http://www.educ.mq.edu.au/atea/palmerw.htm (Now disappeared)

Macquarie University

1995 ATEA Conference papers

W P Palmer, Northern Territory University.

Science through their eyes: reflections of student teachers of their own science learning

For the last four years I have asked students of the Diploma of Teaching and Graduate Diploma of Secondary Education to write an individual science autobiography. This includes their recollections of any science lesson that either encouraged them to do science or nearly put them off altogether. They were also asked if the content of the lesson or the personality of the teacher influenced them more. The idea came from an article I had read (Koch, 1990). The purpose of the assignment, which was not assessed, was to ensure that student teachers thought about the occurrences that had influenced them as children as a starting point, to thinking how science should be taught. Interesting comparisons will be made between the reflections of the prospective primary and secondary teachers. These will be contrasted with the recollections of some well-known people (scientists and others / fiction and non-fiction) taken from biographies or novels.

Koch, J. (1990). The science autobiography. Science and children, 28, 3, pp. 42-43.

Session 11 Saturday 8 July 11.05 - 11.45 - 119

25th Annual Conference of the Australian Teacher Education Assoc. Inc.
July 5 - 8 1995

Australian Catholic University, 40 Edward Street, Sydney.

Theme: The Challenge of Change.

Science through their eyes: reflections of student teachers of their own science learning.

W. P. Palmer, Faculty of Education,
Northern Territory University.

SCIENCE THROUGH THEIR EYES: REFLECTIONS OF STUDENT TEACHERS OF THEIR OWN SCIENCE LEARNING.

W. P. Palmer, Faculty of Education,
Northern Territory University.

ABSTRACT

For the last five years I have asked students of the Diploma of Teaching and Graduate Diploma of Education to write "an individual science autobiography". They were asked to include their recollections of any science lesson that either encouraged them to do science or nearly put them off altogether. They were also asked if the content of the lesson or the personality of the teacher influenced them more. The idea came from an article I had read (Koch, 1990). The purpose of the assignment, which was not assessed was to ensure that student teachers thought about the occurrences that had influenced them as children, as a starting point for thinking how science should be taught. Interesting comparisons will be made between the reflections of the prospective primary and secondary teachers. These are contrasted with the recollections of some well-known people (scientists and others/ fiction and non-fiction) taken from biographies or novels.

INTRODUCTION

I will start the paper with a few (perhaps damaging) admissions. For the last five years that I have been teaching primary and secondary courses to prospective teachers, I have given these groups an assignment (see Appendix 1) that asks them to reflect on the way that they were taught science and to highlight good and bad features of the teaching/teachers and the content. The aim was not primarily for my research though I have always had an idea in mind that I would write up the results, but rather to get the students to think about how to teach science based on their own personal experience as a starting point. I also have to admit that I have not used the assignments previously nor have I discussed them with individuals or during lectures Nonetheless I think, whether written up or not, whether commented on or not, that this is a useful exercise for the students. As I have read through these assignments over the past few weeks 'en masse', I have had the feeling that for some students it has been a cathartic experience, exorcising 'the ghosts of science past'. Many are carrying around a considerable amount of emotional baggage with regard to their experiences of science in the past and I think that writing about the experience will have helped them; others have dashed off a quick single page with the feeling perhaps that they have got another assignment out of the way; most have in fact thought how the experiences they have had at school could be of help to the students that they will be teaching in the

future. For all, it is a starting point for making the science education of the next generation better than that of the last generation.

The other research that I have been carrying out independently is to look at autobiographies of well known scientists. In the current study I try to see how much the authors attribute their own success (in science) to their science teachers or to significant other adults with an interest in science. I see these two lines of research as complementary but different and hope that this paper may draw on both.

In somewhat simplistic terms, one hypothesis I hope this research will test is that everyone is deeply grateful for the start in life given them by their teachers. Is this really so?

THE ASSIGNMENT

The assignment, which carried no marks or penalties for not submitting it, was given to three different groups that I have taught over the past five years. These are:

(a) Third year students intending to be primary teachers doing the 3 year Diploma of Teaching course accessing unit EDN 358 (Science in the Primary School) at Northern Territory University;

(b) Science Education students doing Science Methods 1 (EDN 476) in a one year Graduate Diploma Secondary course. These students generally have a science degree before starting the course and intend to be secondary teachers;

(c) Primary education students doing Science Methods unit (EDN 515) in a one year Graduate Diploma Primary course. These students generally have a degree before starting the course, but this may be in any subject;

With regard to the student composition of these courses, all the units contain a mixture of traditional and mature age students. Mature age students often make up as much as half the students in the units, though there is considerable variation in this proportion from year to year. This means that instead of recollections of science experience representing primary schools of about ten years ago, some respondents may be giving us a picture of science education thirty or more years ago. In the Northern Territory (NT), there is considerable movement of population from other states, so many of the replies are commenting on systems in states other than the NT. There are also significant proportions of migrants to Australia in the NT and these too are represented amongst the respondents so that a few replies refer to education systems outside Australia.

A further aspect of the student composition of the courses is that of gender. The gender balance in the third year primary unit EDN 358 is very unequal and always consists of 80% to 90% female students, 92 students out of 103. The gender balance in the secondary unit, EDN 476, Science Methods 1, varies widely from year to year. It only contains small numbers of students and in some years it has been predominantly male, in other years balanced and this year entirely female (overall 10 female students out of a total of 23). In the one year primary course for graduates (now discontinued) unit EDN 515 was more evenly balanced with regard to gender in the only year recorded (overall 6 students out of 12 were female). For the three courses together 108 of the 138 assignments returned (78%) were completed by females.

The obvious comparisons across a variety of issues might be by gender and by course and it might be possible to score a number of views on particular issues in this way, but the vast majority of respondents are females who were enrolled in the three year primary program, so a straight forward quantitative approach is not really possible. Using other data, comparison between mature and school leaver entrants might be possible. Such a comparison could indicate how science teaching at each stage has varied over time.

I should also say that even though this was not a compulsory assignment, and perhaps because it was the first assignment set, it was answered by virtually all students in the primary courses in the years stated, though there is some shortfall in the secondary course in some years.

The approach that I have used is to reduce the one to six page assignments to five to ten lines. If the part, where they wrote - science is ..... was completed, this was recorded. I also tried to record specific information where given about which experiments respondents remembered and what they thought of them. Information about any teacher that they mentioned was recorded as were the names of TV science shows that they thought had influenced their opinion on science. Prizes, field trips, competitions, camps, clubs, books, journals, lectures, radio or significant adults influence their opinion about science were all recorded too. The emphasis was on recording specific facts mentioned. I also tried to record some of their own words to give the flavour of the response. The records now consist of twenty five pages of data for 138 students. The responses are coded so as to protect the identity of the students. Where teachers were mentioned by name their identity is not recorded. However the actual naming of a teacher seemed to me to give the comment made a greater degree of significance.

GENERAL

I suppose the thing that surprised me most was the rationality of almost all the replies. Some had fairly horrific tales of the way they perceived that they had been treated in their school days with regard to science. One would not have been surprised at demands for its total banishment from the curriculum and the retraining of all science teachers. But no! There was generally nothing, but sweet reason and the feeling that they, the respondents, were guilty for failing to understand science as it was really only those who were exceptionally 'brainy' who could do this.

93/A/10F "I shivered and shook because 'science' had always been for the brilliantly intelligent who were slightly forgetful" " However, I only lasted a few weeks because I KNEW NOTHING"

The overall numbers of females taking part in the sciences in Western societies has always been less than the numbers of males taking part in the sciences. This is particularly true of the physical sciences. A fairly much simplified explanation of this fact, called 'The vicious circle of primary science' (Raper & Stringer, 1987) is usually discussed with students.

SCIENCE IS....?

How would one expect students to complete the statement science is ...? Indeed what could they do? Some omitted this part of the assignment. Some made their own general definition and this was what the vast majority of respondents did. What is of interest to me here is the degree of inclusiveness of these definitions. I certainly have the impression that the definitions become meaningless, if they are all-inclusive and therefore of the "everything is science type":

94/A/17F " Science is everywhere. It was here before we were and it will remain even when we are gone. I believe science is an ever evolving process of learning, discovery and changes. science is life and will remain for ever unsolved."

93/A/07F " Science is everywhere.....Science is such a broad area and is all around us in everything we do"

Apart from the over inclusive definitions there are those that for various reasons are only partial. In the following statements, the first is obviously incomplete. The second statement is from a very competent physics graduate and may well indicate the way that many scientists actually think.

91/A/15F "Science is to me biology, it was my favourite and it just came to me and was easy, and took <u>no</u> study to pass exams."

91/B/01M "To me, science is facts and if it is observed you can study it and find out why."

Quite a number of definitions include what I would call science processes (skills). I am not personally a great believer in the overall utility of science processes, but we would have been talking about them at the time that students were working on this assignment, which may account for their pervasiveness.

91/A/04 "The study of science involves researching and hypothesising how and why living and non-living things occur, happen or operate."

91/A/07 "Science is . . . exploring, discovering and understanding the what, where, how and whys of the universe that surrounds."

94/A/18M "Science is experiencing, experimenting, exploring, questioning, inquiring and basically a fun way of learning"

There was also the definition:

93/A/20F "Science is what scientists do (I read that in a book??? ha!!!)"

It was, perhaps, in this case someone trying to be 'clever', but in spite of the obvious circularity of the definition, I think it might have been a good starting point.

As part of the idea of science, there should be some mention of 'organised'/ 'systematic' knowledge or the seeking of general laws. This was almost entirely absent. The idea of reproducible observations was also missing One student used a dictionary to make this point: no one used a scientific dictionary (e.g. Uvarov & Isaacs, 1988, p.359), though the sentence was intended to and generally does represent their ideas of what science are: one student did make the point.

93/A/35F "Science is an orderly body of knowledge. It's not like other areas where almost any answer goes"

The above description and perhaps one or two others, perhaps indicate a Baconian perspective (Charlesworth, 1982, pp. 12-20) on the nature of science, and there are two answers that appear closer to Paul Feyerabend (Charlesworth, 1982, pp. 40-46) than to anyone else.

91/C/09M " Science is one of many belief systems which relentlessly tries to find causalities, but never actually does..... science is a necessary evil."

91/C/11M "Science is ...one perspective among many and equally legitimate perspectives..."

However even amongst those studying science to degree level, there was no one who adopted a Popperian perspective (Charlesworth, 1982, pp. 22-29), limiting science to those statements that could be falsified. This harder view of science just did not appear.

I note that there are other studies on the nature of science as seen by elementary teachers (Abell & Smith, 1994). There are a number of interesting comparisons between the results which would repay further study. I include six pages of definitions as Appendix 2, so that readers may develop their own hypotheses.

ANIMAL DISSECTIONS

The most obvious single controversy is the biology practical relating to the dissection of animals. I have earlier commented on the ethical situation relating to this practical in a PNG context (Palmer, 1987), when it was far from certain that the majority of frogs being experimented upon were dead (they were pithed often by teachers with inadequate training, so that their death was more like crucifixion). In the Australian case, we will assume that the frogs, rats etc were in fact dead, but even then it is doubtful if many students doing this experiment gain sufficient dissecting skills from carrying out disections to be really proficient. Even if they became proficient, what purpose would this skill serve? If it is merely to gain a knowledge of anatomy, one would wonder if printed diagrams/ computer simulations/ plastic models could not equally teach this knowledge. One must suppose that part of the purpose of the experiment is to desensitise the students to the sight of blood and gore. This may in fact be useful, but it is not usually stated as an objective.

In the case of dissection, some students mention it as an attraction of biology whilst others mention it as a factor that made them leave biology. There is a gender difference in that there is obviously a stronger emotional reaction by females, usually against dissections, yet many other female students feel dissections to be an interesting feature of biology. Disections may attract or repel students, but they are not usually ignored as more students (about 15%) comment on this than on any other experiment.

One particularly interesting response is included below. It is interesting in that the emotional response is very easily understandable, yet, if dissections are acceptable, the logical distinction between dissecting pregnant or non-pregnant rats is hard to comprehend. However even the great Linnaeus was far from logical in his opinions regarding human

pregnancy (Koerner, 1995, p. 239) as 'throughout his life he regurgitated his disgust for the adult child-bearing woman".

91/C/02F She did biology in Y 11/12. "Two practicals that I really enjoyed were testing our own blood groups and dissecting rats. When it came to the teacher dissecting a pregnant rat in front of the class, I was disgusted and left the laboratory. That experience was very overwhelming."

It is also interesting to note that the use of human blood in school laboratories has been strongly discouraged on health grounds (ASE, 1981) and the experiments are forbidden in many countries. The description by student 93/A/26F explains the revulsion felt by those opposing dissection very well. The case for dissections is never made, though three students claim positive enjoyment, but is this bravado?

91/C/06M "The most exciting area of early high school science was the biology area. The massacre of mice, rats and frogs. This I found to be fantastic and very interesting. I could have spent hours upon hours in the lab doing dissections."

Overall 21 students mentioned dissections (3 M : 18 F). Thirteen of these comments were strongly opposed to dissections, five just commented that they remembered doing dissections, and three found it to be a positive feature of biology courses.

THE TEACHERS

Little more than very broad generalisations is likely to be generated from this data. Certainly students say that they were encouraged by good teaching and friendly teachers. In one case, one student appreciates a strict teacher, whilst another criticises the class organisation of apparently the same teacher.

Apparently contradictory remarks about the same teacher are not unknown in the literature. For example Clive James in his humorous autobiography (James, 1987) indicates that his physics teacher's speech was incomprehensible, whereas Professor Arthur Birch (Newman, 1983) says the same teacher was extremely popular and a superb showman. TJame's account of this teacher (Mary Luke) are in Appendix 5.

Appendix 4 lists the comments made by the respondents about the teachers who taught them science at primary or secondary schools. One would perhaps expect every respondent to give a great deal of time and attention in their assignments to their teachers and the quality of the science teaching, firstly as it was asked for and secondly as it would be expected to be a major determinant of their own learning. Actually 67 out of 138

respondents mentioned their teachers at all and very few by name. In a rough count 31 unfavourable reports of teachers were given as opposed to 41 favourable reports of teachers (there are more reports than respondents because some gave more than one report).

The overall picture would seem to be few problems with the science teachers in primary schools except that very little science is taught. In secondary schools (Years 7-10) there are some students, unhappy with science, but more frequently there are children, bored with science. In Years 11 & 12 respondents either leave science altogether or choose biology only or find a greater degree of mutual respect and tolerance for their teachers. However if one looks at the unfavourable comments one is left with the impression that there is much that science teachers can do to improve the quality of science teaching.

THE SCIENCES

There are a fair number of examples, where students comment on the component disciplines of science, namely astronomy, chemistry, geology, (sometimes geography), biology and physics. Students comment on the closeness of physics and chemistry to mathematics and give lack of mathematical ability as a reason for not opting for physics and chemistry .

91/B/02M He began to realise that physics and chemistry involved mathematics, where he had a mental block, so he took an increasing interest in biology.

93/A/37F She got a credit in the National Chemistry Quiz and planned to take chemistry but because her maths were below par she was counselled out of that.

There is a very definite feeling that some physics teachers discourage girls from taking their subject.

91/A/05F In Y 11 she was interested in biology, but also struggled with physics, "the teacher (male) had an attitude that females should not do physics thus provided very little support and much controversy."

91/A/11F "I was introduced to another area of science: 'Physics'. Not only did I not enjoy the subject, but I also did not perform at all well. However, I would like to stress out that the simple fact that in those days 'Physics' was thought to be more 'a boy's subject', than a girl's subject."

There was also the feeling that biology was intellectually inferior to the physical sciences.

91/A/20F She began to lose interest in science but studied biology in senior years with "a niggling feeling that it was a 'veggie' subject, and that we were intellectually inferior to physics and chemistry students."

93/A/03F In years 11/12 she liked chemistry, but gave it up because she could not do the calculations and later dropped out of physics because it was too hard to understand.

Then, apart from the alleged difficulty of physics there is the fear of physics and hating physics, as expressed below

93/A/15F Physics and chemistry- "Those two words I dread. May be it's that what turned me off science"

93/A/19F "She studied matriculation biology, failed Y10 astronomy and hated physics and chemistry.

Chemistry comes in for its fair share of criticism, usually in relation to not understanding equations or being bored by it.

94/A/13F " This year (year 9) I earned myself a mastery award in chemistry which to me is quite funny because I believe that I didn't learn anything in chemistry." "Not surprisingly I finished junior high school hating science and of course failing this unit in the JSSC."

91/C/06M "Physics and chemistry were just a touch boring for me..."

91/A/26F At high school "I was never very good at science right from the onset. Although I was fairly competent at maths I could never really grasp formulas etc. in physics and chemistry"

Geology tended to be well liked.

91/A/26F " Geology, I found interesting, plus being an outdoors person I liked getting outside and examining formations, soil etc."

93/A/10F She then chose geology that was "not too threatening and even enjoyable."

If the science disciplines were put in order by a reductionist they would be placed with biology, astronomy, and geology all perhaps equally reducible to chemistry, which in its turn would be reducible to physics which would be reducible to mathematics. Generally the order of reductionism is the reverse of the order of popularity, with physics being the least popular science. Abstraction is generally not popular but there are a few students who thrive on it and feel a need for it.

92/B/03M Never been sure about why he did science except that it seemed natural for him. He is explicit about why he left biology in Year 10. "this was due to my perception that all that biology required was a good memory and I could see no relation between the various topics, whilst physics and chemistry always offered a connection between areas (somewhat tenuous at times but usually there)."

ENCOURAGING SCIENCE

Teachers, academics, industry and society at large spend a great deal of time and money in encouraging the young to take an interest in science. Earlier in the paper the question was asked "Did prizes, field trips, competitions, camps, clubs, books, journals, lectures, radio or significant adults influence their opinion about science when they were young?" Looking at the statements made in the assignments, very few of these, if any, are mentioned by more than 5% of the respondents, but different things appealed to different respondents. School excursions would be the most popular, but they were to a variety of different activities including museums, zoos, parks, Rapid Creek mangroves. Many benefits are claimed for students participating in such trips (Price & Hein, 1994, p. 516) and the evidence of this paper indicates that such trips are memorable a long while after the event.

The popular science shows on television/radio are well remembered. One student remembered the 'Science Territory' program on local TV that attempted to change children's attitudes in favour of science (Robertson & Palmer, 1993).

91/A/18F She liked the 'Science Territory' TV programs.

Friends, parents, uncles, brothers etc are all great encouragers of science talent. School prizes and outside competitions get mentions as do lectures by outside speakers. Chemistry sets, microscopes and electronic sets have been an encouragement for some.

When adults ask which of these activities are important and which are a waste of time, this research gives no sure answers. Each of the general activities that I can think of, has appealed to some students, yet none are widely popular. The best solution still seems to be to keep a wide and varied range of activities going and students looking back will see some of these scientific activities in a favourable light.

REFERENCES

Abell, S. K. & Smith, D. C. 1994 What is science ?: Preservice elementary teachers' conceptions of the nature of science, *International Journal of Science Education*, 16(4)475-487.

Association for Science Education (ASE) 1981 *Safeguards in the school laboratory* (Eighth edition), Association for Science Education, Hatfield, UK, p. 23.

Charlesworth, M. 1982 *Science ,Non Science and Pseudo Science*., Deakin University Press, Geelong, Australia.

James, C. 1980 *Unreliable Memoirs,* Picador/Pan Books, London, U.K., pp. 86-87& pp. 87-88.

Koch, J. 1990 The Science Autobiography, *Science & Children,* 28(3)42-43.

Koerner, L 1995 Women and Utility in Enlightenment Science, *Configurations: A Journal of Literature, Science and Technology*, 3(2)233-255.

Newman, W. 1983 Scientist's Viewpoint : Professor Arthur Birch, *The Australian Science Teachers Journal* 29(3)80-83.

Palmer, W. P. 1987 Environmental, Ethical and Safety Issues in Chemistry/Science Curricula in Schools, *Science in New Guinea*,, 13, (2) 82-91.

Price, S. & Hein, G. E. 1991 More than a field trip: Science programmes for elementary school groups at museums, *International Journal of Science Education*, 13(5)505-519.

Raper, G. & Stringer, J. 1987 *Encouraging Primary Science*,, Cassell Publishers Ltd, London, UK, p. 42.

Robertson, B. & Palmer, W. P. 1993 'Popularising Science through Television: Where are we now?', *The Australian Science Teachers' Journal* , 39(1)46-47.

Uvarov, E. B. & Isaacs, A. 1988 *The Penguin Dictionary of Science*,, Penguin Books, Harmondsworth, UK.

APPENDIX 1

AN INDIVIDUAL SCIENCE AUTOBIOGRAPHY

ASSIGNMENT A (No grades or marks given)

Please try to give a very full answer (about 2-3 typed pages or equivalent) to the detailed request below to be available in a week from now.
Please also include your recollections of any science lesson that either encouraged you to do science or nearly put you off altogether. Was it the content of the lesson or the personality of the teacher that influenced you more?

Looking Through the Lens of Science

When you look at your education through the lens of "science", what do you see? Did you have much of it? Did you like it? Did you ever even think about it? A science autobiography is a personal description of your experience with science, or out of school, through teachers, friends, parents, museums, magazines, and other sources.

Frequently, we bring preconceived ideas and beliefs to our science learning and teaching experiences. These are formed by our direct experiences with science, the people we meet who work in science, and the publicity science receives. Please think about your own personal experience with school science, scientists, science in the media, and science teachers. It doesn't matter how limited or extensive your experiences are, only that you describe them.

Relate your earliest memories of school science and your reactions. Write about your experiences with school science up to the present, explaining what you think the study of science involves. What have you grown up to believe about the scientists themselves? Who are they, and what do they do? Be as candid as possible. This writing-and-thinking exercise will be your first step toward school science *teaching!*

Idea from :- Koch, J. 1990 The Science Autobiography, *Science & Children,* Nov/ Dec, Vol 28, No 3, pp 42-43.

APPENDIX 2
SCIENCE-DEFINITIONS. SCIENCE IS.....!

EDN 358 LIST 1991

91/A/01 "Science is a study of human beings and the environment using methods of measuring, recording, observing, and experimenting."

91/A/03 "Science is about discovering the wonders of this earth and universe."

91/A/04 "The study of science involves researching and hypothesising how and why living and non-living things occur, happen or operate."

91/A/05 "Science above all is a discovery process whilst being a very challenging one."

91/A/07 "Science is . . . exploring, discovering and understanding the what, where, how and whys of the universe that surrounds."

91/A/08M "Science is a subject that most people can find enjoyment and usefulness out of."

91/A/11F "'Science' is part of our everyday life, and that in each single one of us participates daily in Science, although I believe most of the time without being aware of our actions in relation to Science."

91/A/12M "Science is a part of life which can never be totally satisfied and fulfilled. The element of intrigue always prevails."

91/A/13F "Science is a diverse group of disciplines, on one hand connected to life and living and totally relevant and then on the other totally abstract and attempting to explain the unexplainable."

91/A/14F "Science is the Study of Life - the past, present and looking toward the Future."

91/A/15F "Science is to me biology, it was my favourite and it just came to me and was easy, and took no study to pass exams."

91/A/16F "The process of science may be summarised as observation, questions and solution to phenomenons of nature. Science helps to predict results by experiments."

91/A/17M "Personally I think that science is a very broad, encompassing term which can be applied to most studies."

91/A/18 "Science is a means of finding results of questions by experimenting, analysing and proving the answers to be correct."

91/A/19F "Although, science can be made simple or presented in a complex manner, the preconceived idea that science is for the genius still holds fast in society."

91/A/20F "Science is an absorbing subject and can be enjoyable!"

91/A/21F "Science involves the world around us. Science is the necessary part of a person's development, opening up areas which no other areas could. It is weird how it is a part of everyone's ordinary life and yet is mainly thought to be only performed in 'top secret labs'."

91/A/22F "To me science is . . . All world around us, it doesn't have to be complex letters, words, sums, formulas or experiments. My bath tub is no longer with me, but my house provides great science starters. All I have to do is look in my yard, garden, fridge and cupboards."

91/A/23 F "Science is about magic tricks demonstrated by mystical individuals, according to my earliest childhood thoughts."

91/A/24 F "Finally, Science is . . . a world without limitations, which is ours to explore."

91/A/25 F "Science is an interesting part of nature and it gives me a challenge. It will also give me great satisfaction to teach it to children."

91/A/26 F "To me science is the study of how and why things have happened, are happening and will happen. It also involves finding out how to change some aspects, such as medical research does for diseases etc."

EDN 358 MARK LIST 1993

93/A/02F " To me, science is like maths, only more mystifying. You see science all around you. Science is included in everyday living, but you don't necessarily understand it, nor ever think about it."

93/A/03F " Science is having fun, enjoying yourself while doing it as well as learning and broadening your knowledge of science."

93/A/04F " In Australia I feel Science is the way Europeans look at things and explain phenomena. It deals with substances, life and natural law."

93/A/07F " Science is everywhere.....Science is such a broad area and is all around us in everything we do"

93/A/08F "Science is an enterprise, an activity of people. Science is people searching . It is men, women and especially children investigating, inquiring and seeking verifiable knowledge."

93/A/09F "Science is the study of the elements in and out of this world and how they work."

93/A/11F " Science is the finding out of why and how certain events happen the world"

93/A/15F "Science is something that should be enjoyed by everyone and that it should be treated as an equal in all schools."

93/A/16F " Science is a creative act on the part of a human being to experiment with their surroundings and attempt to discover something new."

93/A/17F "Science to me is the discovery through experimentation and testing of theories pertaining to health or technological matters, by which, when proven correct , mankind can benefit."

93/A/20F "Science is what scientists do (I read that in a book??? ha!!!)"

93/A/21F "Science is about many and varied things which we as students, scientists endeavour to understand." Scientists "I see them as smart and terrifically organised people"

93/A/22F "Science is an attitude towards learning, of questioning and continual amending of what we believe to be true."

93/A/23F "Science is exploring and discovering the world around us."

93/A/24F "Science is an area of study that holds the potential to stimulate curiosity, excitement and satisfaction at discovering results."

93/A/26F "Science is fun and can incorporate the teaching of other subjects through it, such as mathematics and language, but that more importantly science is for your pupils what you the teacher makes of it.."

93/A/27F "When used properly science can open a person's mind allowing them to experience the wonders that surround them both in nature and in human accomplishment."

93/A/28F "Science is knowledge of the world"

93/A/29M "In primary and secondary school I had 'sciencophobia'"

93/A/33F " Science is the study of the world, its make-up, its creatures and its future."

93/A/35F "Science is an orderly body of knowledge. It's not like other areas where almost any answer goes"

93/A/36F "Science is the combination of chemistry, physics, biology, astronomy, environment and marine...this covers the land, sea and air, so in basic terms, science is all around us....everywhere."

93/A/37 F "Science is rocks in my shoe, soil in my clothes and long periods of time. Science is a product of a tired mind" But she goes on to say that this is not what she really thinks. "Science is exploring The world and what makes it tick. "

93/A/38F "Science is observing, discovering, witnessing, interpreting and attempting to explain and make sense of how our world works. It constantly changes."

EDN 358 1994

94/A/01F "Science to me was the key to unlock the mystery involving the world and its surroundings."

94/A/02F "Science is essential responsible for many forms of development, may be even life itself."

94/A/03F "The word science is represented by two 'evil' words, namely chemistry and physics"

94/A/04F "Science I felt to me was a mixture of positive and negative experiences."

94/A/06F "Science is reacting and interacting with the environment"

94/A/07F "The study of science involves looking at things more closely to see what it is made of, how it functions (what its function is), how it may be altered and how it may be used."

4/A/08F " Science is the study of our natural and artificial world"

94/A/17F " Science is everywhere. It was here before we were and it will remain even when we are gone. I believe science is an ever evolving process of learning , discovery and changes. science is life and will remain for ever unsolved."

94/A/18M "Science is experiencing, experimenting, exploring, questioning, inquiring and basically a fun way of learning"

94/A/19F "Finally, science to me is the constant fascination of why things function , grow, disappear, change or destroy. Science is life itself."

94/A/20M " Science is a topic that encompasses a broad range of topics, ideas, theories and concepts people have thought up and used since caveman/woman first walked the earth."

94/A/21M "My view is that science is all about "discovering" to understand our present world and to make new discoveries to advance our world."

EDN 358 FULL CLASS LIST 1995

95/A/03F "Finally, science is like a bowl of chocolates, you never know what you are going to find. (Gump 94).

95/A/04F " I never critically associated the enjoyment of the subject with the ability of the teacher presenting the subject. Only much later did I realise how tightly the two are woven."

95/A/05M "I also believe that science, as a subject, was not an educational priority for students who "come from the bush".

95/A/06F " I believe that this is the key element of science -discovery"

95/A/09F "Science is a whole world waiting to be explored, again and again by all."

95/A/10F " At primary school, the subject (science) should be one of experiences and wondering, rather than instruction and note-taking."

95/A/11F In science the fundamental question should be " Why are we doing what we are doing?"

95/A/13F "Science is looking for answers to life's questions, looking for the truth in the unknown. Science is learning something about our surroundings."

95/A/14F " It (science) looks at what makes us tick as a planet and how things work together and against each other.

95/A/15F " Science to me is very important in our everyday life."

95/A/17M " Science is observation, inquiry and searching- all of which I value and hope that I can foster in students."

95/A/19F " Scientists were white-coated weirdos..." "Science is FUN"

EDN 476 Science Method 1 1991

91/B/01M "To me , science is facts and if it is observed you can study it and find out why."

91/B/03F " Science is interesting, progressive, exciting, challenging, relevant and thought-provoking."

91/B/04M " Science is all around us at all times."

91/B/05F "Science is a multi disciplinary study, of science, technology and society..."

91/B/06F "Science for me was trying to understand the theory, the reasons behind events that surrounded me or I had heard or seen..."

91/B/07F "Science is a learning process, whereby human beings acquire the knowledge of their universe and themselves, by constantly observing, questioning, and making theories , hypotheses and observations."

91/B/09F "Recently I have come to appreciate that science is all about observing, discovering, and explaining the way things work."

Science Method 1. EDN 476 1992

92/B/01M "Science is the process of piecing together bits of information obtained through interaction with the world to answer questions formulated during previous scientific activity."

92/B/02M "Science is a collection of factors all organised within a body where problem-solving is an aim...."

92/B/03M "Science is the process of extending our understanding of what is in order in order to create more accurate models of all things which happen."

92/B/04M "Science is the careful study of the world in which we live; it is about discovering how things work and why they work...."

92/B/05F "Science is the study and observation of the world around us and of natural phenomena...."

92/B/06M "Science is a process by which we can discover and describe why nature and the universe are the way they are, and make predictions about events and objects that we never directly observed."

92/B/07M "Science is worthwhile hobby for everyone."

92/B/08F "Science is the study of the functioning universe through observation, experimentation, research and conjecture. It is the basis of the technology on which society functions.""

92/B/09M " Science is the honest pursuit and development of knowledge of the natural/physical world."

92/B/10M He feels that science and religion will eventually combine as a new paradigm.

Science Method 1. EDN 476 1993

93/B/01 M Alternative definitions of science

(i) "Science is an abstract concept used by people to explain and rationalise the physical world and its idiosyncrasies: it is capable of immense frustrations and great rewards."

(ii) "Science is a means to power, to be used to save the world from toxic green mutants and other nasties or to be used for its destruction and/or exploitation."

Science Method 1. EDN 476 1994

94/B/01M " Science is the study of the world and how it works".

94/B/02F "Science is asking questions and trying to find their answers in the hope that we will expand our understanding of the universe."

94/B/03F "Science is a way of describing the world around us, science is life."

Science Method 1. EDN 476 1995
None returned

Grad Dip Prim EDN 515 1991

91/C/01F "Science is a tool for discovery."

91/C/02F "Science is investigation into the physical and natural world."

91/C/03M " Science is a way of looking at things to find out how they work and why they existing the form that they do.

91/C/04F "Science is the knowledge and understanding of the nature of the world and beyond.."

91/C/06M Science (Dictionary definition given).

91/C/07F " Science is the study of nature (of past and present) incorporating the environment and all its inhabitants ..."

91/C/08M "Science is whatever you are able to make of it." "The academics of science are of no real interest to me...it's better to get right into the real thing."

91/C/09M " Science is one of many belief systems which relentlessly tries to find causalities, but never actually does..... science is a necessary evil."

91/C/10F " Science is imagination and learning. Through witnessing and practical experiments we learn the nature and what constitutes our world and beyond."

91/C/11M "Science is ...one perspective among many and equally legitimate perspectives..."

91/C/12M "Science is watching, dissecting, analysing, testing, exploding, growing, counting, etc to discover systematic or generalised ways of going about things. It is the development of knowledge."

APPENDIX 3

DISSECTIONS: A SUMMARY.

91/A/07F "I found having to dissect frogs and rats revolting."

91/A/21F I loved biology but doesn't everyone, it is the only place where you get to cut up rats.

91/A/23F Another experiment which I can remember is the dissection of a frog. This experiment caused the class to divide in regard to their opinion about whether it was a worthy experiment. "Science is about magic tricks demonstrated by mystical individuals, according to my early childhood thoughts."

91/A/26F My main worry with Biology came the day we had to cut up a rat, I just couldn't handle that. I hated the sight of blood.

93/A/10F "The night that we had to cut up a frog was the last night that I attended biology"

93/A/12F She remembers ... chopped up a cow's heart (to my horror) ...

93/A/13F Dissection of frogs made her violently ill.

93/A/17F At high school in years 1 &2 she says of the dissection of a frog "many students both male and female found this a distressing lesson."

93/A/25F .... At primary school she has vague recollections of ... breeding tadpoles in the classroom. In high school she recollects the dissection of frogs. "I always wondered if there was a class of primary students (breeding tadpoles) somewhere so that we could mutilate them as frogs."

93/A/26F At high school in Darwin she remembers" "The picture is a dissected tree frog its green shiny body belly-up with its entrails on show, skinny elongated legs made to look longer through the process of being stretched and pinned to the dissection board. Humiliated in its death , it continued to twitch and shiver, as if failing in its macabre dance to recognise its own demise. "There was a small exodus of young ladies that ended in the ignominy of detention within the first week of term.

93/A/28F "I also remember enjoying dissecting frogs and mice and examining specimens under microscopes."

93/A/32F "The one thing I really hated about science in high school was having to witness dissections."

94/A/10F Experiments that she remembers were.... dissecting a rat.

94/A/19F At high school she remembers rat dissections.

95/A/15F Frog dissections put her off medicine.

92/B/05F She did not like pithing frogs or dissecting them.

94/B/01M Little specific recollection of being taught much science at high school, though remembers a rat dissection,

91/C/02F She did biology in Y 11/12. "Two practicals that I really enjoyed were testing our own blood groups and dissecting rats. When it came to the teacher dissecting a pregnant rat in front of the class, I was disgusted and left the laboratory. That experience was very overwhelming."

91/C/04F At high school her early interest in biology continued with highlights such as dissecting frogs and learning about the human reproductive system.

91/C/06M "The most exciting area of early high school science was the biology area. The massacre of mice, rats and frogs. This I found to be fantastic and very interesting. I could have spent hours upon hours in the lab doing dissections."

91/C/08M He only did biology in year 12 also with a good teacher ; he notes that the entire class vetoed experimenting on animals.

APPENDIX 3
OWN VIEW OF SCIENCE- TEACHERS

91/A/02F She had a good teacher (male). "He combined practical experiments, excursions, personal enthusiasm and interest to create lessons that one looked forward to attending."

91/A/05F She says that teachers tended either to lack knowledge of the subject or the ability to motivate if they had the knowledge. In yr 11 she was interested in biology, but also struggled with physics, "the teacher (male) had an attitude that females should not do physics thus provided very little support and much controversy."

91/A/06F She recognises that her science teachers (male) encouraged her in science. She believes it to be important for teachers to be more than teachers, that is to be regarded as friends.

91/A/08M He had good teachers in years 8 and 9 and in year 9 did well in Natural Science Competition. In year 11 he did chemistry and biology but with several changes of teacher, failed and dropped it.

91/A/10F I really enjoyed what I was learning due to the interesting way in which it was presented to me."

91/A/12M He also indicates that the quality of teachers in science is variable.

91/A/16F I was interested in Chemistry and Biology only, because my Physics teacher was changing all the time and I felt physics was only good for boys."

91/A/17M At senior high school he attended a better equipped school, and the teacher made science interesting and relevant.

91/A/21F "In junior high science the most memorable thing was the teacher. Woo, she was something. In the black and white movies they portray scientists as muddled, dotty, vague and forgetful, well our teacher was exactly like that. If you asked a question, it was answered in such a way that you became more puzzled than you were before. For zillions of lessons we copied zillions of notes off the blackboard."

91/A/24F She remembers a teacher (named Mr X) explaining pollination in yr 6. At secondary school she liked science. "One aspect of my experiences with science, that I will never forget, is the support and caring nature of my science teachers."

91/A/25F "I have always had good and scary memories of the science teacher I had in grade ten, as I thought he looked like a real scientist."

93/A/03F She believes that she had good teachers.

93/A/05F She mentions a local teacher (male) by name as a good teacher.

93/A/06M He remembers one good teacher at primary school and only remembers copying down copious notes at secondary school. As a teacher he wants to try to make science and teaching relevant to everyday events.

93/A/09F Enjoyed junior high school science and mentions one local female teacher by name and also enjoyed science teaching from a male teacher.

93/A/12F " My science teachers had little enthusiasm and no encouragement for our class of budding scientists."

93/A/14F In some people's teaching there is too much spoon-feeding, and not enough room for self experimentation."

93/A/15F " She remembers one particular science teacher (female) as being excellent.

93/A/19F " She remembers at high school how they used to torment a first year out male science teacher. "...his hand shook and his chalk broke. Whenever he yelled (and it was easy to provoke him) his face went really red!"

93/A/20F "At high school she says" I hated it (science). All because a teacher (male) who made me feel very uncomfortable and used to make me stay in after school to perform my experiments alone. "She then went to a different school with a new teacher from whom she learnt a lot but "his breath smelt something chronic". Male teacher local named.

93/A/22F Her most vivid memory is of her new fresh from college male Year 5 teacher's experiments on a balcony outside the classroom with a chemistry set as a reward for good behaviour. She says "they were designed to enthuse us to science, but all they served to do was to reinforce the view that science was too hard for me!" "our experiments were never experiments as such, but rather clumsy mixings of whatever happened to be around . None of us ever considered what we were doing....-we just did it. I have one awful memory of accidentally making a test tube explode. I have no idea how it happened, all I know is that I burst into tears and never

liked to go out on to the balcony after that because I was afraid it would happen again.

93/A/23 F She has quite a clear memory of science at primary school making fans and the teacher explaining how things such as light bulbs worked.

93/A/26F She has quite a clear memory of science at her primary school in Port Moresby, PNG, where the students were terrified of their teacher , Mrs X (Old Grouchy), in case they happened to spill or break one of the fragile glass beakers.

93/A/27F She has little memory of science at primary school. At high school she had a good teacher with the following qualities (i) His knowledge (ii) His ability to express himself (iii) his ability to motivate students to want to learn (iv) His love for the subject.

93/A/31F In a small aboriginal community there was no science taught. Everything was by correspondence, though they did eventually get a science teacher who taught them together to Year 12, so much was not understood.

93/A/35F She believes this was because there was a good teacher.

94/A/05F Most of the reminiscences refer to a particular strict female teacher by name. She says of her " I do believe I learned more from her class and what I learnt stayed in my mind"

94/A/07F Then high school and a specialist teacher and laboratory referred to as a "semi-sterile environment".

4/A/08F High school (i) private good strict clear female teacher (ii) public school teacher strict and difficult to understand, almost all theory (iii) correspondence school :again no practical but the work was more interesting.

94/A/09F At high school she had a good secondary teacher in Darwin, but back in Perth lost interest when the teacher followed the text book. She then had a female teacher for biology in Year 11 & 12, but nearly failed as the teacher encouraged them to work on their own and did not push.

94/A/11F She says of her high school teachers (2 female, 3 male) that they were real normal people.

94/A/14F Enjoyed science at secondary school with a knowledgeable but strict female teacher.

94/A/15F Did not think much of secondary school teachers (boring).

94/A/18M " I have been extremely fortunate throughout my education to have had teachers who have enthusiastically promoted science within the classroom and have possessed the ability to motivate their students to explore, experience and experiment."

95/A/04F Remembers that her father (a biology teacher) showing flowers and birds. no recollection of science at primary school. Secondary stated to be dull with dull teachers

95/A/06F Her first memories are from primary school, where the Vice - Principal taught Grade 6 about hydro electricity and other alternative sources of power. At secondary school she was highly motivated by her female science teachers.

95/A/07M He also speaks favourably of local secondary school teaching (biology).

95/A/08F An uncle interested in science at age of 12 sparked new interests. "Certainly he had a lot more influence than any school teacher".

95/A/10F Encouragement by parents in looking at nature in rural Victoria. Similar encouragement at a rural primary school by an interested teacher. Secondary school teaching was unremarkable, but no discouragement of girls studying science." At primary school, the subject should be one of experiences and wondering, rather than instruction and note-taking."

95/A/12F Some memory of geology at high school, but had a ' clash with the teacher' and that was 'the end of geology'.

95/A/14F Little recollection of being taught science at primary school until Year 6. Had a good science teacher in Year 6 and remembers floating a pin on water, food dye with celery sticks.

95/A/15F In secondary school did not like the chemistry teacher, who explained the lesson too fast and was impatient and questions were not welcome.

95/A/16F The teacher did all the experiments from start to finish, all we were required to do was look and not have a go ourselves'."

95/A/18F Liked physics teacher in year 10 and did well but changed to music.

95/A/19F All theory and memory work We always wanted to know WHY.?. Story of science teacher who asked whether plastic or metal scouring pads were better. She ridicules the question on the grounds that anyone who had used one would know. Evidently he did teach her how to eat a mango properly.

91/B/02M Good biology teacher (named). His physics and chemistry teachers did nothing to rekindle his interest.

91/B/03F She did physics and biology in Y 11/12. The physics teacher seldom came to class and the students read the textbook. he was later dismissed for making improper advances to his students. Biology was more motivating.

91/B/04M Preferred physics and chemistry to biology and geology. Not sure of the reason for the choice, but felt that he had good teachers. He then studied science at university and feels that some lecturers did not communicate their knowledge well.

91/B/05F She did not like astronomy because the teacher was unkempt and did not explain things well. She hated chemistry yet enjoyed this particular unit because of the teacher.

91/B/06F Her high school was also very encouraging of female participation in science. " in Y 11 there were more girls doing physics and maths than typing and shorthand."

91/B/08F She had a good patient biology teacher (female) from Canada. Maths and chemistry teachers were very strict.

91/B/09F High school science seemed boring and irrelevant to her as an adolescent, but matriculation science led to a mellowing of feelings and better rapport with teachers, one of whom was female.

92/B/01M Science teacher at high school remembered as a hero. (Mentioned by name) Remembers making miniature river catchments in a fish-tank with Dr X. An excursion with Dr X and a few friends leads them to discover some small pocket of alluvial gold in a local stream. When he went back with his family a week later he discovered Dr X had turned the place upside down the day before. The day after he graduated he went back to see Dr X " who showed no interest in knowing me at all."

92/B/03M ...though he does say that then "they were able to lead their teacher into discussions and bounce around ideas."

92/B/05F In Y9 she remembers three troublesome boys who were hit on the palm of the hands with a metal ruler for their crimes. One day the boys managed to take the ruler, cut it one inch sections and tape it together again. She also had a run-in with the teacher (male)who she names.

92/B/06M He says that the teacher was too strict so that some students hated the teacher and science.

92/B/07M "Secondary school science began with some heroic experiments. In physics a teacher made a barometer with mercury. In chemistry "interest was spurred on by experiments that flared and popped in the fume-cupboard..."

92/B/08F At year 7 she was told she would never make university (she was third out of 43). She now had a burning determination to prove her wrong. In high school science classes she is always asking questions. She transferred to another school in Y 10 to do more science. Physics is a problem, with an unsympathetic teacher, but improves with a more interesting teacher.

92/B/09M At high school "the quality of the science classes/ teachers was poor from my experience." He liked his chemistry teacher in Years 11 &12 as he was also in the school band. The physics teacher was authoritarian, "but if you had done the required work you could be a little cheeky with him.

92/B/10M At high school he had one teacher (female), who taught him right the way through to Y12 biology who was a competent knowledgable teacher. "By this time though -and mainly due to the totally inept teaching in physics and chemistry by the other teachers, I was getting quite suspicious that science- or more specifically the SCIENCE METHOD were not what I dreamed of as a youngster."

93/B/01M He got on well with his teachers ..

94/B/01M He did physics and chemistry in Years 11/12 and had an excellent teacher (female).

94/B/03F "Science lab no 1' write down all the observations you can make about this burning candle, you should be able to get at least 50' the science teacher said. Yuk, yuk, yuk, boring, boring, boring, I HATE SCIENCE! And that is basically how I felt right through high school; I developed a very cynical and negative attitude towards science and science teachers." Nonetheless she did physics and chemistry at Year 11/12 with bad teachers (both male), both hating their jobs, always talking of getting out of teaching, but both still teaching today.

91/C/01F At high school science was introduced by a stiff man with a white coat:

91/C/04F "The physics teacher worked hard to at shining torches through prisms and drawing beautifully labelled diagrams" " My chemistry teacher was an old dragon, though I did enjoy burning magnesium and sodium..." "Science is the knowledge and understanding of the nature of the world and beyond.."

91/C/08M ..In years 8 &9, I struggled not with the difficulty of the subject; but with the boredom of the way it was presented. Our first science lesson I remember as being really enthralling .. the teacher did all sorts of exciting things with coloured water and acid , things to capture our attention on that first day. That, unfortunately, is where the excitement ended." "in year 10, I was at a boarding school in Adelaide, where I had the most inspiring physics and chemistry teacher. This was the only time where he did well at and enjoyed science. He only did biology in year 12 also with a good teacher..

91/C/09M The teacher (male named) evidently did not answer his questions and he was accused of being disruptive and eventually was moved to the average grade.

91/C/12M He does identify 3 features that turned him off science (i) language associated with science (ii) the learning method (iii) the particular teacher. "The straw that broke the 'science camel's back' for me was a teacher (male, named)" " science lessons were generally a time when everybody 'ran amuck'

APPENDIX 5
CONTRADICTORY REMINISCENCES

WARTIME SECONDARY TEACHING (PHYSICS)

Back from his third retirement came Mary Luke. A chronic shortage of teachers led to Mary Luke being magically resurrected after each burial. Why he should have been called Mary was a datum lost in antiquity. The school presented him with a pocket watch every time he retired. Perhaps that was a mistake. It might have been the massed ticking that kept him alive. Anyway, Mary Luke, having already ruined science for a whole generation of schoolboys, came back from the shadows to ruin science for me.

Mary was keen but incomprehensible. The first thing he said at the start of every lesson, whether of physics or chemistry, was, 'Make a Bunsen burner'. He was apparently convinced that given the right encouragement we would continue our science studies in makeshift laboratories at home. So we might have done, if we could have understood anything else he said. Unfortunately 'Make a Bunsen burner' was his one remaining fathomable sentence. In all other respects his elocution made my late grandfather sound like Leslie Howard. The same comparison applied to his physical appearance. How could anyone be that old without being dead? But there were definite signs of life. The mouth moved constantly. 'Combustioff off magnesioff', Mary would announce keenly. 'Magnesioff off oxidoff off hydrogoff off givoff off'. Worriedly I slid the cap off the inverted jar and ignited the gaseous contents to prove that hydrogoff had been givoff off. Carefully I drew the apparatus in my book, already aware that these preliminary experiments would be the last I would ever understand.

Perhaps I was never cut out for chemistry. But I had a right to think that physics might have lain within my scope. I impressed Mary with my precocious knowledge of the planets, which I could name in their order outwards from the sun. Mary looked momentarily blank at the mention of Pluto, but otherwise he seemed well pleased. A novel rearrangement of his lips took place which I guessed to be a smile. The teeth thereby revealed featured eye-catching areas of green amongst the standard amber and ochre. If only we could have stuck to astronomy. Instead, Mary sprang optics on us. 'Thoff angloff off incidoff', he informed us, 'equoff thoff angloff off reflectioff'. We fiddled dutifully with pins and mirrors. I had the sinking feeling of being unable to understand. The moment of breakdown came when Mary started exploring the different properties of concave and convex mirrors. I couldn't see which was which when he held them up. More importantly, I couldn't tell the difference when he said their names. 'Thoff miroff off concoff', he explained carefully, 'off thoff

miroff off convoff'. Proud of having made things clear, he smiled fixedly, giving us a long look at his wrecked teeth. What was going on in that mouth of his? I could see things moving.
(James, 1980).

SCIENTISTS VIEWPOINT : PROFESSOR ARTHUR BIRCH

Q. Do you have any outstanding recollections of science lessons or learnings in science at school? What inspiration (if any) for your future career resulted from your experience of science at school?

My interest in science was not dependent on teachers or lessons but on me. Probably the old Technological Museum in Ultimo, Sydney (despite the deficiencies I now recognise) had more influence on me than schooling. I received in one sense no inspiration since my mind was made up, I *just wanted to know*. However, I can make several points about teachers. "Mary" Luke at the Sydney Technical High School, was, I now realise, rather a charlatan, because he did not really understand many aspects himself. He was however a superb showman, with a Thursday afternoon science club (after school hours) where he did experiments. There was a waiting list for the club. Another teacher, Broome, was totally different. Factual, rather dry, but fully appreciative of the genuine hard work and dedication necessary to lead to real understanding.
(Newman 1983)