53.

There was only one brief mention of the use of such demonstrations during lectures in the 1993 journals. This said that there were "...too many things happening at once i.e. experiments with fruit, as well as the computer screens, rocks, slides... ". However the 1994 and 1995 journals contained quite a few references to the demonstrations. All of them were positive describing their benefits as "helping to maintain concentration", "simple analogies help make things clearer" and "examples help things stick in my mind". The following entry reflects the apparent bemusement of some of the journal comment early in the semester:

> "I also think your sort of monotony breakers during lectures are a good idea. For example the game with the earthquake names on the hats really helped re-iterate what you had lectured on that

> day. I don't think the participants were very good sports, though. Had they been a bit more enthusiastic ... I think we all could have learned something."

In the same journal a comment later in the semester shows that the demonstrations have become more accepted by the students.

> "Todays lecture was a lot of fun and although it is unusual (not for [lecturer's name]) to have this sort of activity in a lecture it made clear to some of us at last what isotropy and anisotropy are"

7.5213 Concept maps

Journals from each of the three years contained references to the use of concept maps, but there was no pattern except that they were all fairly positive. There was some scepticism in some of the early comments and only one of the journals containing this early sentiment followed-up with a subsequent comment about concept maps. The comment recorded after the first lecture was:

> "... but the concept maps are just another way of summarising, I don't see what all the fuss is about."

Included in the last record of the same journal was this comment:

> "Concept maps, after initial scepticism, were found to be quite useful, especially for study preceding exams. Although it was beneficial to construct these ourselves, perhaps some could be included in the hand-out (perhaps as a summary of sections)."

There were other similar comments about the use of concept maps for revision, including a couple which referred to their usefulness in other subjects. Some students indicated that concept maps helped them see the relationship between the major parts of the course; others commented that although they did not help understanding, they were "especially effective for organisation and relation of all sorts of information".

7.5214 Other aspects of the learning environment

Reference to two things was included in almost every journal in 1993 and 1994. These were the value of the field trips in helping to clarify ideas and the use of the rock description exercise at the beginning of each practical class. Most of the comments about the rock exercise were very negative in the early entries and gradually became more positive towards the end of the semester. For example the following two extracts are from the first entry and a late entry respectively:

> "The worst thing about the prac is the rock test..."

> "... the rock descriptions are coming more naturally now."

Other comments showed similar sentiments reflecting dread or apprehension at the beginning and appreciation and more confidence later in the semester. In the 1995 journals there were no references to the use of the rock descriptions even though the students spent as much time in class on them. As was described in Chapter 5, the treatment of the rock description activity in 1995 was different in that much less emphasis was placed on the assessment aspect of the exercise.

There were several references in the 1994 students' journals about a practical exercise which involved the deformation of a banana. All of these comments were favourable and expressed similar sentiments to the following:

> "This entry concerns the practical ... in which we all got to deform a banana. I found this experiment very enlightening - a real eye opener. It was one of those moments when everything just seemed to click into place... seeing the banana deform step-by-step is what made the stress/strain concept really tangible. I hadn't really been able to understand how a fault (or fractures) would result from stress until I saw such features develop in my banana."

This comment shows how this student has made an important learning break-through. Other journal entries reported similar break-throughs in other areas of understanding, several as a result of the field trip.

7.522 University of South Australia results

Journals were kept by both the 1993 and 1994 classes. In 1993 four out of six students in the class returned completed or partly completed journals and in 1994 eight out of nine class members returned their journals. As with the journals from the University of Adelaide students, the records were similar to but elaborated on the formative evaluation section of the questionnaires.

7.5221 Computer for lecture delivery and preparation of hand-out material

Most of the comments in both years mentioned that the computer made the material easier to read and easier to take notes from. Although both groups found the summary hand-outs valuable the 1993 group who did not receive them until after the lectures commented that they would have been more valuable if they had been available during the lecture. One student commented that the ability to borrow a copy of the lecture material on disc "was valuable and should be done by other lecturers".

7.5222 Demonstrations in lectures

About half of the journals contained comments related to the demonstrations. They varied from " the demonstrations were excellent, especially the plastic ruler and the concept map we made from the words" to others about breaking-up the lecture, regaining attention and making use of simple analogies. Another comment which was similar was:

> "The Celebrity Head game seemed a bit of a wank(sic) but it lightened up the lecture and helped consolidate the content presented"

A summary comment contained the following reference to the use of demonstrations:

> "[the lecturer] used experiments or demonstrations to break-up every lecture. Some of them seemed like an excuse to cut-up food to feed us but they all made it easier to recall bits of the subject. I found that in the exam I could remember things related to the experiments better."

7.5223 Concept maps

Reference to concept maps was made in most of the journals and none were critical of their use. Most of the comments were about their usefulness to show relationships that were not otherwise obvious. For example:

> "The concept map that we developed on the white board at the end of the lecture made much more sense of the stuff we have been doing for the last two weeks. It was much more useful to do it together than just copying the ones from the computer."

In another reference to concept maps in a summary comment a student reflected:

> "The concept maps were a good way to show relationships between parts of the subject. Now that I have seen how helpful they can be I will definitely be using them in my teaching. It was much better to use them in practice than in theory."

7.5224 Other aspects of the learning environment

A pattern in the journals of both year groups was the change from anxiety about too much content in the early stages to a feeling of confidence in the final stages of the subject. The anxiety was expressed by comments like: "there seems to be a lot of unrelated facts", "too much too fast" and was replaced by comments such as "I'm getting the hang of this now" and "Today's lecture was very informative in that it applied what we had learnt previously to plate tectonics".

7.53 Interviews.

In 1995 the students in the University of Adelaide class were individually interviewed by a member of the Advisory Centre for University Education. Notes from the interview were transcribed and collated into categories under a number of selected headings which related specifically to the 1995 teaching methods.

7.531 Use of the computer.

In 1995 the student access to the lecture material outside of lecture time was improved by the availability of extra computers. Seven of the 16 students used the computer outside lecture time, with five taking copies of the lectures to view at home. Some students previewed each lecture, so that they were prepared. They all used the computer to review the lecture after it was given. One student did not use the computer at all because of difficulty in getting access to it at home or at University and because it did not suit his learning style. The majority of the students were in favour of its use to deliver lectures especially in association with the booklet.

7.532 Demonstrations

Three students were indifferent to the lecture demonstrations, one of whom said that it helped his understanding, but seemed more concerned that demonstrations took up time that could have been used to get across more information. All of the other students liked the demonstrations because they helped understanding and created interest.

7.533 Lectorials

These were sessions where small groups of students were given a topic and some demonstration materials and were asked to explain the topic to the rest of the class. All of the students saw these sessions as beneficial and enjoyed the activities. They found the activities helpful in promoting their understanding, especially having to explain to other students. They also found that having to work as part of a small group to develop the topic was helpful in that the discussion involved clarified ideas and presented other ways of seeing the topic. There was also a benefit seen in listening to the explanation of topics by other groups during these sessions.

7.534 Concept Maps

All students believed that the concept mapping was useful. They felt that preparing the maps was better than actually being given a map as they were more actively involved in the learning process. Not all of the students saw the benefit of concept maps early in the semester as the following quote from the transcript indicates:

> "At the start I did not like them. Now revising I can see how things are connected. I may even do some more in revision - to summarise information."

Most of the students agreed that it was better to do their own rather than getting them as hand-outs or copying them during a lecture. However they also felt that they needed the instructors input as a 'safety net' to ensure that they had the right connections.

7.535 Other aspects of the learning environment

The interviews confirmed that the methods of learning used by students all varied and that the students appreciated being able to choose the method(s) which best suited them from the various options presented.

7.54 Observation Diary

A diary of observations was kept in which results from informal discussions with students during practicals, field trips and at other times during the period that the subject was taught in 1992-1995 were recorded. In some cases students who had been involved in the class in previous years commented on the process as it applied to their experience either during or subsequent to their taking the subject. The record of these discussions along with other observations about the progress of class activities were collated, summarised and matched to the formative information from the other evaluation processes. These observations as they relate to both groups are reported in one section rather than dividing them into two.

7.541 The use of the computer

Most of the observations recorded in the diary are similar to those reported already from the other forms of evaluation. In the early stages of the use of the computer for delivering lecture material in the structural geology subject at both universities, the method was new to students. Some tended to be more interested in the technology than the content, others were frightened by the rapidity at which the material could be delivered. Even so, most students adapted very quickly and took advantage of the associated benefits such as the hand-out notes and the access to the material outside of lectures. In the later stages this method of lecture delivery was not uncommon. For some students, all of the lectures in the introductory geology subject had been presented in this way so they were used to it and took its advantages for granted. This reduced the anxiety of students in the early stages of the subject which was further reduced by the better availability of the materials outside of lectures.

7.542 Demonstrations

Once again many of the observations that were made have already been discussed under the various evaluation sections. An obvious benefit of the demonstrations and the interactive approach is that it maintains attention and gives students concrete examples upon which to build their knowledge and develop their understanding. When more than one type of demonstration was attempted in a lecture, some students appeared to have their concentration distracted away from the main purpose. A small number of students also felt threatened by questioning because they were afraid that they would be embarassed by not being able to answer. This feeling abated as the subject proceeded through the semester and the students got to know each other better. In 1994 there was a marked improvement in the success of the demonstrations and the students' involvement after they had returned from the field camp in the middle of the semester. In 1995 the field camp preceded the teaching and the students' familiarity with each other allowed the interactiveness to proceed well from the beginning.

7.543 Concept Maps

Some students seemed to embrace the idea of using concept maps from the start, others gradually began to use them and some students did not use them at all. There seems to be no pattern which could be used to predict which students would fit into each of these categories.

During discussions with students during the early part of the project none were critical of the use of concept maps although some were indifferent to them. The majority of students recognised that they were a useful way of summarising information in a way that showed the relationships between different parts of the topic.

At the beginning of the subject many of the University of Adelaide students appeared sceptical about the value of concept maps, but no-one expressed any resistance to their use. In the early stages of the subject some students were not interested in learning how to construct their own maps but changed their attitude when they became more familiar with their use due to the frequent use of concept maps for lecture summaries. In general these students could only construct simple maps yet they could recognise the way that more concepts and links could be incorporated.

A small number of students embraced the idea more enthusiastically and were the ones who volunteered for the tutorial sessions which were offered in 1992. Initially these students were able to construct simple maps of a small number of given concepts chosen by the instructor. Later they were encouraged to summarise their own lecture notes using concept maps and were able to do so in a reasonably competent way. Most of these students expressed the opinion that the process was helpful and a valuable skill to have.

Discussions about the student-constructed concept maps during these tutorials enabled clarification and reiteration of important relationships and recognition of areas of deficiency in students' understanding.

From 1993 to 1995 extra tutorial sessions were not offered, instead more time was spent during practical classes. Comparisons of the maps drawn by students in the early sessions with those drawn later showed a reasonable development of skill by most students. It was also possible to recognise individual students commitment to the use of concept maps. Some spent a good deal of time and care constructing their maps, while others dashed them off without much concern. There was no apparent pattern (in terms of examination achievement) in the kinds of students who actively participated in the concept mapping and those who did not.
Conversations with students in later years indicate that those who found concept mapping useful continued to use them in other subjects.

7.544 Other aspects of the learning environment

The change in the way the rock description was used prior to 1995 and in 1995 had an obvious effect on students attitude to the exercise. Prior to 1995 when the exercise was treated as a 'test' students approached it without any enthusiasm and as their journal entries confirm, with some apprehension. Despite this, from week to week there as an obvious improvement in their ability to recognise and record the appropriate features of the rocks. In 1995 the approach of the students to this exercise at the beginning of each practical was obviously different. It was clear that they still had the same sort of difficulties in recognising the appropriate features but because they were able to confer with the other members of their group they were not at all apprehensive. Although their descriptions were not always collected, they were just as conscientious about completing each exercise and just as attentive when the rock was described by the instructor.

7.6 CONCLUSION

This chapter has presented a summary of the results of both the quantitative and the qualitative data that has been collected to answer the eight research questions. These questions are related to the effectiveness of modifying the teaching and learning methodologies in the tertiary geology curriculum.

Qualitative and quantitative data was collected to elucidate the effect on student learning on two separate groups of students studying advanced structural geology. This data was collected for two groups of students in different universities in each of four years. One aspect of the modified teaching and learning method was also used with an Introductory Geology class where it was possible to collect quantitative data to compare the performance of two groups.

As will be discussed in the next chapter, both the quantitative and the qualitative data have been interpreted to show the methods were effective in the two different parts of the geology curriculum.

CHAPTER 8

DISCUSSION OF RESULTS

8.1 INTRODUCTION

This chapter contains a discussion of results of both the qualitative and the quantitative data which was described in Chapter 7. Each of the research questions is treated in turn. The overall outcomes of the study and the conclusions are dealt with in the next chapter.

8.11 Orientation Study

Research Question 1

> **Was students' attainment in structural geology and geophysics equal prior to the modification of teaching methods in structural geology?**

This question was posed because of the need to be able to make comparisons between the exam results of the structural geology class prior to and after the modifications to teaching were implemented in 1992 with another score to determine whether there was any significant change in the structural geology score which resulted from the modified teaching method.

The descriptive statistics show that the mean examination score for the two subjects, structural geology and geophysics is close to 60 in each year from 1985-1991 and that neither mean is consistently higher than the other. This result is consistent with the hypothesis that the two subjects are similar in the nature of the concepts that they contain and that under the same conditions, students will achieve equally well in them.

The comparative statistics confirm this hypothesis. There is a statistically significant correlation between individual student's examination scores in structural geology and geophysics for each year. This conclusion is further reinforced by the results of the analysis of the difference between individual student's scores in the two subjects. From

1985 to 1991 there is no significant difference between the two exam scores and the mean of the difference between the two scores for the total class is close to zero.

Conclusion 1

From these results it is possible to conclude that structural geology and geophysics are similar and that under the same conditions, students will achieve equally well in them.

8.12 Detailed Study

This was the main part of the study and both quantitative and qualitative data were collected to determine whether the modified teaching methods employed from 1992 in the teaching of the structural geology part of the subject had any significant effect on the performance of the students. The result of the orientation study shows that it is reasonable to compare the examination results of structural geology with the examination results of geophysics to obtain quantitative data to assess any effect.

Research Question 2

Has the modification of teaching methods improved students' attainment in structural geology?

Quantitative Study

It is clear from the analysis of this data that there is a difference between the students' scores in the structural geology and the geophysics parts of the examination each year from 1992 to 1995. During the period from 1985-1995 the examination format remained the same. The kinds of questions which were asked in both the geophysics part and the structural geology part were similar from year to year and although some questions varied there were enough repeated questions to ensure that the degree of difficulty of each of the parts of the examination remained the same. In the orientation study (1985-1991) the class means for the two parts were both about the same and neither part was consistently higher than the other. In 1992 the class mean for both structural geology and geophysics climbed above 60% but the mean for structural geology was significantly higher than the mean for geophysics. From 1993 to 1995 the class mean for geophysics returned to be close to 60% but for structural geology the mean score remained significantly higher for each year.

The Pearson's product-moment correlation shows that there is a statistically significant correlation between the scores of individual students in the two parts of the examination in each year and the independent t-tests show that the higher score for structural geology is statistically significant for each year from 1992-1995.

The results of each of these analyses is consistent with the hypothesis that the modified teaching methods employed from 1992 in the structural geology component of the subject resulted in higher achievement as measured by examination scores.

The geophysics data for 1992-1994 was broken down into a mineral geophysics and a petroleum geophysics component and similar statistical comparisons were carried out on this data. There was a statistically significant correlation between individual student's scores in the structural geology part of the subject with each of the geophysics components for each year, and the higher mean examination score for structural geology was also statistically significant in 1993 and 1994. In 1992 the difference between the structural geology and petroleum geophysics was not significant at $\alpha = 0.05$, but the difference between the structural geology and the mineral geophysics component was significant at $\alpha = 0.05$.

When the two geophysics components are compared, the relationship between them is not as consistent. The correlation between them is only statistically significant in 1993 while the difference between the examination scores is only statistically significant in 1992. This indicates that individual students are performing differently in the two geophysics components of the subject, but that overall there is a consistent pattern in the performance of individual students when geophysics scores are compared with structural geology scores.

Conclusion 2

These results indicate that the modified teaching used in the structural geology part of the subject from 1992-1995 has significantly improved the achievement of students as measured by attainment in the examination.

Qualitative Data

The improved performance in structural geology as measured by the quantitative data is also borne out by the positive comments of students reported in the qualitative data both at the University of Adelaide and at the University of South Australia. No single part of the modified teaching was identified as being best, rather it appears from the different comments that the variety of learning opportunities provided allowed different students to choose the methods which suited them best.

Directly-projected computer generated images

Most students favoured the use of directly-projected computer generated images to deliver lectures. Both the summative data in the evaluation questionnaires and the formative data in the other forms of feedback from students showed that they appreciated the organised way in which the material was presented. Although it is not difficult to achieve this using a more traditional approach, the computer allows for the sequence of information delivery to be carefully planned and structured. It is more difficult for the presenter to stray from the planned sequence because the order can not be easily changed during a presentation. At the same time it is possible to move forward or backwards through a presentation if necessary.

An advantage of using the computer in this way according to the students in feedback was the availability of lecture hand-outs which were the same as the screen images viewed during the lecture. Another feature which students appreciated was the availability of the individual presentations outside of the lecture either on a network or on disc for use on their own computers.

Demonstrations

There was strong endorsement in the various types of formative evaluation feedback from the students at both universities for the use of demonstrations during lectures. There was a general feeling that the demonstrations aided concentration and provided useful analogies on which students could build their understanding.

Concept maps

The use of concept maps was also strongly endorsed by the majority of students in their comments in the various forms of feedback. The students appreciated the use of concept maps developed by the lecturers which were projected during lectures to summarise information, or to show the relationships between concepts previously presented. Their comments also showed that the majority of students felt that they benefitted from learning to construct their own maps throughout the semester. The tenor of the comments about concept maps was the same from both the University of Adelaide students and the University of South Australia students. However the latter group who were studying geology as part of their science teacher training course consistently commented on the practical use of concept maps. They were already familiar with the theory of the use of concept maps from the literature and from their studies in the education studies part the course, but for most this subject was the first time that they had had the opportunity to practise using them. The positive responses by this group of students reinforces the idea that the incorporation of concept mapping into the teaching is beneficial to learning.

Research Question 3

Is there a gender related difference in students' attainment in structural geology and geophysics after the modification of teaching methods?

The results of the independent-t test to determine the influence of gender on attainment show that there is no significant difference in structural geology or in petroleum geophysics in any of the years 1992-1995. The only significant difference in the performance of males and females was in the mineral geophysics component in 1993 when females out-performed the males in the group. When the 1993 and 1994 groups were combined into one sample and the first year score was used to reduce the error of variance, the results were the same. The two-way analysis of variance (ANOVA) showed that there was no significant difference between the performance of males or females for structural geology or petroleum geophysics. The only significant difference was in the mineral geophysics section which is consistent with the results from 1993. However when a two-way analysis of covariance (ANCOVA) was carried out using the first year score as the covariate and removing the variation in the scores due to the difference in how well individual students performed in first year, gender was no longer significant.

Conclusion

These results show that the modification to the teaching methods did not favour males or females.

Research Question 4

Is there any difference in attainment between the 1993 and the 1994 cohort?

It was thought that there may be some improvement in the performance of students from one year to the next as the experience of using the modified teaching methods grew in the teaching staff. However, there was no significant difference between the 1993 cohort and the 1994 cohort of students in their performance in structural geology. The two-way ANOVA was carried out to look at the difference in performance between the 1993 and the 1994 groups in each of the examination components and also in the first year exam score. The only significant difference was again in the mineral geophysics where the mean examination score was 58 in 1993 and 37 in 1994. There was no significant difference between the performance of the two cohorts in structural geology, petroleum geophysics or first year. In this case when the two-way ANCOVA was carried out using the first year score as the covariate and removing the variation in the scores due to the difference in how well individual students performed in first year, the difference in performance between the two cohorts in mineral geophysics remained significant.

Conclusion

Although this analysis only compared two consecutive years the correspondence between the two cohorts suggests that the influence of individual teachers has less effect than does the change in the methodology.

Research Question 5

Are first year results a good predictor of success in second year?

The final part of the analysis was to determine if the end of first year score could be used to predict success in second year. The two-way ANCOVA showed a statistically significant relationship between the first year score and each of the components of the structural geology and geophysics examination. The Pearson's Product-Moment Correlation Coefficient analysis also showed a statistically significant correlation between the first year score and each of the components of the structural geology and geophysics examination.

Conclusion

The results indicate that students' attainment in first year introductory geology classes are a good predictor of success in second year geology subjects.

This consistency of performance from one year to the next and the similarity in performance of the different year cohorts supports the hypothesis that the modified teaching methods in structural geology are responsible for the improved performance relative to:

- the performance of students in the years preceding the introduction of the modified teaching methods; and
- the performance of students in geophysics in which traditional teaching methods were used.

8.121 Summary

Prior to 1992 both components of the second year structural geology and geophysics subject were taught by traditional methods using fairly formal discursive lectures and practicals. From 1985 to 1995 the structural geology component was taught by the same person, during which time there was only minor modification to the content. From 1992 the teaching methodology for the structural geology component of the subject was modified taking into account the constructivist model of learning. Coinciding with this change in approach to teaching was a change in relative examination performance between the structural geology component and the geophysics component of the subject. From 1985 to 1991 both parts of the subject had an average examination score of close to 60% and neither part was consistently higher than the other. From 1992 to 1995 there was a change to this pattern wherein the mean score for structural geology climbed above 60% and was consistently higher than the mean examination score for geophysics which remained at about 60%. The statistical analysis shows that there is a strong correlation between the two components and that the difference is significant.

It is possible that the difference is due entirely to the ability of the teacher rather than the methodology but if this was so, the structural geology scores should have been consistently higher prior to the introduction of the modified teaching. This possibility is further negated by the results of the investigation with first year students at the University of South Australia where the students who were taught to use concept maps performed better and the same teachers were involved with both groups.

8.13 Introductory Geology Study

This study directly compared two similar groups which were taught differently. One group was taught to construct and use concept maps, the other group was not. This was the only difference between the teaching methods for the two groups. The principal purpose of the study was to evaluate research reported in the literature which shows that the use of concept maps in tertiary teaching improves meaningful learning and understanding.

Research question 6

> **Was the teaching modification incorporating the use of concept maps successful in improving achievement by students in the first year introductory geology subject?**

This question relates specifically to the effect of using concept maps on the performance of students in tests designed to test knowledge of the subject, understanding and application of the knowledge. Two tests were administered to the students before the teaching of the subject began and two were administered at the completion of the subject.

The Pearson Product-Moment Correlation test shows that there is a statistically significant correlation between the individual students' university entrance scores and their performance in each of the end-of-subject tests. This shows that the entrance score can be used to remove the variation in initial ability between the two groups. The comparison of the two differently taught groups shows that there is no significant difference in their university entrance scores or in their pre-test scores, but that there is a significant difference between the scores of the two groups on the end-of-subject test scores. The similarity between the scores of the two groups in the pre-test shows that there was no difference in their prior knowledge so any difference in the scores at the end of the subject must be the result of something that happened during the teaching of the subject. The group which was taught to construct and use concept maps achieved higher scores on each of the end-of-subject tests suggesting that they had better understanding and were able to apply their knowledge better. The statistically significant difference between the performance of the two groups was shown by both the ANOVA method and the ANCOVA method using the university entrance score as a fixed variable. These results are consistent with those obtained from the study of using modified teaching methods for teaching structural geology in the second year geology course and thus reinforce the conclusion that the modified teaching methods result in more meaningful learning. Because the teachers were the same for both groups in the first year study, the possibility that the higher achievement is the result of a better teacher rather than better teaching methods is reduced.

Conclusion

The higher achievement of the group taught using concept maps supports the hypothesis that the teaching modification incorporating the use of concept maps was successful in improving achievement by students in the first year introductory geology subject.

8.132 Research question 7

Was there a gender related difference in students' attainment?

The comparison of the achievement of males and females shows that the initial difference was changed neither by the way the subject was taught nor by any other of the subjects that the students were taught during their first year in the first year courses that they were studying. There was a statistically significant difference between the entrance scores of the males and females and there is a similarly significant difference between their scores on the total of the end-of-subject test scores, with males scoring higher in both. This suggests that the teaching method does not favour either gender. This is consistent with the results from the study of using modified teaching methods for teaching structural geology in the second year geology course which showed no difference between the performance of males and females.

When the performance of the males and females in the individual tests is compared the results are not as consistent. There is no significant difference (at $\alpha = 0.05$) between the scores for either the pre-test or TEST3. The significant difference between males and females in the entrance scores suggests that for this particular cohort, males were more successful learners than females when they began their university studies. Both the entrance tests and the post-subject tests are to determine how successfully students have learned a specific subject and therefore test the students ability to learn a topic. The pre-test on the other hand does not measure successful learning, rather it measures the pre-existing knowledge about the subject that the students had prior to the teaching of the subject. The result shows that there was no difference in this the pre-existing knowledge between males and female, but that there was a difference in the ability to learn, as measured by end-of-subject exams and this difference was unaffected by the teaching method.

For TEST3 there is no significant difference (at $\alpha = 0.05$) between the performance of males and females but the difference is significant at $\alpha = 0.1$ and males achieved higher than females which is consistent with the other post-subject tests and the University Entrance scores.

8.133 Research question 8

Are Year 12 results a good predictor of success in introductory geology?

There is a high correlation between the university entrance score and each of the post-subject test scores indicating that the entrance score is a good predictor of a student's chance of success as measured by attainment in tests and examinations.

Summary

The results of this part of the study show that, for one cohort of students, the use of concept maps has caused a significant improvement in their achievement as measured by attainment in tests and examinations when compared with a similar cohort of students who were not taught concept mapping, but were otherwise taught in exactly the same way. This result is consistent with those of the other part of the study where examination achievement in structural geology improved when the use of concept mapping was introduced. It is suggested that the difference in achievement is the result of more meaningful learning by the more successful cohort of students.

Chapter 9

SUMMARY AND CONCLUSIONS

9.1 INTRODUCTION

This research has reviewed aspects of geology curricula in secondary and tertiary education. It has investigated the geology curriculum at three levels and the relationship that exists between one level and the next. At the secondary school level the way in which the senior geology/earth science curricula link to the introductory geology curriculum at tertiary level was of particular interest. The introductory tertiary geology curriculum was viewed from the perspective of the effect of prior knowledge on student performance and the advanced tertiary geology curriculum was investigated in the context of quality teaching and learning using the structural geology part of the curriculum as a focus.

The review of the senior secondary school curriculum involved a comparison of geology/earth science curricula for the Australian states and the K-12 science curriculum statements for Australia, the United States, and England and Wales. The content of each of the Australian state senior secondary school geology/earth science curricula was studied in detail and the aims and objectives and assessment methods were compared. The development of the goals and the content of the Earth Systems approach to science education, which was proposed by Mayer et al (1992) in the United States, was reviewed and was used as a framework for the comparison of the content of all of the curricula including the K-12 statements. The content of the Australian state senior secondary school geology/earth science curricula was also compared using the more traditional framework which has dominated geology/earth science curriculum design for many years.

This review of the Australian state senior secondary school geology/earth science curricula was then used as the basis for studying pre-requisite knowledge required for introductory tertiary geology/earth science subjects. The advanced geology curriculum study investigated the quality of teaching and learning in structural geology and was carried out as an action research project. During the project teaching methodologies were modified to try to improve the quality of student learning. The modifications involved changing the way information was delivered to students and included a move towards the development of electronic courseware, changing the structure and organisation of the curriculum and introducing and encouraging students to use new learning strategies, particularly concept maps.

The outcomes of the modifications were evaluated quantitatively using end of year subject examinations results, and qualitatively by analysing student evaluation of the subject, by interviews and teaching questionnaires and reflective journals kept by the students. The quantitative results showed that there was a statistically significant improvement in student learning as measured by end of subject examination performance as a result of the modifications and this was supported by their comments in the evaluation questionnaires, interviews and in their comments in reflective journals.

This final chapter draws together the conclusions that have been reached about the different aspects of geology curricula that have been studied and goes on to make some recommendations about the methodologies and follow-up studies and actions that should be pursued in the area. These conclusions and recommendations are grouped under the headings of the three main aspects of the geology/earth science curricula that have been studied, namely: the syllabus framework and content, assessment and teaching of the senior secondary geology/earth science curriculum; the implications of prior learning for the introductory tertiary geology/earth science curriculum; and quality teaching and learning in the advanced tertiary geology/earth science curriculum.

9.2 SECONDARY GEOLOGY/EARTH SCIENCE

9.21 Syllabus Content and Framework

Geology/earth science is an important and some would say an essential part of everyone's education (Carpenter 1990; Dineley 1990; AGI 1991). Although generally acknowledged by science curriculum designers, this belief has not been implemented in Australia until recently. The inclusion of geology/earth science components in the curriculum document *A Statement on Science for Australian Schools* (AEC 1994) which has been produced to guide K-12 science curriculum design in Australia is mirrored by similar developments in the United States and the United Kingdom.

The study of Australian senior secondary geology/earth science curricula reveals that, with one exception, they are very similar in content and follow the same traditional framework that has guided geology/earth science curriculum design for many years. This framework enables the study of geology to be broken into discrete packages and does not encourage the links between different parts of the discipline to be made. Whilst this traditional framework may be useful in an introductory tertiary course where students are going on to a more detailed study of the discipline and will be able to explore the connections between the different parts as they go, it is not valuable to a student who will not study geology again.

The geology/earth science curriculum should equip students with an understanding of the Earth and its environs that enables them to make rational and informed decisions about the environment. We need to ensure that the geology/earth science education that they receive prepares our future physical scientists, engineers, economists, politicians and industrialists to understand the relationships between the processes scientists have harnessed for economic and defence purposes and the Earth system from which they were derived. A powerful case can be made for making the Earth System a central organising theme for the senior secondary geology/earth science curriculum and for future K-12 science curriculum development.

In the past the junior secondary geology/earth science curriculum has been a watered down version of the traditional senior curriculum. In many cases it was taught by teachers who had no formal training in geology/earth science who consequently were unable to design a relevant or motivating curriculum. The development of the Australian K-12 curriculum provided an opportunity to change this, however, the curriculum guidelines contained in the *Statement on Science for Australian Schools* still does not guide teachers and curriculum developers to prepare a balanced or relevant geology/earth science curriculum. Issues such as global warming, species extinction, soil degradation and water quality will dramatically affect the human population in the future. An understanding of these short term global changes is essential for the health of future generations of humans and the planet as a whole, it is therefore disappointing that the statement on science for Australian schools does not address these issues very strongly. The geology/earth science content of the national curriculum needs to be rethought.

9.22 Assessment

It is apparent that much of the teaching and learning at the senior secondary level is assessment-driven. This is principally because students need to obtain a high score to gain university entrance. There is little doubt that assessment exerts a disproportionate influence on what students actually choose to learn. At Year 12 level it appears that students focus their learning efforts on what they believe will be assessed. Even though curriculum documents indicate that problem-based learning, critical thinking, high level analysis, and synthesis of ideas should be encouraged, the focus of assessment is end of subject exams which emphasise rote learning and uncritical regurgitation of information. Students are encouraged to this attitude by subject associations which publish books of past exam papers containing type answers and which arrange meetings where students can meet the examiners.

The consequence of this is that although the majority of students come to undergraduate courses computer literate, possessing good keyboard skills and with sophisticated research skills, they are generally unprepared to be independent learners and without many of the skills required to be life-long learners. Since preparing independent and lifelong learners is often one of the aims of undergraduate courses it is important to bear these student attributes in mind when framing undergraduate course and when setting subject objectives.

9.23 Teaching

The workload of teachers in schools has increased to the point that they have very little time to develop new teaching techniques, read around their subject or prepare courseware materials. The reduction in funding for professional development activities and the limited opportunities for teachers to attend the courses or conferences which are available because of the need to replace them while they are away adds to the dilemma.

For these reasons there is little innovation in teaching methods and little in the way of innovative curriculum development. To encourage better teaching and motivate better curriculum development in the geosciences, tertiary institutions and professional societies should become more involved in professional development both at the curriculum development level and by presenting workshops and short courses. However, involvement should be in partnership with teachers and teacher associations. Much better results will come from curricula and curriculum support materials which are developed through partnerships between classroom teachers, content experts, and design experts and, where appropriate, software experts. Positive results have come from partnerships between teachers and professional geologists sponsored by the Geological Society of America (Palmer, 1992) and more relevant curricula have resulted from collaborations between teachers and tertiary experts. On the other hand, many attempts at the preparation of materials for use in the classroom by professional associations and private organisations such as mining companies have been expensive failures.

As well as curriculum development, there is also a need for teachers to be able to upgrade their knowledge and in some cases their skills. The increasing emphasis on science in the K-6/7 grades means that many teachers have limited experience with and/or lack confidence to teach these topics. Tertiary experts with the help of teacher associations can help in this area by arranging workshops and short courses. Once again the design and content of workshops and short courses needs to be carefully planned and should be done in partnership with participants (Carpenter in press).

9.3 INTRODUCTORY TERTIARY GEOLOGY/EARTH SCIENCE

The study of the nature and effects of prior knowledge on students' attitudes and achievement in introductory tertiary geology/earth science subjects showed some interesting results. Although the follow-up study was not completed, analysis of the data collected provided some useful insights into the range of prior knowledge of students and it appears that students' prior knowledge has some effect on their performance and attitudes. With the implementation of science curricula guided by *A statement on science for Australian schools* it is likely that all students coming to universities will have been taught some geology/earth science. This has not been the case in the past and has implications for the design and content of introductory curricula. It is recommended that a properly designed study should be conducted over several years to determine the effects of prior knowledge, so that they can be taken into account in the design of introductory geology/earth science curricula. To be successful this will have to be undertaken in association with the subject coordinator or with his or her full cooperation.

9.4 QUALITY TEACHING AND LEARNING

The study of quality teaching and learning involved an evaluation of the effects of modified teaching and delivery methods on student learning in an advanced structural geology class which was carried out over a period of more than three years. The modifications to the teaching involved changes to the traditional lecturing style, the use of computers to deliver information and the introduction of concept mapping as a learning tool. The changes were based in the constructivist theory of learning and resulted in modifications to the content and content sequence of the curriculum. The conclusions and recommendations from this aspect of the study of geology curricula are grouped under three headings: the overall outcomes; concept maps and science education; and computer delivery and courseware.

9.41 The Overall Outcomes

The study of the effects of modified teaching and delivery methods clearly showed that student achievement improved, as measured by end of subject examination results. There were two related parts to the study with one part looking at a range of teaching modifications on student learning in advanced structural geology, and the other part looking at the effect of one modification on student learning in an introductory geology subject. In both parts of the study the quantitative results showed that the average mark for the end of subject examination increased significantly after the modification to the teaching methods in both parts and the qualitative results confirmed this by showing that the students felt that the modified methods were helpful and contributed to improved learning.

The overall conclusions to the study are that the modified teaching methods have improved student learning and this is confirmed by the results of the two different but related parts. Similarly the results in both parts of the study show that the modification to the teaching methods do not favour males or females. The results of the study with the students in the advanced subject show that student achievement in an introductory subject is a good predictor of success in advanced subjects. In the other part of the study a related result is that a student's university entrance score is a good predictor of success in the introductory geology class.

There is scope to follow-up this study by looking at the continuing effects of the improved learning techniques that have been introduced. Will the students continue to be better learners? Will they be more motivated as a result of better understanding and greater success?, and Has their attitude to, and interest in geology/earth science changed?

9.42 Concept Mapping and Science Education

The methods used for the modifications to teaching were founded in well researched and reported science education theory and the results of this study show that the methods are successful. Much of the theory, however, is based on studies which have been carried out in primary and secondary schools. Very few of the reported studies have been done with tertiary students and even fewer have been carried out in geology/earth science departments or with geology/earth science students. It is clear that Science Education has much to offer the teaching of tertiary science but in most universities Science Education research is carried out in the Education Faculty and the teaching of science is carried out in schools/departments in the Science Faculty. Improving and increasing the communication between these two groups will be of benefit to both groups, for example if opportunities were available for science educators to conduct research in science departments it would enable them to broaden their research base and work collaboratively with university science lecturers who are consciously or unconsciously modifying the way they teach in response to student evaluations or administrative pressures. The benefit to the science department is the potential to improve the quality of teaching and learning by having the results of modifications rigorously evaluated and by having access to up to date science education developments. Such partnerships will allow science teachers to practise soundly based, high quality teaching methods without spending valuable time away from their other activities. This latter concern is addressed by Laurillard (1993) who suggests:

> *A relatively low proportion of academics read the research journals on teaching in their subject. Reading is now a luxury for academics, and the precious time there is must be for research, or at best scholarship, never teaching itself. In*

> *fact, many of the journals of subject teaching reflect this concern, being devoted entirely to informing the teacher about developments in the subject, and about teaching strategies based on experience in the classroom, rather than an analysis of what students are likely to need.* (Laurillard 1993, p191)

Science departments will benefit from being able to use the results of the research to demonstrate their commitment to good educational practice.

Possible areas for research include the nature and impact of misconceptions held by students, the significance of prior learning, encouraging students to take responsibility for their own learning, and ways of preparing students for lifelong learning.

9.43 Computer Delivery and Courseware

Courseware is a package of teaching and learning materials that is delivered to students via a computer (Edwards 1995). This study shows that the incorporation of courseware into the teaching of geology/earth science has been influential in improving student learning. Student evaluations of teaching indicate that they appreciate the benefits of courseware such as self-paced tutorial and learning packages. It is clear that courseware should be used where possible, however there are problems associated with this, the principal one being cost. Commercially available packages are expensive and rarely contain exactly what is needed or give complete coverage of a particular topic. They also go out of date quickly either because of the software or the content. Generally speaking it is better to prepare in-house material using authoring packages such as Powerpoint, Authorware Professional or HyperStudio (Edwards 1995), but this is also expensive and the product is not always as good. Preparation of packages is expensive in time and money. Software and hardware costs are high as is the time to learn them. Once the software has been learned, there is the still developmental time needed to prepare the packages all of which is time away from face-to-face contact with students and research.

Laurillard (1993) suggests that media-based materials, including computer programs, are too expensive to be developed by individuals, or by departments, or even by individual institutions. She suggests that to be economically feasible, they must be made available, and used by, larger numbers of students than one institution can provide. Whilst this may not be true for distance learning institutions it is true for campus-based teachers. A possible solution is to have inter-institutional collaboration to provide the larger student numbers needed. It is still necessary to be selective about what areas of the curriculum are catered for with these materials.

> *The two key criteria for selecting specific areas of the curriculum for development are that topics must be (a) taught widely, and (b) widely acknowledged to present difficulties for students* (Laurillard 1993, p 182).

Structural geology certainly fits these criteria but introductory geology is not widely acknowledged to present difficulties for students. In fact introductory geology is probably one of the least difficult science subjects. Thus consideration for preparation of expensive multi-media materials for introductory geology needs to carefully considered. In the case of structural geology it seems that the feasibility of developing these materials depends on collaboration between institutions. Collaborative development avoids expensive duplication of effort and allows pooling of the best ideas to ensure that the best possible packages are prepared.

9.44 Evaluation and Action Research

This research has relied heavily on the students' evaluation of teaching. Evaluation of teaching by students can be viewed as more than a tiresome task imposed by the administration at the end of a subject. It has been shown in this study to be a valuable source of information towards improving the quality of teaching and learning. Although students in science departments are not used to providing formative feedback in the form of reflective journals, questionnaires and interviews, with time and patience, they can be persuaded to participate and the outcomes for the teacher and the student make the effort worthwhile.

The responses to information gleaned from the various forms of evaluation in this case were changes to the teaching methodology. This kind of self-reflective enquiry into one's own teaching is a form of action research, especially as it was designed to promote understanding of what counts as quality teaching and learning. Action research also involves collaboration, critical reflection, theorising, and strategic action. All of these processes are part of most university teaching practice. Initially this kind of approach to teaching may seem daunting, but the benefits can be seen in a relatively short time for both the teacher and the students. This view is supported by Schratz (1993) who contends that action research is both rewarding and contagious:

> *After assessing the first phase of the project "Researching While Teaching' at Innsbruck University, it can be said that this kind of action approach to teaching in higher education is not only valuable experience for the individual participant. Looking into one's own teaching practice through the eyes of a researcher is a challenging task for both faculty and student if they are willing to venture into this rich and virtually untapped resource for the improvement of teaching, curriculum and learning. Although the extra work sometimes meant spending more time on the actual teaching, most participants gained satisfaction out of this approach, as can be found, for example, in the following statement of a participant in the project:*
>
> *By dealing more intensively with my teaching commitments I got more joy out of them, which contributed to the good mood I felt in class. Moreover, through the ripple effect of attracting more and more people in a department or institution unit, this approach helps in making reflective teaching a vital part in organisational development* (Schratz 1993).

9.5 CONCLUSION

This research has investigated aspects of geology curricula in secondary and tertiary education and the relationships that exists between them. It is apparent from the outcomes that the content and framework of senior secondary geology/earth science curricula are not relevant to the widely accepted aims of geology/earth science education and that more consideration should be given to alternative frameworks to cater for a more diverse student population. Another conclusion is that prior knowledge of geology/earth science topics has an important influence on students' achievement in and attitude to introductory tertiary geology/earth science subjects and should be assessed and taken into account when developing introductory curricula. Finally, it has been shown that modifications to the curriculum content and the way it is delivered has affected student learning and that the incorporation of strategies into the teaching process such as demonstrations and the use of concept maps has increased the possibilities for student learning.

APPENDIX

QUEENSLAND Years 11and 12 content statement

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Astronomy Earth & Moon system Solar System **Physical Geology*** Water cycle	**Mineralogy** Identification of minerals using physical properties **Petrology** Origin and characteristics of 3 major rock types; rock cycle; classification **Physical Geology*** Weathering, erosion and sedimentation; landforms	**Palaeontology & Geological Time** Fossils, relative time scale **Stratigraphy*** Principles	**Geotectonics** earthquakes; internal structure and composition of the Earth; continental and oceanic crust; plate tectonics **Structural Geology & Geological Mapping** Deformation features, unconformities, maps	**Economic Geology** Origin, mining and uses of Earth materials; exploration methods	**Physical Geology*** Soil forming processes, classification; land degradation, desertification, effects of humans **Stratigraphy*** Geological history of local area
*** Topic covered in more than one part**					

Table 1

NSW 2 Unit course Core component

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
	Surface Processes Weathering, transportation, deposition; landforms **Earth Materials** Common silicates, structures & physical properties; igneous rocks - origin & composition; sedimentary processes & products; metamorphism & metamorphic textures & structures	**Geological Time** Immensity of time; fossils & fossilisation; superposition, correlation and relative time; absolute time	**Solid Earth I** Shape of the Earth; internal structure & geophysical properties; earthquakes; continents and oceans; isostasy **Solid Earth II** Dynamic nature of Earth; evidence for continental drift; concept of sea-floor spreading; plate tectonics	**Geology & Society*** Finiteness of geological resources; political factors; formation of Earth resources; economic factors; engineering geology	**Geology & Society*** Exploitation versus conservation; quality of environment; environmental effects of exploitation; restoration

Table 2

NSW 2 Unit course ELECTIVES

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Earth as a Planet* Earth's place in the Solar System. Earth tides and Earth-Moon system	**Mineralogy & Crystallography** Classification of minerals, symmetry, optical properties; identification **Contemporary Sedimentary Processes** Investigation of a modern sedimentary environment and all of its characteristics **Igneous Rocks** Identification and classification of volcanic and plutonic; origin; related ore deposits **Metamorphism** Mineralogy, zones and grades, texture and structure of regional and thermal metamorphic rocks; distribution	**Palaeontology** Fossil history of the major groups of invertebrates, vertebrates and plants of NSW & Australian significance **Stratigraphy** Principles of stratigraphy and application to geological time; facies; radioactive age dating and its application	**Mapping & Structures** Interpretation of 3-dimensional relationships of rocks; nomenclature identification and description of deformation features; simple field mapping; intepretation of geological maps **Earth as a Planet*** Internal structure, composition and large-scale dynamic processes	**Economic Geology** Study of two types of economic deposit in terms of its genesis, exploration, evaluation, extraction, economics, management, and environmental implications **Exploration Geology & Geophysics** Techniques & procedures used in exploration for mineral deposits including energy resources	**Regional Geology** Field, laboratory and reference study of the geology of a region of NSW **Mountains** Variety, distribution; composition, formation and human effects of volcanic and tectonic mountains **History of ideas in Geology** Case histories of some significant ideas in geology (uniformitarianismage of the Earth, Continental Drift etc.)

Table 2 (continued)

NSW 3/4 Unit Course - CORE

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Origins* Origin of elements, the Universe and Solar System; origin of the Earth; history of atmosphere, hydrosphere and lithosphere		**Dynamic Earth** Internal structure and composition of the Earth and seismic evidence; lithosphere; continental drift, sea-floor spreading and plate tectonics	**Origins*** Origin of life, meaning of absolute and relative age; age of the Earth; fossils; superposition		**Origins*** Evolutionary theory, natural selection and evolution of life

Table 3

NSW 3/4 Unit Course - OPTIONS

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Chemistry and the Environment* Atmospheric composition and cycles; water supplies and cycle	**Surface Processes & Stratigraphy*** Weathering, sedimentary processes & environments **Earth Materials*** Physical and chemical properties of silicates and their identification; igneous rocks and processes; sedimentary rocks; metamorphism		**Surface Processes and Stratigraphy*** Uniformitarianism	**Chemistry and Environment** Nuclear power, nuclear reactions, disposal of nuclear wastes **Earth Materials** Formation of fossil fuels; concentration of useful minerals by igneous and sedimentary rock-forming processes **Geological Resources** Environmental considerations for exploitation of mineral deposits; finiteness of resources; management considerations; mining methods; engineering geology	**Regional Geology** Field and laboratory study of a region of NSW **Mountains** Variety, distribution; composition, formation and human effects of volcanic and tectonic mountains

Table 3 (continued)

South Australia Year 11

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structures	Part 5 Earth Resources	Part 6 Other Topics
Water from the Ground* Ground water resources, storage, formation and extraction; management & pollution problems **Oceanography*** Sea level changes, tides, weather patterns **Planetary Geology** Structure and formation of the Solar System; Earth in space, meteors, solar activity and effects on humans; impacts	**Minerals*** Identification of minerals using physical properties **Restless Earth*** Volcanoes and igneous processes; igneous landforms; global distribution; planetary and local volcanic activity **Water from the Ground*** Limestone caves and karst processes	**Restless Earth*** Earthquakes, measurement, interior of the Earth; continental drift, seafloor spreading and plate tectonics **Oceanography*** Seafloor features; oceanic crust and processes, palaeomagnetism; plate tectonics	**Dinosaurs and Dating** Geological time, age of the Earth, stratigraphy; fossils and their uses; history of life on Earth; uniformitarianism	**Minerals*** Use of metallic and non-metallic mineral resources; formation of metallic minerals; extraction of metals; mineral exploration; mining; non-metallic mineral uses, location and extraction; environmental considerations **Restless Earth*** Effects of volcanoes on human activities **Energy for Society*** Energy resources, their formation and distribution; finiteness of energy resources and their economic and environmental cost; alternative energy resources	**Minerals*** Rehabilitation of mine sites **Geology of local area** Economic, physiographic and geological features of the Earth's crust in the local area **Energy for Society*** Energy efficient housing **Oceanography*** Life in the sea, pollution, cycles; chemistry of the sea **Greenhouses and Ice Ages** The Greenhouse Effect, global warming; ice ages; local evidence for past climatic change; future climates

Table 4

South Australia Year 12

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structures	Part 5 Earth Resources	Part 6 Other Topics
Hydrology Porosity, permeability, aquifers, artesian supplies	**Minerals** Classification; physical properties and identification; crystals; formation of minerals **Igneous Rocks and Products** Magma; extrusions and intrusions; composition texture and classification of igneous rocks **Surface Processes and Sedimentary Products** Weathering; erosion transport and deposition; depositional environments; sedimentary rocks	**Stratigraphy** Superposition; unconformities; correlation; relative and numeric time and time scales **Numeric Dating** Isotopic methods, applications and difficulties; other methods **Fossils** Preservation, uses; fossil record **Geology of Australia** Shields, orogenic zones, basins	**The Interior of the Earth** Seismicity; gravity; magnetism; heat; structure, slate, density and composition of the Earth's interior **Deformation of the Earth's Crust** Stress and strain; brittle deformation; ductile deformation; geological mapping **Structure and Composition of the Earth's Crust** Continental crust; oceanic crust; continent - ocean margins	**Energy** Fossil fuels, formation finiteness; nuclear fuels, types, fission and fusion; geothermal energy; environmental considerations **Metals** Formation and identification of ore minerals **Rocks and Non-metallic Minerals** Construction materials; industrial minerals; gem stones	**Exploitation of Earth Resources*** Environmental considerations **Geology of SA & NT** General features, major geological provinces **Field Studies** Geology of local area or excursion site

Table 5

South Australia   Year 12

	Metamorphism and Metamorphic Rocks Metamorphism; factors affecting metamorphism; types of metamorphism; metamorphic rocks	**Earth Models** Continental drift; seafloor spreading; plate tectonics	**Exploration for Mineral Resources** Mapping, geochemical and geophysical methods; drilling; exploration program **Engineering Geology** Siting constructions **Exploitation of Earth Resources** Economic considerations; case studies		

Table 5 continued

Victoria

	Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Unit 1		**Geology and land use** Weathering and erosion and other controls of landscape	**Geological Time** Geological time scale, fossils, fossil record			**Geology and land use**
Unit 2		**Earth Materials** Minerals, rocks and the rock cycle			**Earth materials: origin,detection and recovery** Formation of earth resources, exploration, mining, and environmental effects. **Earth materials: economic and politics** uses, political considerations	
Unit 3				**Origin and Structure** Plate tectonics, structure and composition of the Earth, origin of the Earth.		
Unit 4		**Geomorphology** Landforms as products of weathering and erosion	**Stratigraphy** principles, absolute and relative time, uniformitarianism,			

Table 6

Western Australia Year 11 Syllabus

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Earth in Space Universe, Sun as a star, Milky Way Galaxy. Solar System, inner and outer planets. Evolution of stars and the Universe, the Solar System. Crystallisation of the Earth's crust.	**Mineralogy** Elemental crustal abundances, common mineral compositions; rock forming minerals; formation of minerals; identification of minerals. **Rock Cycle** A. Igneous rocks. Formation from a magma, relation to crustal location, intrusive and extrusive activity, volcanism on other planets; classification. B. Sedimentary rocks Surface processes, sedimentary environments, soils, classification of sedimentary rocks. C.Metamorphic rocks. Solid state transformation; temp, pressure, fluids and time; classification	**Palaeontology-Time** Fossilisation, Index fossils & fossils as indicators of ancient environments,organic evolution. Immensity of geological time. Superposition, unconformities & the geological time scale(eras & periods)	**Earth Structure** Layered structure of Earth; location of volcanoes, earthquakes and plate boubdaries; crustal deformation structures	**Geology and Society** Mining and mode of formation of metallic mineral, non-metallic resources and fossil fuels. Environmental and engineering geology, hazards.	

Table 7

Western Australia Year 12 Syllabus

Part 1 Earth in Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
Earth in Space Universe, Sun as a star, Milky Way Galaxy. Solar System, inner and outer planets. Evolution of stars and the Universe, the Solar System. Crystallisation of the Earth's crust.	**Mineral Systems** Common min comp.; silicate structures, rock forming mins; Physical props, relationship to lattice structure; id of minerals. **Melting of Lithosophere** Bowens Reaction Series, magmatic history, igneous assoc, origin of magmas, xenoliths; id of common rocks.	**Reconstructing Past Environments** **Ancient Life Forms** Fossilisation, Index fossils & fossils as indicators of ancient environments,evolution(eg trilobites, graptolites, ammonites) . Correlation	**Melting of Lithosophere Dynamics** Determination of the layered structure of Earth; Plate tectonics as an explanation for crustal features and deformation, continental drift and earthquakes. Isostasy and eustasy	**Crustal Resources** Ore deposits, formation of metallic mineral, non-metallic resources and fossil fuels. Environmental and engineering geology.	

Table 8

Western Australia Year 12 Syllabus

	Crustal Deformation Metamorphic grade, progressive metamorphism. id of common rocks, metamorphic textures. **Reconstructing Past Environments Ancient Environments.** Surface processes and sed rocks as indicators of past conditions; uniformitarianism Assoc resources; sed structures, textures and rock compositions; weathering	**Dating the Past** Absolute and relative time, principles of stratigraphy; radiometric methods, varves. Geological history of WA.	**Interpretation** Geological maps, cross-sections, block diagrams, folds, faults, dip & strike, geological history from maps, sections and field data.		

Table 8 (cont)

Proposed National Curriculum

Part 1 Earth In Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
BAND A (lower primary) Movements of the Sun Observe and record tides. Cyclic relationships, night & day, seasons, year.	Texture and composition of soils; weathering of buildings; floods	Evidence of recent changes to the local environment			Weather
Band B (upper primary) Exploration and investigation of the Universe Scale of Solar System, existence of stratosphere and ionosphere, holes in ozone layer, galaxies & black holes. Observe phases of Moon; identification of Milky Way, constellations. Eclipses; Sun as a source of energy	Surfaces processes; soil quality		Structure of crust and crustal features eg. volcanoes, earthquakes, craters, icecaps, oceans.	Soils and soil quality	Human impacts on the environment; Technology for space exploration Earth hazards

Table 9

Proposed National Curriculum (cont)

Part 1 Earth In Space	Part 2 Earth Materials	Part 3 Earth History	Part 4 Earth Structure	Part 5 Earth Resources	Part 6 Other Topics
BAND C (LOWER SECONDARY) Evolution of Sun and stars; life in other Solar Systems	Classify rocks and landforms Origin and formation of geological features; formation of soil. Rock cycle	Evolution of life	Australian continent. Investigate changes that result from continental drift, plate tectonics. Earthquake prediction.	Environmental impacts; Case study of a local mining industry' management of resources	Work of scientists in exploration of space, oceans, moon atmosphere.
Band D (upper secondary) Newer theories of science that explain planetary and stellar behaviour		Use of radioactive dating and the use of fossil markers to investigate evolution of Earth and Solar System		Relationship between exponential growth and finite nature of resources; use of earth materials; economic, political, social and geologic implications of resource development	Geological history of the local area

Table 9 (cont)

REFERENCES

AEC (1994). Science:a curriculum profile for Australian schools. Carlton, Victoria, Curriculum Corporation.

AEC (1994). A statement on science for Australian schools. Carlton, Victoria, Curriculum Corporation.

AGI (1991). Earth Science Education for the 21st Century: A Planning Guide. Alexandria, VA, National Center for Earth Science Education.

Ahmed, F. and D. Almond (1983). Field mapping for geology students. London, Allen & Unwin.

Allen, D., B. Bowers, et al. (1989). "Writing to learn: A reconceptualisation of thinking and writing in the nursing curriculum." Journal of Nursing Education **28**(1): 6-11.

Anderson, J. R. (1985). Cognitive Psychology and its implications. New York, W.H. Freeman.

Ault, C. R. (1985). "Concept mapping as a study strategy in Earth Science." Journal of College Science Teaching **15**(1): 38-44.

Ausubel, D. P. (1963). The psychology of meaningful verbal learning. New York, Grune and Stratton.

Ausubel, D. P. (1968). Educational Psychology: A cognitive view. New York, Holt, Reinhard and Winston.

Ausubel, D. P., J. D. Novak, et al. (1978). Educational Psychology: A cognitive view. New York, Holt, Rinehart and Winston.

AVCC (1993). Guidelines for quality assurance in university course development and review. Canberra, Australian Vice-Chancellors' Committee.

AVCC (1993b). Guidelines for effective university teaching. canberra, Australian Vice-Chancellors' Committee.

Baldwin, P. (1991). Higher Education: Quality and Diversity in the 1990s. Canberra, AGPS.

Barnes, J. (1981). Basic geological mapping: Geological Society of London Handbook Series. Walton Hall Bletchly Bucks, Open University Press.

Barrows, H. S. (1985). How to design a problem-based curriculumfor the preclinical years. New York, Springer Publishing Co.

Barrows, H. S. (1986). "A taxonomy of problem-based learning methods." Medical Education **20**: 481-486.

Bassis, M. and A. Guskin (1986). "Building quality: Research and the regional institutions." Change **18**(4): 57-60.

Batts, J. and L. Wilkes, Eds. (1993). Reflective journalling in Science learning. Promoting Teaching in Higher Education(Reports from the National Teaching Workshop). Brisbane, Griffith University Press.

Beyerbach, B. A. (1988). "Developing technical vocabulary on teacher planning: Preservice teachers' concepts maps." Teaching and Teacher Education **4**(4): 337-347.

Beyerbach, B. A. and J. A. Smith (1990). "Using computerised concept maping programs to assess preservice teachers' thinking about effective teaching." Journal of Research in Science Teaching **27**(10): 961-971.

Biggs, J., Ed. (1988). Approaches to learning and to essay writing. Learning Strategies and Learning Styles. New York, Plenum.

Bjornerud, M. G. (1991). "Conveying principles of finite strain with standard graphics software." Journal of Geological Education **39**(1): 23-27.

Boud , D. and S. Knights (1993). Designing courses to promote reflective practice. HERDSA Annual Conference, University of New South Wales,

Boud, D., R. Keough, et al., Eds. (1985). Promoting Reflection in Learning: A model. Reflection: Turning Experience into Learning. London, Kogan Page.

Boud, D. and R. Walker (1991). Experience and Learning: Reflection at Work. Geelong, Deakin University Press.

Bousquet, W. S. (1982). "An application of Ausubel's learning theory to environmental education: A study of concept mapping in a college natural resources management course. (Doctoral dissertation, Ohio State University, 1982)." Dissertation Abstracts International **43**: 1515A.

Brimley-Norris, C. (1991). "Evaluation of English oral skills through the technique of writing." System **19**(3): 203-216.

Bruner, J. (1966). Towards a Theory of Instruction. Cambridge, Mass., Havard University Press.

Candy, P. C., G. Crebert, et al. (1994). Developing lifelong learners through undergraduate education. National Board of Employment, Education and Training.

Carey, S. (1985). Conceptual changes in childhood. Cambridge, Mass., MIT Press.

Carpenter, J. (1994). "(Geo) Science education reform in the United States: an overview." Teaching Earth Sciences **19**(1): 8 -14.

Carpenter, J. (in press). Characteristics of effective inservice instructions for teachers. Proceedings of the First International Geoscience Education Conference, Southampton,

Carpenter, J. R. (1990). "Importance of Earth science in the precollege curriculum." Journal of Geological Education **38**(5): 445-451.

Carpenter, J. R. (1993). "An overview of geoscience education reform in the United States." Journal of Geological Education **41**(4): 304-311.

Carroll, M., Ed. (1994). Participatory curriculum design: Journal writing as a learning and research tool for adult ESL students. Adelaide, University of South Australia.

Clark, B. (1987). The Academic Life: Small Worlds, Different Worlds. Princeton, Carnegie Foundation for the Advancement of Teaching.

Clark, I. and B. Cook (1983). Geological Science: Perspectives of the Earth. Canberra, Australian Academy of Science.

Clement, J., Ed. (1987). Overcoming students' misconceptions in physics: The role of anchoring intuitions and analogical validity. Proceedings of the Second International Seminar on Educational Strategies in Science and Mathematics. Ithaca, New York, Cornell University.

Cliburn, J. W. J. (1986). "Using concept maps to sequence instructional materials." Journal of College Science Teaching **15**(4): 377-379.

Compton, R. (1985). Geology in the field. London, John Wiley & Sons.

Confrey, J. (1984). An examination of the conceptions of mathematics of young women in high school. American Educational Research Association, New Orleans,

Corcoran, M. and S. Clark (1984). "Professional socialisation and contemporary career attitudes of three faculty generations." Research in Higher Education **20**(2): 131-153.

Cowan, J. (1991). "Opinion: Commenting on learning journal entries." Educational and Training International Journal **28**(3): 261-264.

Dantono, M. and P. Beisenherz (1990). "Don't just demonstrate-motivate!" The Science Teacher **57**(2): 27-29.

De Neve, H. (1992). "University teachers' thinking about lecturing: student evaluation of lecturing as an improvement perspective for the lecturer." Higher Education **22**(1): 63-91.

Dennis, J. (1987). Structural geology, an introduction. Wm C Brown.

Dentith, M. and A. Trench (1992). "Teaching geophysics to students with various scientific backgrounds." Journal of Geological Education **40**: 325-328.

Dewey, J. (1933). How we think: A restatement of the relations of reflective thinking and the educative process. Chicago, Henry Regney.

Dewey, J. (1938). Experience and Education. New York, Collier Books.

Dineley, D. (1990). "The role of earth sciences in secondary schools in England and Wales." Journal of Geological Education **38**: 458-460.

Donald, J. (1984). "Quality indices for faculty evaluation." Assessment and Evaluation in Higher Education **9**(1): 41-52.

Donaldson, M. (1978). Children's Minds. London, Fontana.

Driver, R. (1983). The pupil as a scientist. Milton Keynes, Open University Press.

Duckworth, E. (1987). The Having of Wonderful Ideas. New York, Teachers College Press, Columbia University.

Edwards, D. (1995). "Recent developments in courseware for university teaching." Teaching Earth Sciences **20**(1): 3-6.

Emden, C., Ed. (1991). Becoming a reflective practitioner. Towards a discipline of nursing. Melbourne, Churchill Livingstone.

Entwistle, N., Ed. (1988). Motivational factors in students' approaches to learning. Learning Strategies and Learning Styles. New York, Plenum.

Entwistle, N. and P. Ramsden (1983). Understanding Student Learning. London, Croom Helm.

Entwistle, N. and H. Tait (1990). "Approaches to learning, evaluations of teaching and preferences for contrasting academic environments." Higher Education **19**: 169-194.

Everett, J. and L. Entrekin (1987). Academic Attitudes. North Ryde, Methuen.

Feldman, K. (1976). "The superior college teacher from the students' view." Research in Higher Education **5**: 243-288.

Feldsine, J. E. (1988). "The construction of concept maps facilitates the learning of general college chemistry: A case study.(Doctoral dissertation, Cornell University,1987)." Dissertation Abstracts International **48**(9): 2301-A.

Fensham, P. (1989). Theory in practice: how to assist science teachers to teach constructively. Adolescent Development and School Science Ed. P. Adey. London, Falmer Press.

Fraser, K. and J. Edwards (1985). "The effects of training in concept mapping on student achievement in traditional classroom tests." Research in Science Education **15**: 158-165.

Friere, P. (1972). Pedagogy of the oppressed. Harmondsworth, Penguin.

Fulwiler, T. (1987). The Journal Book. Portsmouth, NH, Boynton and Cook.

Gardner, P. (1995). Measuring attitudes to science: unidimensionality and internal consistency. Paper presented at the 26th Annual conference of ASERA, Bendigo, Victoria,

Gibbs, G., S. Habeshaw, et al. (1984). 53 Interesting things to do in your lectures. Bristol, Technical and Educational Services Ltd.

Gill, R. (1994). "Good practice in HE lecturing - a self-assessment questionnaire." Teaching Earth Sciences **19**(3): 97-98.

Haneman, V. (1975). "Faculty research and undergraduate institutions." Engineering Education **65**(6): 450-451.

Harrison, C. (1994). "The role of learning technology in planning change in curriculum delivery and design." Association for Learning Technology Journal **2**(1): 30-37.

Heinrich, K. (1992). "The intimate dialogue: journal writing by students." Nurse Educator **7**(6): 17-21.

Heinze-Fry, J. A. and J. D. Novak (1990). "Concept mapping brings long term movement towards meaningful learning." Science Education **74**(4): 461-472.

Hobbs, B., W. Means, et al. (1976). An outline of structural geology. New York, John Wiley & Sons.

Holly, M. (1987). The journal. Keeping a personal-professional journal. Geelong, Deakin University Press.

Horton, P. B., A. A. McConney, et al. (1993). "An investigation of the effectiveness of concept mapping as an instructional tool." Science Education **77**: 95-111.

James, P. and I. Clark (1991). Computer animation and multimedia presentation software as an aid to tertiary geological education in the Earth Sciences. 8th ASCILITE Conference, Similulation and Academic Gaming in Tertiary Education, Launceston,

James, P. R. and I. F. Clark (1993). "Grid sketching to aid teaching geological mapping in an area of complex polydeformation." Journal of Geological Education **41**(5): 433-437.

Jarvis, P. (1987). Adult Learning in the Social Context. New York, Croom Helm.

Jegede, O., F. Alaiyemola, et al. (1990). "The effect of concept mapping on students' anxiety and achievement in biology." J. of Research in Science Teaching **27**(10): 951-960.

Johnson, D., G. Maruyama, et al. (1981). "The effects of cooperative, competetive and individualistic goal structures on achievement: a meta-analysis." Psychological Bulletin **89**: 47-62.

Jones, J. (1988). "Students grades and rating of teaching quality." Higher Education Research and Development **17**(2): 131-140.

Kemmis, S. and R. McTaggart (1988). The Action Research Planner. Geelong, Deakin University Press.

Kern, E. L. and J. R. Carpenter (1984a). "Enhancement of student values, interests and attitudes in Earth Science through a field oriented approach." Journal of Geological Education **32**: 299-305.

Kern, E. L. and J. R. Carpenter (1984b). "Effect of field activities on student learning." Journal of Geological Education **34**: 180-183.

Kern, E. L. and J. R. Carpenter (1995). "A highly successful science and mathematics enhancement effort for grades K-6." Journal of Geological Education **43**: 121-127.

King, C. J. (1993). "Earth science in the National Curriculum of England and Wales." Journal of Geological Education **41**(4): 318-323.

Kolb, D. (1984). Experiential Learning. New Jersey, Prentice Hall.

Koran, M. L. and J. Koran (1980). "Interaction of learning characteristics with pictorial adjuncts in learning from science texts." Journal of Research in Science Teaching **17**(5): 477-483.

Kuder, G. and M. Richardson (1937). "The theory of the estimation of test reliability." Psychometrika **3**(3): 151-160.

Laurillard, D. (1993). Rethinking University Teaching. Routledge, London.

Leahy, R. (1989). "Concept mapping: Developing guides to literature." College Teaching **37**(2): 62-69.

Lisle, R. (1988). Geological structures and maps: A practical guide. Permagon.

Lochhead, J. (1983). Constructivist approaches to teaching science and mathematics at the college level. Annual meeting of the North American Group for the Psychology of Mathematics Education, Montreal,

Locke, W. W. (1989). "A non-traditional geology field trip." Journal of Geological Education **37**: 107-109.

Lonsdale, A. J., Ed. (1990). Achieving institutional excellence through empowering staff:an approach to performance management in higher education. Higher education in the late twentieth century: reflections on a changing system. Kensington, NSW, HERDSA.

Malone, J. and J. Dekkers (1984). "The concept map as an aid to instruction in science and mathematics." School Science and Mathematics **84**(3): 220-232.

Marsh, H. (1987). "Students' evaluations of university teaching: Research findings, methodological issues, and directions for future research." International Journal of Educational Research **11**: 255-378.

Marshak, S. and G. Mitra (1988). Basic methods of structural geology. Englewoods Cliffs, Prentice Hall.

Martin, P. (1987). "Student evaluation of teaching: potential and limitations." Nursing Outlook **35**(2): 86-88.

Marton, F., Ed. (1988). Describing and improving learning. Learning Strategies and Learning Styles. New York, Plenum.

Marton, F. and R. Saljo. (1984). Approaches to learning. in F. Martin et al. (eds) The Experience of Learning. Edinburgh, Scottish Academic Press.

Mason, C. (1992). "Concept mapping: A tool to develop reflective science instruction." Science Education **76**(1): 51-63.

Mayer, V. (1988). Earth Systems Education: A new perspective on planet Earth and the science curriculum. Columbus, Ohio, Ohio State University Research Foundation.

Mayer, V. (1989). "Earth Appreciation." The Science Teacher (March, 1994):

Mayer, V. (1990). "Teaching from a global point of view." The Science Teacher (January 1990):

Mayer, V. (1991). "Earth-Systems Science: A planetary perspective." The Science Teacher (January, 1991):

Mayer, V. and R. Armstrong (1990). "What every 17-year old should know about planet Earth: the report of a conference of educators and geoscientists." Science Education **74**(2): pp 155-165.

Mayer, V. J., S. M. Brown, et al. (1992). "The role of planet Earth in the new science curriculum." Journal of Geological Education **40**(1): 66-73.

McClay, K. (1987). The mapping of geological structures: Geological Society of London Handbook Series. Open University Press.

McCombs, J. (1990). "Rocks your students dig." The Science Teacher **57**(3): 49-51.

McGowran, B. (1993). Strategic Plan for the Department of Geology and Geophysics, University of Adelaide.

Mezirow, D. (1981). "A critical theory of adult learning and education." Adult Education **32**(1): 3-24.

Moore, B. and R. Smith (1994). Guide to valuing and evaluating teaching in the University of South Australia. Centre for University Teaching and Learning.

Moreira, M. A. (1979). "Concept maps as tools for teaching." Journal of College Science Teaching **8**(3): 283-286.

Morrel, P. (1990). "The ATP energy jar." Science Teacher **57**(1):

Morton, P. (1987). "Student evaluation of teaching: potential and limitations." Nursing outlook **35**(2): 86-88.

Moseley, F. (1981). Methods in field geology. San Francisco, Freeman.

Mullins, G. and R. Cannon (1993). Judging the quality of teaching: A report to the DEET Evaluations and Investigations program. Canberra, Australian Government Publishing Service.

National Union of Students (1992). Quality in higher education. Th quality of higher education: Discussion papers Ed. H. E. Council. Canberra, AGPS.

Neumann, R. (1992). "Perceptions of the teaching-research nexus: A framework for analysis." Higher Education **23**(2): 159-171.

Neumann, R. (1994). "Valuing quality teaching through recognition of context specific skills." Australian Universities' Review **37**(1): 8-13.

Novak, J., Ed. (1989). The use of metacognitive tools to facilitate meaningful learning. Adolescent Development and School Science. Lewes, Falmer Press.

Novak, J. (1990). "Concept mapping: A useful tool for science education." Journal of Research in College Teaching **27**(10): 937-949.

Novak, J., D. Gowin, et al. (1983). "The use of concept mapping and knowledge vee mapping with junior high school science students." Science Education **67**(5): 625-645.

Novak, J. D. (1988). "Learning science and the science of learning." Studies in Science Education **15**: 77-101.

Okebukola, P. (1990). "Attaining meaningful learning of concepts in genetics and ecology: an examination of the potency of the concept mapping technique." Journal of Research in Science Teaching **27**: 493-504.

Pankratius, W. J. (1990). "Building an organised knowledge base: Concept mapping and achievement in secondary school physics." Journal of Research in Science Teaching **27**: 315-333.

Park, R. G. (1989). Fundamentals of Structural Geology. Glascow, Blackie.

Parker, L. (1992). "Language in science education: Implications for teaching." Australian Science Teachers Teachers Journal **38**(2): 26-32.

Pearson, M. (1992). Improving quality in higher education in the 90s: responding creatively. ANU Reporter. Canberra,

Piaget, J. (1926). The Language and Thought of the Child. New York, Harcourt Brace.

Pratt, D. (1992). "Conceptions of teaching." Adult Education Quarterly **42**: 203-220.

Price, N. J. and J. W. Cosgrove (1990). Analysis of Geological Structures. Cambridge, Cambridge University Press.

Project 2061 (1989). Science for all Americans. American Association for the Advancement of Science.

Ramsay, J. G. and M. I. Huber (1987). The techniques of Modern Structural Geology. London, Academic Press.

Ramsden, P. (1991). "A performance indicator of teaching quality in higher education: The course experience questionnaire." Higher Education **16**: 129-150.

Ramsden, P. (1992). Learning to teach in higher education. New York, Routledge.

Ramsden, P., Ed. (1993). Effective teaching in higher education. Promoting Teaching in Higher Education. Brisbane, Griffith Institute for Higher Education.

Ramsden, P. and A. Dodds (1989). Improving teaching and courses: a guide to evaluation. Parkville, Victoria, Centre for the Study of Higher Education, University of Melbourne.

Roy, E. C. (1993). "Reform in College-level geoscience education." Journal of Geological Education **41**(4): 312-314.

Savery, J. and T. Duffy (1994). "Problem Based Learning: An instructional model and its constructivist framework." Educational Technology **29**(August):

Sawyer, W. (1943). Mathematician's Delight. Harmondsworth, Penguin.

Schon, D. (1983). The reflective practitioner. New York, Basic Books Inc.

Schon, D. (1988). Educating the reflective practitioner. San Francisco, Jossey Bass.

Schratz, M. (1993). "Researching while teaching: promoting reflective professionality in higher education." Educational Action Research **1**(1): 111-133.

Second Tier Settlement for Academic Staff in Higher Education Institutions. (1988). Reproduced in Appendix C. Higher Education . A Policy Statement Canberra: AGPS

Simpson, I. (1977). Fieldwork in Geology: Introducing Geology Series. London, Allen & Unwin.

Smith, J. V. (1992). "A concept matrix for geological structures." Journal of Geological Education **40**(5): 356-359.

Smyth, J. (1986). Reflection - Action. Geelong, Deakin University Press.

SSABSA (1996). Stage 2 Geology Syllabus. Adelaide, SSABSA.

Starr, M. and J. Krajcic (1990). "Concept maps as a heuristic for science curriculum development: toward improvement in process and product." Journal of Research in Science Teaching **27**(10): 987-1000.

Startup, R. (1985). "The changing perspective of academic researchers 1973-1983." Studies in Higher Education **10**(1): 71-78.

Steffe, L. and P. Cobb (1987). Construction of Arithmetical Meanings and Strategies. New York, Springer-Verlag.

Stein, H. (1988). "On that note." Science and Children **26**(3): 16-18.

Stensvold, M. S. and J. T. Wilson (1990). "The interaction of verbal ability with concept mapping in learning from a chemistry laboratory activity." Science Education **74**(4): 473-480.

Stevens, E., L. Goodwin, et al. (1991). "How are we different? Attitudes and perceptions of teaching across three institutions." Journal of Staff, Program and Organisation Development **9**(2): 69-82.

Stewart, J., J. Van Kirk, et al. (1979). "Concept maps: A tool for use in biology teaching." The American Biology Teacher **41**(3): 171-175.

Suppe, J. (1985). Principles of Structural Geology. New York, Prentice Hall.

Svensson, L. (1977). "On qualitative differences in learning. III - Study skill and learning." British Journal of Educational Psychology **47**: 233-243.

Svensson, L. and C. Hogfors, Eds. (1988). Conceptions as the content of teachng: Improving education in mechanics. Improving Learning: New Perspectives. London, Kogan Page.

Symington, D. and J. Novak (1982). "Teaching children how to learn." Educational Magazine **39**(5): 13-16.

Theall, M. and J. Franklin (1991). "Using student ratings for teaching improvement." New directions for teaching and learning **48**: 83-96.

Uemura, T. and S. Mizutani, Eds. (1984). Geological Structures. Tokyo, Tokyo University Press.

vonGlaserfield, E. (1989). "Cognition, construction of knowledge and teaching." Synthese **80**(1): 121-140.

Vygotsky, L. (1962). Thought and Language. Cambridge, Mass, MIT Press.

Wallace, J. and J. Mintzes (1990). "The concept map as a research tool: exploring conceptual change in biology." Journal of Research in Science Teaching **27**(10):

Webb, L., Ed. (1993). Address to the National Teaching Workshop. Promoting Teaching in Higher Education. Brisbane, Griffith Institute for Higher Education.

Westhorp, P., Ed. (1994). The experience and outcomes of action research and reflective teaching in occupational therapy. Adelaide, University of South Australia.

White, R. and R. Gunstone (1992). Probing Understanding. London, The Falmer Press.

White, R. T. (1988). Learning Science. Oxford, Blackwell.

Wilkes, L. (1992). The role of physical sciences in clinical nursing practice. University of New South Wales, Sydney.

Wittrock, M. C. (1974). "Learning as a generative process." Educational Psychologist **11**: 87-95.

Woods, D. R. (1989). "Developing students' problem-solving skills." Journal of College Science Teaching **19**(2): 108-110.

Working Party on Quality in Teaching and Learning (1992). Quality in teaching and learning. University of Adelaide.

Yoxhall, W. H. (1990). "An earth science process centre." Journal of Geological Education **38**: 225-228.

Zuber-Skerritt, O. (1992). Action Research in higher education: examples and reflections. London, Kogan Page.