The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9.

A Research and Development Report

prepared for the

Department of Education, Science and Training

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Executive Summary

The study was commissioned by the Department of Education, Science and Training (DEST) and investigated the impact of using curriculum materials specifically designed to support the use of remote telescopes by students and their teachers. The Chief Investigator was Associate Professor David McKinnon from Charles Sturt University.

Research design

The research employed a quasi-experimental pre-test, post-test mixed method design to evaluate the impact of an intervention, comprising a suite of curriculum materials, an Internet web site, and access to the Charles Sturt University Remote Telescope located in Bathurst, New South Wales. The intervention was implemented in Year 7, 8 and 9 science classes in four jurisdictions. The study builds upon a previous national study conducted by Goodrum, Hackling and Rennie entitled *The Status and Quality of Teaching and Learning of Science in Australian Schools* (2000).

Methods and data sources

A repeated-measures design was employed to evaluate the impact of the curriculum materials and use of the remote telescope on students and teachers. Data sources included:

- a student survey containing both rating-scale items and open ended questions completed by 2036 students on the pre-intervention occasion and by 1196 students on the post-intervention occasion in Years 7, 8 and 9;
- an assessment of students' knowledge of astronomy prior to, and again at the conclusion of, the intervention;
- a teacher survey containing both rating-scale items and open-ended questions completed by 101 teachers on the pre-intervention occasion and by 31 teachers on the post-intervention occasion; and,
- six case studies of implementation practice derived from interviews with students and their teachers.

Findings

The results of the pre-intervention investigation show that little has changed since the publication of *The Status and Quality of Teaching and Learning of Science in Australian Schools.* The intervention has demonstrated that there is significant value in introducing remote telescopes into the teaching of astronomy in Years 7, 8 and 9 coupled with quality curriculum materials. Significant changes were made to students' perceptions of science in science education, astronomy content knowledge, reduced the incidence of alternative conceptions and increased the complexity of students' explanations of scientific phenomena despite the fact the period during which the intervention took place was short varying from four to seven weeks.

RECOMMENDATIONS

Recommendation 1

It is recommended that the Commonwealth and educational jurisdictions promote the importance of science education in schools.

Recommendation 2

It is recommended that the Commonwealth and educational jurisdictions make haste in implementing all recommendations made in the *Status and Quality of Teaching and Learning of Science in Australian Schools.*

Recommendation 3

It is recommended that the Commonwealth and educational jurisdictions provide the support of ongoing professional development to help science teachers teach science in ways that promote improved learning outcomes.

Recommendation 4

It is recommended that the Commonwealth and educational jurisdictions provide further funding to investigate the impact on student learning outcomes from using remote and robotic telescopes in Years 10, 11 and 12.

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1 THE EYE OBSERVATORY REMOTE TELESCOPE PROJECT.

A research and development contract funded under the Quality Teaching Program by the Federal Department of Education, Science and Training.

1.1 Introduction

The Chief Investigator for this project had read with great interest the research report prepared for the then Department of Education, Training and Youth Affairs by Goodrum, Hacking and Rennie (2000) entitled *The Status and Quality of Teaching and Learning of Science in Australian Schools.* The report painted a disturbing picture of the then current teaching and learning practices when data were collected during 1999. The authors also painted an ideal picture of what “quality” in the teaching and learning of science should be and which was informed by extensive consultation with teachers, scientists and community members as well as an extensive review of national and international literature on science education, curriculum documents and reports.

The interest generated by the DETYA study led the Chief Investigator to reflect on the work that we were conducting at Charles Sturt University on the use of remotely controlled telescopes that we were using for educational purposes in the primary school. The research conducted led to the belief that at least some of the elements of the ideal picture of science painted by Goodrum et al. (2000: p vii) were being enacted within the Charles Sturt University Remote Telescope Project. For example, of the nine themes identified in the DEST report, five could be identified as being directly applicable to what we were trying to achieve and the remote telescope project was perhaps capable of delivering. These are:

1. Science curriculum is relevant to the needs, concerns and personal experiences of students.
2. Teaching and learning of science is centred on inquiry. Students investigate, construct and test ideas and explanations about the natural world.

3. Assessment serves the purpose of learning and is consistent with and complementary to good teaching.
4. The teaching-learning environment is characterised by enjoyment, fulfillment, ownership of and engagement in learning, and mutual respect between the teacher and students.
5. Teachers and students have access to excellent facilities, equipment and resources to support teaching and learning.

The ways in which using remote telescopes in education could deliver on these themes is the subject of this research and development report.

The first robotic telescope to be made available over the Internet was established at the University of Bradford, United Kingdom, in 1992 (Baruch, 2000). That project demonstrated that there was an enormous interest in using the instrument to get a picture of astronomical object both by the community at large and by students in schools. In 1996, the Telescopes in Education (TIE) project started in the United States of America. The TIE project had access to one 24 - inch telescope at Mount Wilson in California, a refurbished research instrument. Access to this telescope was achieved using a modem over normal telephone lines, an expensive prospect for the few Australian schools that used it.

Since 1996, a number of systems have appeared that use the Internet to gain access to telescopes. The Charles Sturt University Remote Telescope Project is one of these. It commenced operations in 1999. It was conceived within a curriculum research and development framework designed to evaluate its impact on students' attitudes, motivation and performance in science and technology in the primary school. These trials took place during 2000, 2001 and 2002 both in Australia and overseas. Research into the impact on students' knowledge, skills and attitudes was conducted by the Chief Investigator for the current project and has resulted in a number of publications (e.g. McKinnon, Geissinger & Danaia, 2002; McKinnon, 2002; McKinnon & Geissinger, 2002; McKinnon & Mainwaring, 2000) investigating the impact of the primary curriculum materials and telescope control on students and their teachers.

In 2001, the Australian National University announced a partnership with the Faulkes Educational Trust to locate a 2-metre class telescope at its observatory at Siding Spring Mountain, New South Wales. The ANU donated the telescope time it received for looking after the telescope for Australian schools to use. This sophisticated research-grade telescope with extensive instrumentation will be a superb resource for Australian high schools to use when completed but it begs many questions of what will be required to make effective use of it. The associated curriculum development that will be required to align its use with the science syllabus requirements of the various States and Territories will require considerable effort and investment in resource development. There is no doubt, however, that making effective use of such an instrument will require students and teachers to be well prepared.

The current project has developed and trialled educational materials designed to support the use of remote telescopes in junior high school science. A research program was implemented to investigate the impact of the educational materials and use of a remotely controlled telescope on students' knowledge, skills and attitudes towards science. In particular, the research program was constructed to determine the following:

- What are students' current attitudes towards science and what happens in junior secondary school science?
- What content knowledge do students have about astronomy?
- Teachers' and students' experiences during the project.
- Any impact on students' attitudes and content knowledge.

1.2 Overview

Resources developed for the project included:

- a printed teachers' guide and accompanying CD-ROM,
- a printed workbook for students in Years 7 to 9,
- two supporting websites and
- remote access to telescopes at Charles Sturt University.

The research portion of the program implemented and evaluated the impact of the educational materials and the use of a remote telescope run by Charles Sturt University. This project is called *The Eye Observatory Remote Telescope Project.*

The project commenced at the beginning of December 2003 with the development of the student and teacher resources, CD-ROM, Internet web sites and a professional development program for teachers. Application to the Charles Sturt University Ethics in Human Research Committee followed normal University protocols.

On receipt of ethical clearance from the University in late March 2004, applications were made to the following:

- New South Wales Department of Education and Training;
- Victorian Department of Education;
- ACT Department of Education;
- Queensland Department of Education
- Catholic Schools Offices
- Independent Schools in each State.

Final approvals were obtained from each of these organisations by the end of July 2004.

The first professional development program was run in mid-July in New South Wales for teachers from Independent and Catholic schools. Further professional development sessions were run in Queensland (1), Victoria (1), the ACT (1), and New South Wales (4). Professional development was completed by the middle of August 2004.

The delivery of online services commenced at the beginning of Term 3, 2004. The first schools to participate were from Queensland, followed by schools in New South Wales, and finally, those in Victoria and the ACT. All online services were completed by the middle of December 2004.

1.2.1 Data Collection

One goal of this research had been to see if anything had changed since the data collection period conducted during 1999 by Goodrum et al. (2000). Consequently, this study employed the same *School Science Student Questionnaire* reported in Goodrum et al. (2000) to elicit data from students. With minor modifications, the same questionnaire was used after the intervention had been completed.

For the purpose of this project, the *School Science Student Questionnaire* was reverse-mapped and modified slightly to produce a *School Science Teacher Questionnaire* that could be administered to participating teachers. The same questionnaire was used on the post-intervention occasion with minor modifications and the addition of a number of evaluation questions specifically related to teachers' experiences with the project and the materials produced. Data were also elicited from e-mails, the web-site forum and telephone calls made to, and by, teachers.

The *Astronomy Diagnostic Test* (ADT) was used to determine what astronomy content knowledge students already possessed. The ADT was also used as a post- intervention instrument to assess the changes in students' content knowledge outcomes, alternative conceptions and complexity of reasoning. An additional benefit of the ADT administered on the pre-intervention occasion was that some assessment could be made of the learning outcomes achieved by students in their exposure to the astronomy components of science curricula studied in primary school. The returns from participating classes using both instruments amounted to approximately 60% of the return rate for the initial administration.

At the initial professional development day, signed ethical clearance was obtained from teachers. Data collection commenced with the administration of the *School Science Teacher Questionnaire*. The return rate for the final teacher questionnaire compared with the initial one was a disappointing 30% from teachers. This situation is perhaps understandable given the length of the post-intervention instrument.

The two main student instruments, *School Science Student Questionnaire* and the *Astronomy Diagnostic Test*, were administered by teachers before the project commenced in their schools. At the end of the intervention, these instruments were re-administered by teachers and returned to the University.

Teachers made decisions based on their individual, departmental and State curricula as to what to implement from the materials supplied. This led to varied treatments of the educational materials supplied by teachers and their classes. The research project had no control over these decision making procedures, nor did it wish to.

Where project materials were implemented with some of integrity, the educational activities and the motivating influence of learning how to take, and actually taking, control of a remote telescope, led to quite substantial learning effects.

Six levels of implementation could be identified. These ranged from just learning how to control the telescope to take images and process them, through to an extensive implementation of all components of the educational materials and telescope and image processing features. The period of time during which materials were used by teachers varied between four weeks and an entire school term.

Six schools were visited, two from country New South Wales, two from metropolitan Sydney and two from metropolitan Brisbane. Participating teachers and students at each location were interviewed to seek their reactions to what was happening during the project. Four vignettes that contrast a number of features in the schools from which they are drawn are presented in this report.

1.3 Structure of this report

The remainder of this report is structured into nine chapters. Chapter 2 describes the methods by which data were obtained. Chapter 3 presents the analysis of the *School Science Student Questionnaire* and compares the findings with those of Goodrum et al. (2000). The pre-intervention data analysis serves to set the scene for what happened in this project.

Chapter 4 presents a comparison of the results from the pre-intervention to the post-intervention occasion for the *School Science Student Questionnaire.*

Chapter 5 reports the results of the *School Science Teacher Questionnaire* data and compares them with the data obtained from students on the pre-intervention occasion.

Chapter 6 reports the teacher data obtained on the post-intervention occasion and compares them with teacher data obtained on the pre-intervention occasion. In addition, evaluative data about the project materials and services delivered to students and teachers are presented.

Chapter 7 presents an analysis of the Astronomy Diagnostic Test results as mapped to the curricula of the participating States and Territory. Three levels of analysis are presented covering the students' content knowledge in astronomy, the alternative scientific conceptions held by students mapped to the items used in the analysis and the level of complexity of the their written responses. The same items are used in the post-intervention analysis to determine the extent to which students have learned astronomy content knowledge.

Chapter 8 of results presents four vignettes describing the reactions of students and their teachers to the project.

The final chapter presents a short discussion of the results and discusses some implications of the research.

2 METHOD

The contract specified that the investigation was to take place in junior high school science classes in the eastern educational jurisdictions of Australia. The major aim was to evaluate the educational impact of using remote control astronomical telescopes. This aim required at least two periods of data collection, one at the beginning prior to the intervention being implemented and a second after the intervention had been completed in schools to assess the impact of using these devices. An associate researcher visited six schools during the intervention to interview teachers and students.

A mixed-methods longitudinal research design was employed to elicit information from students and teachers about their thoughts and feelings about how science is taught, students' knowledge about astronomy and to evaluate the impact of the educational materials employed in conjunction with access and use of the Charles Sturt University Remote Telescope. On the post-intervention occasion additional questions were asked of teachers about their involvement with the project, the quality of the materials and their experiences. The instruments employed in the project are described more fully below.

2.1 Participants

Participating schools were drawn from four educational jurisdictions in both the public and private sectors: Australian Capital Territory, New South Wales, Queensland and Victoria. The number and type of participating schools in each jurisdiction is shown in Table 2.1 and the participating teachers from each school in Table 2.2.

Table 2.1: Number and type of participating schools in each jurisdiction

	State or Territory			
	Australian Capital Territory	New South Wales	Queensland	Victoria
Public	3	5	6	10
Private		7	1	2
Science Centre			*2*	
Number of schools	3	12	7	12

Table 2.2: Participating teachers by school type in each jurisdiction

	State or Territory				
Type of school	Australian Capital Territory	New South Wales	Queensland	Victoria	Total
Government School	5	11	25	23	64
Catholic School		5			5
Independent School		26	3	6	35
Science Centre			3		3
Participating Teachers	5	42	31	29	107

2.2 Recruitment of participants

Participants in each jurisdiction were recruited in different ways. Schools in each State or Territory were identified on an opportunity basis. The methods are described below in temporal order.

2.2.1 Queensland

In March 2004, the Brisbane Astronomical Society invited the Chief Investigator to provide a keynote address at their biennial Astronomy Education Conference at the University of Queensland. Over 80 science teachers from a number of Brisbane and rural schools attended the conference. A few interstate teachers also attended. An invitation to participate was extended at the conclusion of the address. Teachers from 21 schools identified themselves as being interested in participating in the project.

An information package was subsequently sent to the principal, head of science and the teachers who had expressed an interest. Of these, seven schools from Queensland and one from Victoria identified themselves as willing to participate given the time constraints. Staff from two science centres also expressed and interest in receiving copies of the materials developed for the project.

2.2.2 New South Wales

In May 2004, the Australia Telescope National Facility (ATNF) ran a three-day professional development workshop for science teachers at the Parkes Radio Telescope. The Chief Investigator had been invited by the ATNF Education Officer to run a number of sessions on practical astronomy and remote observing. There were 24 participants from city and country schools and two interstate teachers, one from Victoria and one from Queensland. As for the astronomy education conference in Queensland, an invitation was extended to participate.

An information package was sent to the principal, head of science and the teachers who had expressed an interest. Of these, 12 schools identified themselves as willing to participate given the time constraints.

2.2.3 Australian Capital Territory

The CSIRO Education Liaison Officer based in Canberra attended the ATNF workshop at Parkes. The Liaison Officer offered to identify and contact schools in the ACT with a view to participating in the project. Of the six schools contacted, three chose to participate.

2.2.4 Victoria

Contact with Victorian schools was made primarily through the Metropolitan Directorates of the Department of Education. Teachers from two private schools had attended the Brisbane Astronomical Society Conference and the ATNF professional development days and wished to be involved.

Once identified, the public state high schools were contacted directly and information packages sent to their principals, heads of department and interested teachers. Of these, 10 state high schools agreed to participate together with the two private schools.

2.3 Ethics Clearance

Obtaining ethics approval from the various organisations proved to be a monumental task. All Departments of Education required clearance from the Charles Sturt University Ethics in Human Research Committee before they would consider applications to their own Committees. In addition, before giving permission, each Independent school required a direct letter with all documentation provided to the CSU Ethics Committee together with a copy of the letter of clearance to proceed from that committee. Each Catholic Diocese with a particpating high school under their jurisdiction required a separate application. No two organisations required the same information. This resulted in a total of 1194 pages of application. Clearance from the various offices took some considerable time with one office not considering the application and granting clearance until late July, 2004.

These difficulties caused considerable delays to the project and were one of the major reasons why some schools who were originally anxious to participate ended up withdrawing because of time constraints.

The procedures to conduct research in schools needs to be re-visited and perhaps re-assessed by educational jurisdictions so that a common approach might be adopted to streamline the process. It may be added here that the Queensland Department of Education responded most quickly.

2.4 Materials Development

Work commenced on the project upon the signing of the contract by Department of Education, Science and Training and Charles Sturt University early in December 2003. The materials that were developed, or modified, for this project are: student workbook, teacher guide, CD-ROM, Internet website, information searching package, PowerPoint instructional presentations, and further hardware development.

2.4.1 Student Workbook and Teacher Guide

During December 2003 through February 2004, the Student Workbook (184 pages) and Teacher Guide (142 pages) were completed. The materials contained within these were adapted from earlier materials developed by the Chief Investigator.

The Student Workbook was printed in colour at Charles Sturt University and the Teacher Guide in black and white. These were ready for shipping to schools in late March 2004. Mailing did not take place until schools were identified and clearance from the various Ethics committees obtained from authorities.

2.4.2 CD-ROM

CD-ROM development was completed in late February 2004. The self-installing CD-ROM contains approximately 400 megabytes of resources and includes the following.

- Instructional PowerPoint presentations covering: a motivational sequence of what the students are to do; how to control the telescope and cameras; and; introductory image processing. These were adapted from earlier versions. Adaptation principally involved making changes to the contact procedures through education departments' firewalls.
- Planetarium software that students use to work out what is visible above the telescope at the time when they will control it.
- Image processing software that the students use to enhance their images and to extract scientific information.
- A library of images taken by the Chief Investigator that students use to develop their image processing skills.
- Document templates for such things as image processing records, command sheets for software and observation request forms.
- Spreadsheets to calculate such things as: the diameter of the Sun; asteroid impact energies and crater sizes; and, the distance to the Moon.
- A short movie to show how the telescope works.

2.4.3 DEST Website

The DEST website is a password protected site with two levels of access with one for students and one for teachers.

Students gained access to the following resources on the website:

- a communication Forum;
- an interactive teaching package for planning research, searching the various sources of information and locating materials;
- weather information;
- a timetable of bookings for the telescope;
- an All-sky camera showing the entire sky above the telescope; and,
- a live infra-red camera stream of the telescope as students control it.

Teacher logon gained additional access to:

- State and Territory curriculum documents, and,
- Password-protected access to control the telescope.

2.5 Professional Development

Professional development days were delivered in each educational jurisdiction during July and August, 2004. Table 2.3 sets out the delivery of the professional development days at the various locations.

Table 2.3: Dates and Locations of Professional Development days

Date	Location
June 24, 2004	Blue Mountains Grammar School, Leura, NSW
July 19, 2004	Sandgate District High School, Brisbane Queensland
July 26, 2004	Kinross Wolaroi School, Orange, NSW
2 August, 2004	Our Lady of the Sacred Heart, Kensington, NSW
4 August, 2004	Methodist Ladies College, Melbourne
6 August, 2004	Canberra, ACT
9 August, 2004	Georges River College, Sydney, NSW
11 August, 2004	Condobolin High School, NSW

2.5.1 Content of the professional development day

The content of each professional development day, with minor variations at each venue, followed the schedule outlined below.

- Welcome and Introductions
- Outline of the Project and project research
- Ethical issues
- Informed consent from teachers, parents, students and school principals
- Teacher questionnaire on pre-intervention occasion
- The Teacher Guide and Student Workbook – issues, content, how to use
- The CD-ROM, installation and content
- Web-site and the services provided
- Making contact with the telescope
- Using the planetarium and image processing software provided on the CD-ROM
- Distribution of informed consent letters for parents and students and student questionnaires
- Questions and discussion
- Evaluation

2.6 Sources of Data

Multiple sources of data were employed to investigate the efficacy of using the practical materials as well as the impact of using the telescope and associated cameras. The major sources of data comprised questionnaires completed by both students and teachers prior to, and again at the conclusion of, the intervention. The Astronomy Diagnostic Test (CAER, 2001) was used to assess what students knew about astronomy prior to the intervention and again at the end to assess what they had learned in terms of their content knowledge, alternative scientific conceptions and the complexity of their explanations. An associate researcher visited and conducted interviews with students and teachers at six schools in New South Wales and Queensland. Additional data were provided by email interactions with teachers and with students as well as telephone calls to teachers to remind them to check their e-mail.

2.6.1 Student Data

On return to their schools, participating teachers distributed information letters and obtained informed consent from the students and their parents. Once these were returned to the teacher and forwarded to Charles Sturt University, the teacher administered the two pre-intervention questionnaires.

The first questionnaire probed students' thoughts and feelings about science. The second instrument ascertained the level of students' astronomical knowledge.

Six schools in country NSW (2), Sydney (2) and Brisbane (2) were visited where interviews with groups of students took place.

2.6.1.1 Pre-intervention School Science Student Questionnaire

This questionnaire is the same questionnaire administered to students by Goodrum, Hackling and Rennie (2000) as part of the data collection for "The Status and Quality of Teaching and Learning of Science in Australian Schools". Permission to use the questionnaire was obtained from DEST.

The questionnaire contains 42 Likert-scale items and four open-response items. An additional three Likert-scale items were added to probe students' enjoyment of science in general, at their school and in their science class. The open response items sought information about what they liked/disliked about science, how the science they experienced could be improved, and what they thought the purpose of learning science at school was.

Demographic items asked students to identify themselves, their school, year level, teacher and gender. The reason for this was to allow the pre-intervention responses to be matched with post-intervention responses and with their pre- and post-intervention responses on the Astronomy Diagnostic Test.

The year levels of students had to be matched. Queensland Year 8 students were identified as being in their first year of high school. Consequently, Queensland year levels were recoded to match their equivalent levels in New South Wales, Victoria and the Australian Capital Territory.

2.6.1.2 Post-intervention School Science Student Questionnaire

The same questionnaire was administered by teachers at the conclusion of the subject. Before completing the instrument, students were asked to think specifically about the science that they had been doing over the past six weeks related to astronomy.

The four open-response items asked students to reflect on what had happened during the intervention and how they had enjoyed the experience. The items sought information about what they had liked/disliked about the science experience, how it could be improved, and what they now thought the purpose of learning science at school was.

Demographic items asked students to identify themselves, their school, year level, teacher and gender.

2.6.1.3 Astronomy Diagnostic Test (ADT)

The ADT is a standardised instrument developed by The Collaboration for Astronomy Education Research (CAER, 2001). The instrument was designed for students in the northern hemisphere. Changes to a number of items were made to render it appropriate to assessing southern hemisphere students' astronomical knowledge.

The ADT probes students' knowledge about astronomy and consists of 21 multiple choice items. An additional four knowledge items were added which required students to draw a diagram in order to explain what caused particular phenomena (day and night, orbits of the Earth and Moon in relation to the Sun, lunar phases, seasons) and space provided at the end of each question for them to explain what their drawings represented (Dunlop, 2000).

For each of the 21 multiple-response items, students were asked to leave the response blank if they did not know the answer, or, if they thought they knew the answer, to tick the appropriate response and to give a written reason for their response choice.

Demographic items asked students to identify themselves, their school, year level and gender allow the pre-intervention responses in the School Science Student Questionnaire to be matched with their ADT pre- and post-intervention responses.

2.6.1.4 Post-intervention ADT

The same questionnaire was used to elicit information about how students' knowledge, scientific conceptions and complexity of their thinking about the various phenomena they had encountered had changed.

2.6.1.4.1 Scoring of the ADT

The 25 knowledge items of the ADT were scored at three levels: right/wrong, the alternative conceptions revealed in the written response and the level of complexity of the written response scored using the Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs & Collis, 1982). Two variables were assigned for the coding of the students' alternative conceptions. Thus for each item in the ADT, four variables were assigned to describe the level of knowledge as well as the complexity of the reasons given for a particular answer.

2.6.1.5 Interview Data (Students)

Two schools in country NSW, two in metropolitan Sydney and two in metropolitan Brisbane were visited. At each school, small groups of students who had participated in the project were interviewed about their experiences.

2.6.2 Teacher data

During the professional development day, once agreement to participate had been obtained, teachers were invited to complete a pre-intervention questionnaire on their thoughts and feelings about teaching science. A similar questionnaire was completed by the teachers at the conclusion of the intervention. Teachers also supplied data on the topics that they and their classes had undertaken during the intervention.

A small number of schools in country NSW, Sydney and Brisbane were visited where interviews with teachers took place.

2.6.2.1 Pre-intervention School Science Teacher Questionnaire

The student version of the Goodrum et al. (2000) questionnaire was reverse mapped to provide 42 items that could be asked of teachers. A one-to-one mapping of the items on the student questionnaire was possible by changing the stem of the questions to ask teachers what happened in their classrooms.

An additional five items asked respondents to rank what they perceived their roles as science teachers to be. Four free response items sought information about what they liked/disliked about their teaching of science, how their science class could be improved and finally what their thoughts were about the declining numbers of students taking science courses beyond the compulsory years of school.

Demographic data elicited included: type of school, years to whom the astronomy was taught, gender, state or territory, science qualifications, teaching qualifications, professional development courses attended in astronomy, science subjects taught and to whom over the past 10 years.

2.6.2.2 Post-intervention School Science Teacher Questionnaire

The post intervention teacher questionnaire contained the same items as the pre-intervention version but lacked the information on qualifications, professional development courses attended, science subjects taught and to whom over the past 10 years. Teachers were asked to think about their teaching of the astronomy content using the materials supplied in the project. An additional three free-response role items were added to the five original items ranking their roles as science teachers

An additional 40 items focused specifically on the content and resources supplied by the project and the extent to which they used, and their level of satisfaction with, the materials.

2.6.2.3 Teacher day-record of materials taught

A program in both print and electronic versions was supplied to teachers so that they could record the projects taught and indicate the usefulness of these to their teaching. A day-book approach was employed for teachers to detail their activities in the teaching of the astronomy content and their thoughts and feelings about the materials.

2.6.2.4 Interview Data (Teachers)

Two schools in country NSW, two in metropolitan Sydney and two in metropolitan Brisbane were visited. At each school, some of the teachers who had participated in the project were interviewed about their experiences. Interviews with teachers were conducted according to their availability on the day of the visit. Some of the interviews were conducted individually, while others were conducted in a group interview session.

2.7 Treatment of Data

The methodology dictated that a longitudinal design be adopted. Students and teachers were requested to identify themselves on both pre- and post-intervention instruments. This allowed a longitudinal data set to be constructed from the individual instruments on the pre- and post-occasions.

2.7.1 Student data

Student data were collected by teachers prior to the intervention beginning and again at the end. Once coded and entered, the data were amalgamated into a longitudinal data set. A small sample of students were interviewed at case-study schools.

2.7.1.1 Pre-intervention School Science Student Questionnaire

This questionnaire comprised a number of demographic items, 42 Likert-scale items and four free-response items. Class lists were obtained from participating schools and a unique case number assigned to each student and teacher, as well as codes for the class, school and State/Territory.

The 42 Likert-scale items were coded as indicated on the questionnaire. For each of the free response items, a categorical coding was developed according to the content of the response. Initially, the response categories were developed from the comments presented in the Goodrum et al. (2000) report. As new ones were encountered, new response categories were developed.

A research assistant was provided with the category definitions to code the written responses provided by the students. Two variables were assigned for each of the four free-response items. This proved to be adequate in capturing the major intent of the students' written responses.

Inter-rater reliability was investigated for the coding of the students' written responses. From the developed category definitions, the researcher and the research assistant independently coded 200 items for each of the four free-response items. An inter-judge concordance was computed from the number of agreements/disagreements on each of these 200 items. The inter-judge concordance achieved was better than 97% agreement on each of the four free-response items.

2.7.1.2 Post-intervention School Science Student Questionnaire

The same format was used for the post-intervention questionnaire with instructions to students to reflect on what had happened in the astronomy unit they had been studying over the past few weeks and to circle their responses accordingly.

For the post-intervention free-response items, it as necessary to develop an additional set of response categories by adding to the original set for the pre-intervention questionnaire. The additional set of categories was required because the students were asked to reflect on what had happened in their science classes over the previous weeks while they had been studying astronomy and to write down what they had liked/disliked about the approach and how it could be improved.

Once coded, the questionnaires were entered by the university data entry operator who recorded all of the numerical data in Excel spreadsheets. These files were amalgamated and finally read into the Statistical Package for the Social Sciences (SPSS v11.5) for later analysis.

The longitudinal data set on students' thoughts and feelings about their science experiences was constructed from the two separate pre- and post-intervention data sets using the unique student case numbers assigned during the initial data-collection phase to match cases.

2.7.1.3 Astronomy Diagnostic Test

Each item in the ADT provided four pieces of data: whether the answer was right or wrong, two for the alternative scientific conceptions evident in their answer, and the fourth to indicate the level of complexity of their written reason.

2.7.1.3.1 Alternative scientific conceptions

A manual was developed to classify the students' alternative conceptions evident from the given written reasons for each of the 25 knowledge items. A total of 59 alternative conceptions related to astronomy were identified.

Two research assistants were trained in identifying the alternative conceptions evident in the students' written responses. After the initial training using the definitions of the alternative conceptions, four individuals classified 100 separate questionnaires. Problematic definitions and interpretations were identified and discussion led to clarification and modification of the definitions. A further 100 questionnaires led to inter-judge concordances of better then 95% for all of the 25 items.

Throughout the identification phase of students' alternative scientific conceptions, random groups of 10 questionnaires were triple coded by both research assistants and the Chief Investigator. Inter-judge concordance varied minimally with agreement levels all better than 90%. Cumulative records of inter-judge concordance have been maintained throughout the coding of the students' alternative scientific conceptions.

2.7.1.3.2 Complexity of students' written explanations

The complexity of the students' written responses was assessed using the Structure of the Observed Learning Outcome (SOLO) Taxonomy defined by Biggs and Collis (1982). Here, an ordinal scale was developed to describe the level of complexity of the response independent of whether the answer was right or wrong but taking into account whether the student had interacted with the question or had simply guessed at the answer.

A "0" was assigned if the student had not provided an answer. A "1" was assigned if the student had simply re-stated the question or provided an answer that appeared to be totally unrelated to the question. Biggs and Collis (1982) describe such a response as "pre-conceptual." A "2" was assigned if the written response contained one "chunk" of information related to the item (a "uni-structural" response). A "3" was assigned if the response contained two or more chunks of information (a "multi-structural" response). A "4" was assigned if the student provided two or more chunks of information and tried to relate these together (a "relational" response). A "5" was assigned if the student had provided a relational response and then gone on to discuss other, deeper, aspects of the phenomenon in question. Later, a "6" was added to indicate that the student had clearly indicated that they were "just guessing." A code "9" was assigned to responses that could not be deciphered due to bad writing. Responses coded as "6" and "9" were not included in any computations involving the SOLO response level.

Inter-judge concordance investigations were undertaken to ensure the reliability of classification of the students' SOLO responses. These were undertaken by a PhD student and the Chief Investigator. The level of inter-judge concordance achieved for classification of the SOLO response was greater than 97%.

2.7.1.3.3 Interview data

Interviews with students were recorded and later transcribed by a research assistant at the University. The transcriptions were analysed using a thematic approach related to the structure of the School Science Student Questionnaire.

2.7.2 Teacher data

Teacher data were collected using a questionnaire on the pre-intervention occasion and again on the post-intervention occasion using an extended version. Some teachers at each case study school were interviewed.

2.7.2.1 Pre-intervention School Science Teacher Questionnaire

This questionnaire comprised a number of demographic items, 42 Likert-scale items, five role-ranking items and four free-response items. A unique case number was assigned to each teacher.

The 42 Likert-scale items and the five role-ranking items were coded as indicated on the questionnaire. For each of the free response items, a categorical coding was developed according to the content of the response. Initially, the response categories were developed by reading the comments and as new ones were encountered, new response categories were developed.

A research assistant was provided with the category definitions to code the written responses provided by the teachers. Three variables were assigned for each of the four free-response items. This proved to be adequate in capturing the major intent of the teachers' written responses.

Inter-rater reliability was investigated for the coding of the teachers' written responses. From the developed category definitions, the researcher and the research assistant independently coded 20 items for each of the four free-response items. An inter-judge concordance was computed from the number of agreements/disagreements on each of these 20 item lists. The inter-judge concordance achieved was better than 95% agreement on the categories developed for the four free-response items.

2.7.2.2 Post-intervention School Science Teacher Questionnaire

The same format was used for the post-intervention questionnaire with instructions to teachers to reflect on what had happened during their teaching of the astronomy unit over the past few weeks and to circle their responses accordingly. Three of the four free-response items used in the pre-intervention questionnaire were repeated with the questions rephrased to ask teachers to reflect on their experiences during the teaching of the unit.

Additional Likert-scale items were developed to probe the extent to which teachers valued the experience, found it worthwhile, were satisfied with, and the extent to which they used, the curriculum components and services developed for the project. Four free-response items probed the benefits for students and for them, and what could/should be handled differently or improved.

For the post-intervention questionnaire, a set of additional response categories had to be developed by adding to the original set developed for the three repeated free-response items of the pre-intervention questionnaire. The additional set of categories was required because the teachers had been asked to reflect on what had happened in their science classes over the previous weeks while they had been teaching astronomy.

The additional Likert-scale items were coded according to the way they are laid out in the questionnaire. A coding system was developed for the additional free response items probing the benefits for them and for their students, and for what could/should be handled differently or improved.

Once coded, the questionnaires were entered by the University's data entry operator who recorded all of the numerical data in Excel spreadsheets. These files were amalgamated and finally read into the Statistical Package for the Social Sciences (SPSS v11.5) for later analysis.

The longitudinal data set on teachers' thoughts and feelings about their science experiences was constructed from the two separate pre- and post-intervention data sets using the unique teacher case numbers assigned during the initial data-collection phase.

2.7.2.3 Interview data

Interviews with teachers were recorded and later transcribed by a research assistant at the University. The transcriptions were analysed using a thematic approach related to the structure of the School Science Teacher Questionnaire.

2.8 Summary

A longitudinal mixed method design has been employed to collect data from students and teachers. Before embarking on the project, teachers and students completed the relevant School Science Questionnaire. Students completed the Astronomy Diagnostic Test to determine what they already knew about the astronomy that is commonly found in the curriculum documents for primary schools in Australia. Students and teachers again completed the relevant instruments at the conclusion of the intervention involving the project curriculum materials and the remote telescope. Six schools were visited to conduct interviews with participating teachers and students on their experiences with the materials and with the telescope.

The next seven chapters describe the results obtained from the analysis of the questionnaires and interviews.

3 RESULTS I: STUDENTS' PRE-INTERVENTION QUESTIONNAIRE

This first section of results presents a comparison between the results obtained in 1999 by Goodrum et al. (2000) and the results obtained in this project during 2004. The aim of this chapter is to answer the question "What has changed in the period 1999-2004 from the perspective of students' experiences in science?"

This section compares pre-intervention data obtained in the current study with the results obtained by Goodrum et al. (2000: p118-122) in 1999. The responses obtained in this study are presented in tables and immediately followed by the results obtained by Goodrum et al. (2000) enclosed in brackets for comparison.

3.1 The Sample

The results for the Year 7, 8 and 9 sample were based on questionnaires completed by the 2036 students whose year level and sex are described in Table 3.1.

Table 3.1: Sample Description—Secondary School Students

	Year of School						Total	
	Year 7		Year 8		Year 9		Count	%
	Count	%	Count	%	Count	%		
female	781	38.4%	314	15.4%	96	4.7%	1191	58.5%
male	518	25.4%	207	10.2%	120	5.9%	845	41.5%
Total	1299	63.8%	521	25.6%	216	10.6%	2036	100.0%

It can be seen that students in the first year of high school make up almost two thirds of the sample who undertook to provide pre-intervention data. This was to be expected since the science curricula of the participating educational jurisdictions target astronomy/space science in the first two years of high school to varying degrees.

The next two sections report comparisons of the secondary students' responses to the 42 rating-scale items and the four open-ended questions with the data reported in Goodrum et al. (2000). The first research question to be answered is "What has changed in the five years since Goodrum et al. (2000) collected their data in 1999?"

3.1.1 Responses to Rating-Scale Items on the Years 7, 8 and 9 Science Questionnaire

Table 3.2 reports students' responses to items dealing with the typical learning activities that occur in science classrooms. Students report that the most common activity is writing notes given by the teacher with 68% (61%) of students saying this happens nearly every lesson. Reading from a science text book occurs nearly every lesson for 33% (31%) of students. Group discussions and other group work, such as working out explanations with friends is very common and reported by 85% (83%) of students to occur at least once a week. Students seem to have few opportunities to investigate or to check their own ideas with 32% (47%) saying this happens once a term or less and 61% (59%) report that teachers never let them choose their own topics to investigate.

Table 3.2 Learning Activities—Dealing with Content in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
1. I copy notes the teacher gives me.	2 (3)	2 (3)	6 (7)	23 (26)	68 (61)
2. I work out explanations in science with friends or on my own.	3 (3)	3 (4)	9 (10)	38 (37)	47(46)
3. I have opportunities to explain my ideas.	6 (11)	6 (9)	14 (15)	31 (30)	43 (35)
4. I read a science textbook.	11 (20)	8 (10)	17 (15)	31 (24)	33 (31)
8. we have class discussions.	5 (7)	6 (8)	12 (14)	28 (31)	49 (40)
10. we do our work in groups.	3 (5)	7 (7)	19 (16)	42 (36)	28 (36)
In science we:					
16. Investigate to see if our ideas are right.	15 (25)	17 (22)	24 (25)	29 (19)	15 (9)
My science teacher:					
20. lets us choose our own topics to investigate.	61 (59)	19 (24)	13 (11)	5 (4)	2 (2)

(N) shows the % Response from Goodrum et al. (2000)

Table 3.3 reports responses to items concerning practical work in the secondary science classroom. Practical work occurs relatively often, with 75% (70%) of students reporting that they do experiments by following instructions, at least once a week. For 62% (41%) of students, teachers demonstrate experiments at least once a week. According to the majority of students, they rarely plan and do their own experiments with 52% (58%) reporting that this happens once a term or less. Again these data do not differ markedly from those reported by Goodrum et al. (2000) though 21% more in this study say that they watch the teacher do the experiment at least once a week.

Table 3.3 Practical Work in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
5. I watch the teacher do an experiment.	4 (10)	8 (13)	25 (32)	33 (27)	29 (14)
6. we do experiments by following instructions.	2 (3)	5 (7)	18 (20)	33 (37)	42 (33)
7. we plan and do our own experiments.	32 (33)	20 (25)	20 (22)	17 (13)	10 (7)

(N) shows the % Response from Goodrum et al. (2000)

Table 3.4 shows that 66% (70%) of students report that they need to think and ask questions, 64% (59%) report that they have to remember lots of facts, and 58% (54%) claim that they have to understand and explain science ideas *Very Often* or *Almost Always*.

Table 3.4 Thinking about Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
In science we need to be able to:					
31. think and ask questions.	3 (5)	10 (13)	21 (22)	27 (26)	39 (34)
32. remember lots of facts.	3 (5)	10 (12)	23 (24)	34 (29)	30 (30)
33. understand and explain science ideas.	3 (6)	12 (15)	26 (25)	30 (30)	28 (24)
34. recognise the science in the world around us.	6 (9)	16 (17)	24 (27)	27 (26)	27 (21)

(N) shows the % Response from Goodrum et al. (2000)

Slightly fewer of them, 54% (47%) reported that they had to recognise the science in the world around them *Very Often* or *Almost Always*.

Again these data are broadly consistent with the results reported by Goodrum et al. (2000).

Table 3.5 presents students' opinions on the kinds of guidance and feedback teachers give them in science. Formative forms of evaluation, such as the teacher telling the student how to improve their work, happen at least *once a week* for 54% (45%) of them and giving quizzes happens at least *once a week* for 26% (23%) of students.

Table 3.5 Teacher Feedback and Guidance in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
My science teacher:					
17. tells me how to improve my work.	11 (16)	15 (15)	21 (24)	31 (27)	23 (18)
18. gives us quizzes that we mark to see how we are going.	14 (23)	21 (22)	39 (32)	19 (16)	7 (7)
19. talks to me about how I am getting on in science.	25 (33)	29 (29)	22 (21)	17 (12)	7 (5)
My science teacher:	Almost never	Sometimes	Often	Very Often	Almost Always
26. marks our work and gives it back quickly.	12 (19)	15 (26)	27 (20)	33 (17)	13 (18)
27. makes it clear what we have to do to get good marks.	7 (10)	11 (18)	20 (22)	29 (24)	34 (26)
28. uses language that is easy to understand.	6 (9)	7 (14)	10 (21)	20 (24)	57 (32)
29. takes notice of students ideas.	8 (14)	8 (19)	13 (22)	28 (23)	43 (22)
30. shows us how new work relates to what we have already done.	9 (15)	12 (25)	21 (24)	33 (21)	25 (15)
During science class:	Almost never	Sometimes	Often	Very Often	Almost Always
36. we have enough time to think about what we are doing.	7 (13)	26 (31)	32 (29)	22 (17)	12 (10)

(N) shows the % Response from Goodrum et al. (2000)

In the present study, one quarter (33%) of students reported that the teacher *Almost Never* spoke to them about how they were getting on in science. Almost three quarters of students in this study compared with 55% in Goodrum et al. (2000) reported that the teacher marks their work and gives it back quickly *Often*, *Very Often* or *Almost Always*. Teachers are highly likely to explain what needs to be done to get good marks with 83% (72%) reporting that this happens *Often* or more frequently.

Teachers appear to use language that is easy to understand with 87% (77%) of students reporting that this happens *Often*, *Very Often* or *Almost Always*. They also appear to relate new work to old in 79% (60%) of students' responses *Often*, *Very Often* or *Almost Always*.

Fewer students seem to be pressured for time in their science classes in 2004 than they were in 1999 with 33% (44%) reporting that they *Never* or only *Sometimes* have time to think about what they are doing.

Table 3.6 Links with Years 7, 8 and 9 Science Outside the Classroom

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
9. we learn about scientists and what they do.	19 (35)	24 (28)	30 (24)	19 (10)	8 (3)
In science we:					
11. do practical work outside in the schoolyard, the beach or in the bush.	49 (43)	34 (37)	12 (17)	3 (2)	1 (1)
12. have excursions to the zoo, museum, science centre, or places like that.	56 (76)	40 (21)	3 (2)	0 (1)	1 (0)
13. we have visiting speakers who talk to us about science.	73 (84)	21 (13)	4 (2)	1 (1)	1 (0)

(N) shows the % Response from Goodrum et al. (2000)

Table 3.6 presents an almost identical picture to that which was presented by Goodrum et al. (2000). Science continues to be rarely linked with the outside world with 96% (97%) of students rarely undertaking excursions, 84% (80%) rarely leaving the laboratory or classroom to do practical work and 94% (97%) who rarely have a visiting speaker. In this study, a larger proportion, 57% (37%), appear to learn about scientists and what they do compared with the results reported by Goodrum et al. (2000).

Table 3.7 Computer Use in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In science we:					
14. use computers to do our science work.	29 (67)	24 (20)	22 (7)	16 (4)	9 (2)
15. look for information on the Internet at school.	23 (54)	23 (27)	26 (12)	20 (5)	8 (2)

(N) shows the % Response from Goodrum et al. (2000)

Comparisons of the results with those reported by Goodrum et al. (2000) and presented in Table 3.7 appear to show that computer use in science has increased substantially. Nonetheless, 53% (87%) still use a computer to do science work *Once a Term or Less* or *Never* while 46% (81%) use the Internet to look for information with the same frequency.

Table 3.8 Enjoyment and Curiosity in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
During science class:					
35. I get excited about what we do.	25 (39)	40 (37)	18 (14)	11 (6)	7 (4)
37. I am curious about the science we do.	19 (23)	33 (32)	22 (22)	15 (15)	10 (8)
38. I am bored.	16 (17)	40 (37)	14 (13)	12 (11)	17 (22)

(N) shows the % Response from Goodrum et al. (2000)

Table 3.8 shows that the majority of students, 56% (54%), report being bored in science *Never* or *Once a Term or Less* while 52% (55%) are seldom curious about the science they do and only 18% (10%) appear to get excited *Once a Week* or more with the science that they do.

Table 3.9 Perceived Difficulty and Challenge of Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
During science class:					
39. I don't understand the science we do.	28 (31)	48 (43)	13 (12)	6 (7)	6 (7)
40. I find science too easy.	35 (39)	41 (37)	14 (13)	6 (6)	4 (5)
41. I find science challenging.	10 (12)	35 (33)	28 (28)	17 (16)	11 (11)
42. I think science is too hard.	37 (39)	37 (35)	12 (11)	7 (6)	7 (9)

(N) shows the % Response from Goodrum et al. (2000)

The results presented in Table 3.9 are almost identical to those presented in Goodrum et al. (2000). Science is perceived by three quarters in both studies of students to be neither too easy nor too hard. This is indicated by the similar response patterns to the two items about science being too easy or too hard. In this study 56% (55%) find science is challenging *Often*, *Very Often* or *Almost Always*.

The results reported in each cell of Table 3.10 are all within a few percentage points of those reported by Goodrum et al. (2000).

Table 3.10 Perceived Relevance of Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
The science we learn at school:					
19. is relevant to my future.	20 (19)	39 (36)	23 (23)	11 (13)	8 (9)
20. is useful in every day life.	17 (18)	41 (40)	23 (24)	12 (12)	7 (6)
21. deals with things I am concerned about.	33 (31)	35 (36)	20 (19)	7 (10)	4 (4)
22. helps me make decisions about my health.	35 (35)	34 (35)	17 (17)	10 (9)	4 (4)
23. helps me understand environmental issues.	11 (12)	29 (31)	29 (28)	19 (19)	12 (10)

(N) shows the % Response from Goodrum et al. (2000)

Table 3.10 shows that a meagre 19% (22%) of students report that science is relevant while only 19% (18%) report it useful to them *Very Often* or *Almost Always*. One third of students say that science *Almost Never* deals with things they are concerned about or helps them make decisions about their health while another third say science deals with these things *Sometimes*.

Table 3.11 shows the results for three statements that were asked in this study but not in Goodrum et al. (2000) about students' enjoyment of science *in general*, *in this school* and *in this class*. The results show that approximately 40% of students *Agree* or *Strongly Agree* with each of the statements, 40% indicate that they enjoy science *Sometimes* and approximately 20% *Disagree* or *Strongly Disagree*. These results are broadly consistent with the patterns of results presented in the foregoing tables.

Table 3.11 Expressed enjoyment of Science in Years 7, 8 and 9

	% Response				
	Strongly Disagree	Disagree	Sometimes	Agree	Strongly Agree
43. I enjoy science in general.	7	10	38	33	11
44. I enjoy the science we do at this school.	7	11	44	28	10
45. I enjoy the science we do in this class.	7	10	44	28	11

No statements of this nature were used in Goodrum et al. (2000)

3.1.2 Responses to the Open-Ended Questions on Year 7, 8 and 9 Questionnaire

Four open-ended questions were asked of the students covering their likes and dislikes of science in their class, how science could be improved and what they thought the purpose of science was. These were the same questions asked as in Goodrum et al. (2000) and the same coding system was employed. Again, figures obtained in that study are placed in brackets immediately following the figure obtained in this study.

3.1.2.1 What do you like about science in your class?

The first open-ended question on the Year 7, 8 and 9 questionnaire asked students "What are the things that you really like about science in your class?" A total of 1806 students provided 2366 responses to this question, making an average of 1.3 comments on different issues.

Table 3.12: Multiple-response table of what students like about science

	Count	% of cases
Doing experiments	1208	59.3
Doing things on their own	25	1.2
Name a specific activity or topic they like	383	18.8
Working and interacting with their friends	204	10.0
Mention a range of aspects about general learning in science	152	7.5
Comment positively about the teacher	155	7.6
Class discussions	126	6.2
General negative comments in answer to this question	85	4.2
Seeing how things work.	28	1.4
Total responses	2366	116.2

Table 3.12 is a multiple-response table reporting the results of the classification of students' responses to the question of what they like about science. The table clearly shows that the most common response, made by 59% (60%) of students, referred to their liking for doing experiments, with many of them indicating that they wanted to do their own rather than follow directions. This finding shows that little has changed since Goodrum et al. (2000) reported their findings from their data collection in 1999.

Almost 19% (13%) named a specific activity or topic they liked. Working and interacting with their friends was liked by 10% (15%) of students. Another 7.5% (15%) mentioned a range of specific aspects about learning in science. Around 7.6% (13%) of students commented positively about their teacher and another 6.2% (8%) about the discussions that they had in their classroom. Only 4.2% (9%) of students made general negative comments in answer to this question, such as "I hate science" or "I hate writing".

3.1.2.2 What don't you like about science in your class?

The second question asked students "What are the things that you don't like about science in your class?" A total of 2147 comments were made by 1699 students who responded to this question yielding an average of 1.25 comments per student..

Table 3.13 is a multiple-response table reporting the results of the classification of students' responses to the question of what they did not like about science. About 34% (36%) of comments made by students related to their dislike for writing notes or copying from the blackboard, overhead projector or from PowerPoint projection screens and working from books. This finding shows that little has changed since Goodrum et al. (2000) reported their findings from their data collection in 1999.

Nearly 10% (13%) of the students providing comments said that they found science boring. Around 5% (13%) commented on poor teaching. Almost 6% said that they didn't understand the science they were doing, and 12% (13%) found there was too much theory, insufficient depth or challenge and a lack of relevance of the science that they covered in school. Almost 27% mentioned specific aspects of science in the classroom that ranged across badly behaved students spoiling it for everyone to having to cover too much material in too short a time.

Table 3.13: Multiple-response table of what students dislike about science

	Count	% of cases
Writing notes	526	25.8
Working from books	168	8.3
Science is boring	196	9.6
Poor teaching aspects	104	5.1
Didn't understand science	115	5.6
Too much theory/insufficient depth or challenge/lack of relevance	238	11.7
Aspects of helping concentration	2	0.1
Specific aspects.	545	26.8
Other/negative aspects	253	12.4
Total responses	2147	100

3.1.2.3 How could your science class be improved?

The third question asked students "How could your science class be improved so that you could learn more?" The 1653 students responding to this question made 2120 comments at an average of 1.3 comments per student.

Table 3.14: Multiple-response table of how science classes could be improved

	Count	% of cases
Requested more practical and hands-on work.	731	35.9
Science could be made more fun/interesting.	300	14.7
More excursions and similar activities.	206	10.1
Depth, challenge and relevance in science.	95	4.7
Better teaching or better explanations from teachers.	149	7.3
Says that science is already great and can't be improved.	89	4.4
Students: put the onus on changing personal attributes.	84	4.1
More group work.	49	2.4
Other reason not otherwise classifiable.	417	20.5
Total Responses	2120	100

Table 3.14 shows that more than a third of the students requested more practical and hands-on work. Almost 15% (12%) thought science could be made more fun/interesting, and 10% (12%) wanted more excursions and similar activities. Almost 5% (9%) of students thought there should be depth, challenge and relevance in science that they were doing in class. Compared with the 18% reported by Goodrum et al. (2000) who wanted better teaching or better explanations from teachers, this study found that only 7.3% of students made comments in this domain.

3.1.2.4 The purpose of learning science

The final question on the Years 7, 8 and 9 questionnaire "Based on my experience in science lessons, I believe the purpose of learning science is…". drew the least varied responses from the 1682 students who provided 2169 comments, at an average of almost 1.3 comments per student.

Compared with the response patterns for the previous three open-ended questions, the responses from students was the least varied for this question. In absolute terms, one response, that science was to *help them learn about the world around them and about everyday issues*, provided by 988 students or 48.5% (42%) was the most frequently given of all responses on all open ended questions.

Only 9% (27%) said it was to “get knowledge in science” and 11% (15%) said it was about “finding out how things worked”. Over 7% (3%) stated that it was to help them understand the practical applications of science. Only 2% (13%) thought that science was involved in getting a good education and 8% (13%) thought their science lessons were preparation for later science education or to go on to a career in science. Over 6% (7%) of students said that science was pointless and bored them.

Table 3.15: Multiple-response table of the purpose of learning science

	Count	% of cases
Help learn about the world around and about everyday issues	988	48.5
Get knowledge in science	189	9.3
Find out how things work	232	11.4
The practical applications of science	151	7.4
Get a good education	41	2.0
Preparation for later science education or career in science	94	4.6
Science was pointless and bored them	133	6.5
Get a job	82	4.0
Other	259	12.7
Total responses	2169	100

3.1.3 Summary

While presenting a slightly different picture compared with that reported by Goodrum et al. (2000), these data continue to paint a bleak picture of the science education being experienced by students in Years 7, 8 and 9 in 2004. The major difference appeared to be in the use of information technology during science classes where there has been an almost quadrupling of the incidence of reported use at least once a month or more frequently.

4 RESULTS II: WHAT CHANGED FROM PRE- TO POST-INTERVENTION IN STUDENT RESPONSES?

In this section, comparisons are presented in the same way as for Results I to highlight where changes have occurred in the response patterns of students who supplied data on both the pre- and post-intervention occasions. An exhaustive statistical analysis is not provided. Rather, comparisons are presented to highlight the differences between the pre-and post-intervention data. This is done in a similar way to Results I with the post-intervention results presented as response percentages together with pre-intervention response percentages in the brackets. The second research question to be answered is "Has participating in Practical Astronomy for Years 7, 8 and 9 made any difference to students' responses?"

A simple statistical test is used to investigate differences in the distribution of the pre- and post-intervention data. The Wilcoxon signed-rank test is a nonparametric alternative to a paired-samples *t*-test. The researcher did not wish to make the assumptions necessary for a paired-samples *t*-test using ordinal rather than interval scale data. The only assumptions made by the Wilcoxon signed-rank test are that the test variable is continuous and that the distribution of the difference scores is reasonably symmetric. These conditions were checked prior to the analyses. The Two-Related-Samples Test procedure compares the pattern of distributions of the two variables, one obtained on the pre-intervention occasion and the other on the post-intervention occasion.

In order to protect against significant differences that occur by chance in the comparisons of the 45 items, the Bonferroni approach is adopted to reduce the probability at which significance is indicated by a factor of 45. That is, instead of accepting a probability value of 0.05 to indicate that the difference in response pattern is significant, a far more conservative value of (0.05/45) or 0.0011 is adopted below which the difference in response pattern indicates a significant change from the pre- to the post-intervention occasion.

In each of the Tables presented in this section, probability values lower than 0.0011 are indicated by * and if less than 0.0001 by **.

4.1 The Post-intervention Sample

The post-intervention sample results for Year 7, 8 and 9 students were based on questionnaires completed by the 1196 students whose year level and sex are described in Table 4.1.

Table 4.1: Sample Description supplying post-intervention data in Years 7, 8 and 9

	Year of School						Total	
	Year 7		Year 8		Year 9		Count	%
	Count	%	Count	%	Count	%		
female	379	31.7%	238	19.9%	76	6.4%	693	57.9%
male	255	21.3%	144	12.0%	104	8.7%	503	42.1%
Total	634	53.0%	382	31.9%	180	15.1%	1196	100.0%

It can be seen that of the 2039 students who supplied pre-intervention data, 1196 presented valid post-intervention data. This represents a 58.7% return rate.

4.1.1 Responses to Rating-Scale Items on the Years 7, 8 and 9 Post-Intervention Questionnaire

Table 4.2 reports students' responses to items dealing with the typical learning activities that occur in science classrooms. While students continue to report that the most common activity is writing notes given by the teacher with 61% of students saying this happens nearly every lesson, there has been a significant reduction in the amount of time that they spend writing ($p < 0.0001$). The incidence of reading from a science text book, while still a frequent activity, has also reduced significantly ($p < 0.0001$).

Group discussions and other group work, such as working out explanations with friends still remains common and all but one of these have reduced highly significantly over the period of the pre- to post-intervention questionnaires ($p < 0.0001$). The reduction for working in groups also reduced with a significance at the $p < 0.0011$ level. Students continue to have few opportunities to investigate or to check their own ideas with no significant difference between the pre- and post-occasions.

Table 4.2 Learning Activities—Dealing with Content in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
1. I copy notes the teacher gives me.	3 (3)	5 (2)	7 (7)	24 (23)	61(68)	**
2. I work out explanations in science with friends or on my own.	4 (3)	6 (4)	17 (9)	41 (38)	33 (47)	**
3. I have opportunities to explain my ideas.	9 (6)	10 (6)	17 (14)	31 (31)	33 (43)	**
4. I read a science textbook.	23 (11)	15 (8)	22 (17)	24 (31)	16 (33)	**
8. we have class discussions.	7 (5)	9 (6)	16 (12)	29 (28)	40 (49)	**
10. we do our work in groups.	5 (3)	10 (7)	22 (19)	37 (42)	26 (28)	*
In science we:						
16. Investigate to see if our ideas are right.	15 (15)	15 (17)	28 (24)	26 (29)	15 (15)	ns
My science teacher:						
20. lets us choose our own topics to investigate.	52 (61)	20 (19)	16 (13)	7 (5)	5 (2)	**

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0011$, ** $p < 0.0001$, ns=not significant.

Table 4.3 reports responses to items concerning practical work in the secondary science classroom. Practical work occurs relatively often. There has, however, been a significant reduction in students reporting that they do experiments by following instructions, at least once a week ($p < 0.0001$) and in teachers demonstrating experiments ($p <0.0001$). There has, however, been a significant reduction in students planning and doing their own experiments ($p < 0.0001$).

Table 4.3 Practical Work in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
5. I watch the teacher do an experiment.	12 (10)	15 (13)	26 (32)	29 (27)	18 (29)	**
6. we do experiments by following instructions.	10 (2)	13 (5)	21 (18)	28 (33)	27 (42)	**
7. we plan and do our own experiments.	35 (32)	22 (20)	21 (20)	14 (17)	7 (10)	**

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0011, ** p < 0.0001, ns=not significant.

These results were expected given the nature of the resource materials and, as will be seen in subsequent chapters, the expertise of teachers in this content area. That is, lacking expertise, the teachers are more likely to follow the directions supplied in the Teachers' Guide and direct students to follow the procedures specified in the Student Workbook.

Table 4.4 shows that there have been significant reductions in the frequency with which students say they need to think and ask questions (p < 0.0001), report that they have to remember lots of facts (p < 0.0001), and that they have to understand and explain science ideas in most lessons (p < 0.0001). Of concern perhaps, is the significant reduction in the frequency of them reporting that they had to recognise the science in the world around them (p < 0.0012).

Table 4.4 Thinking about Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
In science we need to be able to:						
31. think and ask questions.	6 (3)	13 (10)	28 (21)	23 (27)	30 (39)	**
32. remember lots of facts.	4 (3)	14 (10)	26 (23)	29 (34)	27 (30)	**
33. understand and explain science ideas.	6 (3)	14 (12)	27 (26)	30 (30)	23 (28)	**
34. recognise the science in the world around us.	6 (6)	18 (16)	25 (24)	27 (27)	23 (27)	*

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0011, ** p < 0.0001, ns=not significant.

Table 4.5 presents students' opinions on the kinds of guidance and feedback teachers give them in science for the pre- and post-intervention occasions. All formative forms of evaluation, such as the teacher telling the student how to improve their work and giving quizzes, happen at least once a week. There are, however, significant overall reductions in the pattern of student response ($p < 0.0001$).

Most noticeable in Table 4.5 is the significant reduction in reporting that the teacher marks their work and gives it back quickly (p 0.0001), teachers explaining what needs to be done to get good marks ($p < 0.0001$) and in teachers using language that is easy to understand ($p < 0.0001$). There is also a significant reduction in teachers relating new work to old ($p < 0.0001$).

Table 4.5 Teacher Feedback and Guidance in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
My science teacher:						
17. tells me how to improve my work.	18 (11)	17 (15)	26 (21)	23 (31)	15 (23)	**
18. gives us quizzes that we mark to see how we are going.	19 (14)	24 (21)	32 (39)	18 (19)	7 (7)	**
19. talks to me about how I am getting on in science.	34 (25)	27 (29)	20 (22)	13 (17)	7 (7)	**
My science teacher:	Almost never	Sometimes	Often	Very Often	Almost Always	
26. marks our work and gives it back quickly.	16 (18)	28 (15)	26 (27)	26 (33)	14 (13)	**
27. makes it clear what we have to do to get good marks.	9 (7)	21 (11)	22 (20)	26 (29)	21 (34)	**
28. uses language that is easy to understand.	8 (6)	15 (7)	24 (10)	23 (20)	30 (57)	**
29. takes notice of students ideas.	9 (8)	17 (8)	25 (13)	24 (28)	25 (22)	**
30. shows us how new work relates to what we have already done.	13 (9)	25 (12)	27 (21)	21 (33)	14 (25)	**
During science class:						
36. we have enough time to think about what we are doing.	8 (7)	30 (26)	33 (32)	18 (22)	11 (12)	*

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0011$, ** $p < 0.0001$, ns=not significant.

More students seem to have been pressured for time in their science classes as indicated by the lower proportion of students indicating *about once a week* and the higher proportions indicating *once a term or less* and *almost once a month*. The difference in pattern of responses is significant (p < 0.0011).

Table 4.6 presents a picture of significant changes in students' responses in linking science to what happens outside the classroom. While students still rarely undertake excursions, a significantly lower proportion of them report rarely leaving the laboratory or classroom to do practical work (p < 0.0001) or to having excursions (p < 0.0001).

Table 4.6 Links with Years 7, 8 and 9 Science Outside the Classroom

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
9. we learn about scientists and what they do.	20 (19)	22 (24)	29 (30)	19 (19)	10 (8)	ns
In science we:						
11. do practical work outside in the schoolyard, the beach or in the bush.	42 (49)	31 (34)	20 (12)	5 (3)	2 (1)	**
12. have excursions to the zoo, museum, science centre, or places like that.	49 (56)	41 (40)	6 (3)	2 (0)	1 (1)	**
13. we have visiting speakers who talk to us about science.	65 (73)	25 (21)	7 (4)	1 (1)	2 (1)	**

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0011, ** p < 0.0001, ns=not significant.

It was noted earlier that a larger proportion, 57% (c.f. 37%), in this study appear to learn about scientists and what they do compared with the results reported by Goodrum (2000) at least once a month or more. In this study, the change from the pre- to the post-intervention occasion is not significant.

It was noted above that comparison of the results on the pre-intervention occasion with those reported by Goodrum et al. (2000) appeared to show that computer use had grown substantially.

Table 4.7 Computer Use in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In science we:						
14. use computers to do our science work.	4 (29)	15 (24)	30 (22)	34 (16)	16 (9)	**
15. look for information on the Internet at school.	6 (23)	16 (23)	31 (26)	33 (20)	4 (8)	**

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0011, ** p < 0.0001, ns=not significant.

Table 4.7 shows the results for computer use in science classes on the pre- and the post-intervention occasions and shows that there is a highly significant change in the pattern of students' responses. On the post-intervention occasion, only 19% of students (c.f. 53% and 87% in Goodrum, 2000) reported using a computer to do science work once a term or never (p <0.0001) and 22% (c.f., 46% and 81% in Goodrum, 2000) use the Internet to look for information with the same frequency (p < 0.0001). This is a highly significant change in the pattern of computer use from the pre- to the post-intervention occasion that could be attributed to the intervention.

Table 4.8 Enjoyment and Curiosity in Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Some-times	Often	Very Often	Almost Always	
During science class the students:						
35. I get excited about what we do.	31 (25)	37 (40)	17 (18)	9 (11)	6 (7)	ns
37. I am curious about the science we do.	24 (19)	33 (33)	22 (22)	14 (15)	8 (10)	**
38. I am bored.	13 (16)	36 (40)	15 (14)	14 (12)	21 (17)	**

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001, ns=not significant.

Table 4.8 shows a significant increase in the incidence of boredom with 39% students (c.f. 56% on the pre-intervention occasion) reporting being bored in science *almost never* or *sometimes* and 50% being bored *often, very often* or *almost always* (c.f. 43% on the pre-intervention occasion). In addition, 57% (52%) are seldom or never curious about the science they do and only 22% (25%) appear to be curious *very often* or *almost always*. Both the *boredom* and *curiosity* results are significant at the p < 0.0001 level.

There is little change in the excitement level that students report with only 15% (c.f. 18%) saying this happens *very often* or *almost always*.

The results presented in Table 4.9 show no significant change in students' perception that science is easy, too hard or that it is challenging. There is a significant change in perception by students that they do not understand the science that they do with 33% (c.f. 25%) of students saying that this happens *often*, *very often* or *almost always*.

Table 4.9 Perceived Difficulty and Challenge of Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
During science class:						
39. I don't understand the science we do.	23 (28)	45 (48)	16 (13)	9 (6)	8 (6)	**
40. I find science too easy.	34 (35)	40 (41)	14 (14)	6 (6)	5 (4)	ns
41. I find science challenging.	12 (10)	35 (35)	28 (28)	15 (17)	11 (11)	ns
42. I think science is too hard.	32 (37)	37 (37)	14 (12)	7 (7)	10 (7)	ns

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0011$, ** $p < 0.0001$, ns=not significant.

The results reported in Table 4.10 show that a meagre 16% (c.f., 19%) of students report that science is relevant ($p < 0.0001$) while only 17% (c.f., 19%) report it useful to them *very often* or *almost always* ($p < 0.0001$). These represent significant changes for the worse.

Table 4.10 Perceived Relevance of Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
The science we learn at school:						
21. is relevant to my future.	28 (20)	36 (39)	19 (23)	10 (11)	6 (8)	**
22. is useful in every day life.	22 (17)	37 (41)	24 (23)	11 (12)	6 (7)	**
23. deals with things I am concerned about.	34 (33)	35 (35)	21 (20)	7 (7)	3 (4)	ns
24. helps me make decisions about my health.	42 (35)	29 (34)	17 (17)	8 (10)	4 (4)	ns
25. helps me understand environmental issues.	15 (11)	30 (29)	29 (29)	17 (19)	10 (12)	**

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0011$, ** $p < 0.0001$, ns=not significant.

One third of students continue to say that science almost never deals with things about which they are concerned. As might be expected after a unit of work on astronomy, there is an increase in the proportion of students who say that the science they do never helps them make decisions about their health though the change is not significant. As also might be expected, though disappointingly, there is a significant increase in the proportion of students who say that the science they learn at school does not deal with environmental issues ($p < 0.0001$). Perhaps they have not had the opportunity to digest the fact that their planet is the only place where life is known to exist.

Table 4.11 Expressed enjoyment of Science in Years 7, 8 and 9

	% Response					Sig. p
	Strongly Disagree	Disagree	Sometimes	Agree	Strongly Agree	
43. I enjoy science in general.	10 (7)	13 (10)	38 (38)	29 (33)	10 (11)	**
44. I enjoy the science we do at this school.	9 (7)	14 (11)	44 (44)	25 (28)	8 (10)	**
45. I enjoy the science we do in this class.	11 (7)	12 (10)	41 (44)	26 (28)	9 (11)	**

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0011$, ** $p < 0.0001$, ns=not significant.

Table 4.11 shows the results for three additional statements that were asked in this study about students' enjoyment of science *in general*, *in this school* and *in this class*. The results show that 39% (c.f., 44%) of students agree or strongly agree with the statement that they enjoy science in general. This represents a significant change in the pattern of response away from enjoyment ($p < 0.0001$). In addition there is a significant reduction in the proportion of students who indicate that they enjoy the science that they do at their school from 38% to 33% ($p < 0.0001$). Finally, there is a significant change in the pattern of responses for students' enjoyment of the science that they do in their class from a 39% level of agreement to one of 35% accompanied by an increase in their level of disagreement with the statement from 17% to 23% ($p <0.0001$).

4.1.2 Responses to the Open-Ended Questions on Year 7, 8 and 9 Questionnaire

Four open-ended questions were asked of the students covering their likes and dislikes of science in their class, how science could be improved and what they thought the purpose of science was. On the post-intervention occasion students were asked to think about what had happened in their science classes over the past six to eight weeks when they had been doing astronomy.

A more extensive coding system had to be developed which perhaps reflects on the freshness of the students' memories. Again, figures obtained in the pre-intervention study are placed in brackets immediately following the figure obtained on the post-intervention occasion.

4.1.2.1 What did you like about science over the past 6-8 weeks?

The first open-ended question asked students "What are the things that you really liked about the science in your science class over the past 6-8 weeks?" A total of 1006 students from a maximum of 1196 who submitted data on the post-test provided 1300 responses to this question, making an average of 1.3 comments on their experiences. Percentages shown in brackets are those obtained from the pre-intervention questionnaire.

Table 4.12 is a multiple-response table reporting the results of the classification of students' responses to the question of what they like about science. The table clearly shows that the most common response, made by 24% (59%) of students, referred to their liking for doing experiments. This finding shows a marked drop compared with the data reported on the pre-intervention occasion.

Of the 1196 students, 31.4% mentioned many of the computer related aspects of the intervention such as using the software, getting information on the Internet, image processing or simply using computers. Since only two codes were assigned to each questionnaire item to categorise responses, the 31% is an underestimate of the true response rate of all categories involving the use of computers. A further 22.5% mentioned specific topics within the astronomy programme such as making models, going outside to make scale models of the solar system.

Table 4.12: Multiple-response table of what students liked over the 6-8 weeks of astronomy

	Count	% of students
Doing experiments	291	24.3
Names a specific activity or topic they liked in learning astronomy, moon, planet, stars, galaxies, space	268	22.5
Using computers/ computer lessons	201	16.8
General negative comments in answer to this question	111	9.3
Mention of software e.g. Star MX 5, MX 5, skyglobe, controlling the telescope	105	8.8
General positive comment	86	7.2
Working and interacting with their friends	51	4.3
Image processing/ pictures, getting pictures and or processing them	40	3.3
Comment positively about the teacher	28	2.3
Mention a range of aspects about general learning in science	24	2.0
Researching using the internet/ library/ getting good information	18	1.5
Class discussions	17	1.4
Making models	16	1.3
Doing things on their own	14	1.2
Other aspects e.g. hands on aspects, mathematics	12	1.0
Interacting with the person on the telescope	9	0.8
Less writing, reduced textbook work	7	0.6
Seeing how things work	2	0.2
Total	1300	100

Working and interacting with their friends was liked by 4% (4%) of students. Around 2.3% (7.6%) of students commented positively about their teacher and another 1.4% (6.2%) about the discussions that they had in their classroom. Only 9.3% (4.2%) of students made general negative comments in answer to this question, such as “I hated having to wait for a computer”.

The response pattern has changed markedly from the pre-intervention to the post-intervention occasion. This is not altogether unexpected since the experiences on which the students were being asked to reflect were fresh in their minds. Nonetheless, two of these response categories are notable: the "doing experiments" and "computer use" categories. The halving of comments made about doing experiments could perhaps be interpreted in two ways. Perhaps the students experienced a surfeit of practical work and the doing of experiments now no longer was an issue. Alternatively, perhaps they had done so many practical activities that they were now sick of them.

Computer use has, perhaps, a simpler interpretation. It was noted above that the increase in computer use was significant over the pre- to post-intervention occasions. Perhaps getting access to computers during science was still regarded as a novelty. For those 373 comments from 31% of students in this domain, the experience was liked.

4.1.2.2 What didn't you like about science over the past 6-8 weeks?

The second open-ended question asked students "What are the things that you really didn't like about the science in your class over the past 6-8 weeks?" A total of 999 students from a maximum of 1196 who submitted data on the post-test provided 1210 responses to this question, making an average of 1.2 comments on their experiences. Percentages shown in brackets are those obtained from the pre-intervention questionnaire.

Table 4.13 is a multiple-response table reporting the results of the classification of students' responses to the post-intervention occasion question of what they did not like about science.

The table shows that the proportion of students making comments related to writing notes or working from books has dropped markedly to 18.4% (34%). A separate but related category of comment relates to 6.4% students complaining about the increase in writing, textbook work and being given more homework.

Around 6% (5%) commented on poor teaching. On this occasion, only one comment mentioned badly behaved students spoiling it for everyone.

Almost 5% (6%) said that they didn't understand the science they were doing, and 12% (13%) found there was too much theory, insufficient depth or challenge and a lack of relevance of the science that they had covered.

Table 4.13: Multiple-response table of what students did not like over the 6-8 weeks of astronomy

	Count	% of students
Writing notes	182	15.2
Specific aspects mentions moon, planet, stars, galaxies, space, hands on aspects, mathematics	149	12.4
Other/negative aspects/Everything/All of it	143	12.0
Too much theory/insufficient depth or challenge/lack of relevance	142	11.9
Nothing / not very much / it was all good/ Better class behaviour, split class, smaller class, people	107	9.0
Science is boring	89	7.4
Pressure of assignments/ not enough time to do things/ big assignments	79	6.6
More writing, more textbook work, more homework	77	6.4
Poor teaching aspects	70	5.9
Did not understand science	58	4.8
Working from books	38	3.2
Using computers/ computer lessons/ waiting for computers to be available at school	25	2.1
Mention of software/book e.g. Star MX 5, Skyglobe, the	23	1.9
The weather: bad weather at the telescope, weather patterns,	20	1.7
Image processing/ pictures, getting pictures and/ or processing them	8	0.7
Total	1210	100

Around 7% (10%) of the students provided comments saying that they found science boring with a further 12% saying that they found all of the astronomy boring and 12.4% nominating specific topic areas that they did not like such as the mathematics, or the Moon. This is counterbalanced by 9% of the student making positive comments in a question asking about the negative aspects.

Around 5% of students specifically identified computer related aspects in a negative way such as not being able to access the technology or getting to use the software.

4.1.2.3 How could your science class be improved?

The third question asked students "How their science classes over the past six to eight weeks could be improved so that you could learn more?" The 953 students responding to this question made 1208 comments at an average of 1.26 comments per student.

On this occasion, almost 30% (36%) of the comments requested more practical and hands-on work. Almost 15% (15%) thought science could be made more fun/interesting, and 7.9% (10%) wanted more excursions and similar activities. About 7% (5%) of students thought there should be more depth, challenge and relevance in science that they were doing in class.

Table 4.14: Multiple-response table of how science classes could be improved

	Count	% of students
More practical and hands-on work	357	29.8
Science could be made more fun/interesting	183	15.3
Depth, challenge and relevance in science	87	7.3
Better teaching or better explanations from teachers	92	7.7
Science is already great and cannot be improved	49	4.1
Student put the onus on changing personal attributes	85	7.1
Better class behaviour, split class, smaller class, people to listen more, everyone be quiet	64	5.4
More group work	42	3.5
More excursions and similar activities	95	7.9
More computers	50	4.2
Less homework	97	8.1
More pictures in textbook, shorter textbook	7	0.6
Total	1208	100

Compared with the 18% reported by Goodrum et al. (2000) who wanted better teaching or better explanations from teachers, this study found on the post-intervention occasion that 7.7% (7.3%) of students made comments in this domain.

The issue of class behaviour is again seen as important with 5.4% of students raising the issue of better class behaviour, separate classes based on gender, smaller classes, students to listen more and everyone to be quiet and a further 7% saying that the onus should be on students to improve their behaviour.

Around 4% mentioned that there should be more computers and 8% said that there should be less homework.

4.1.2.4 The purpose of learning science

The final question on the Years 7, 8 and 9 questionnaire "Based on my experience in science lessons, I now believe the purpose of learning science is…" again drew the least varied responses from the 935 students who provided 1127 comments, at an average of almost 1.2 comments per student.

Table 4.15: Multiple-response table of the purpose of learning science

	Count	% of students
Help learn about the world around and everyday issues	588	49.2
Get knowledge in science	118	9.9
Find out how things work	81	6.8
The practical applications of science	41	3.4
Get a good education	13	1.1
Preparation for later science education or career in science	21	1.8
Science was pointless and bored them	123	10.3
Get a job	34	2.8
Other	69	5.8
Make it fun, more enjoyable	39	3.3
Total	1127	100

The results presented in Table 4.15 show that in absolute terms, one response, science was to *help them learn about the world around them and about everyday issues*, and was provided by 49.2% (48.5%) of students. This was again the most frequently given of all responses on all open ended questions.

Only 9.9% (9%) said it was to get knowledge in science and 6.8% (11%) said it was about finding out how things worked. Over 3% (7.2%) stated that it was to help them understand the practical applications of science. Only 1.1% (2%) thought that science was involved in getting a good education and 2.9% (8%) thought their science lessons were preparation for later science education or to go on to a career in science. Over 10% (6%) of students said that science was pointless and bored them.

4.1.3 Summary

The results of the Likert-scale items show many significant differences on the post-intervention occasion compared with the pre intervention occasion. Some of these outcomes can be regarded as positive, for example, the increased use of computers in science classes and in searching the Internet for information, the reduced incidence of copying notes that the teacher gives them and reading from the textbook, the increased incidence of students reporting carrying out investigations and, in the free response item, the reduced call for carrying out more practical work.

If these results can indeed be attributed to the intervention, then it could be said that the intervention has had a significant impact on the students, albeit sometimes negatively, but more often in a positive way.

5 RESULTS III: TEACHERS' RESPONSES – PRE-INTERVENTION

This section of results presents a profile of the teachers who said that they would take part in the project and the data they supplied on the pre-intervention questionnaire. The instrument used to collect data from teachers was the reverse mapped Student Questionnaire.

5.1 The Sample

The results for the teacher sample were based on questionnaires completed by 107 teachers whose first degree fields are described in Table 5.1. Some teachers supplying data had degree fields that covered more than one classification, for example Mathematics and Earth Sciences. It can be seen that 34.6% of those who supplied data had a first degree in physics, chemistry or astronomy, 22.4% in the biological sciences and 47.7% had degrees in allied science fields such as Veterinary Science, Health or Sports Science.

Table 5.1: Sample Description—Degree Fields

	Count	%
Physics/Chemistry/Astronomy	37	34.6
Earth Sciences	8	7.5
Biological Sciences	24	22.4
Agriculture	1	0.9
Mathematics	3	2.8
Other (Vet,Science, Health, Sports Science)	51	47.7
Total Number of Teachers	107	

Table 5.2 shows the educational jurisdiction and the type of school from which participating teachers were drawn. The Science Centre staff were all located in Queensland and participated in providing data even though they did not formally teach

any classes. Their attendance at the professional development day on which data were collected was undertaken at their own discretion and because of their relationship with the many schools attending the science centres. In addition, three heads of science departments attended before committing their staff to participate. These attendees did not have classes to whom they taught the content. Thus, 101 of the 107 teachers who supplied data actually taught classes in Years 7, 8 or 9. The remainder of this section will only report those data from the 101 teachers who actually taught classes.

Table 5.2: Sample Description—Location and Type of School

	State or Territory				
	Australian Capital Territory	New South Wales	Queensland	Victoria	Total
Government School	5	11	25	23	64
Catholic School		5			5
Independent School		26	3	6	35
Science Centre			3		3
Participating Teachers	5	42	31	29	107

Table 5.3 shows the teachers in each jurisdiction who "intended" to teach the content and the level at which it was to be taught by the participating teachers. It can be seen that one teacher in Victoria intended to teach differing sections of the content to each of Years 7, 8 and 9.

Table 5.3: Sample Description—Years to whom content intended to be taught

	State or Territory				
	Australian Capital Territory	New South Wales	Queensland	Victoria	Total
Year 7	1	16	16	13	46
Year 8		13	11	5	29
Year 9		9		6	15
Years 7 and 8	2	1	2	1	6
Years 7 and 9		2		1	3
Years 8 and 9				1	1
Years 7, 8 and 9				1	1
Total	**3**	**41**	**29**	**28**	**101**

The third research question to be asked is "How do teachers' responses to the items compare with students' responses?"

5.1.1 Responses to Rating-Scale Items on the Teacher Questionnaire

In each of the tables presented below, the response percentages of the teachers are presented together with the response percentages of the students on the pre-intervention occasion for comparison. The comparisons should be treated with some caution since the teacher teaches one class among many whereas the students were responding to what happened in their science classes. Nonetheless the comparisons are interesting.

Table 5.4: Learning Activities by teachers—Dealing with Content in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
1. Students copy notes that I give them.	4 (2)	1 (2)	11 (6)	49 (23)	36 (68)
2. I give my students the opportunity to work out explanations.	0 (3)	1 (3)	11 (9)	44 (38)	45(47)
3. I provide opportunities for my students to explain their ideas.	0 (6)	1 (6)	4 (14)	29 (31)	66 (43)
4. My students read a science textbook.	4 (11)	5 (8)	16 (17)	57 (31)	18 (33)
8. I provide opportunities for class discussions.	0 (5)	1 (6)	6 (12)	31 (28)	62 (49)
10. Students work in groups.	0 (3)	0 (7)	8 (19)	57 (42)	35 (28)
In my science class I plan for students to…					
16. Investigate to see if their ideas are right.	3 (15)	29 (17)	35 (24)	26 (29)	8 (15)
As a science teacher I…					
20. allow students to choose their own topics to investigate.	21 (61)	58 (19)	15 (13)	5 (4)	1 (2)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.4 reports teachers' responses to items dealing with the learning activities commonly found in science classrooms. Students' responses for the same items are shown in brackets. There are some interesting differences in the response percentages from both groups. For example, while teachers say that copying notes happens in only 36% of classrooms, 68% of students reported that this happens in nearly every lesson. Another example of such a disparity can be seen with Q3 where 66% of teachers claim that they provide opportunities for students to explain their ideas in nearly every lesson, compared with the 43% of students. With Q20, students "*choosing their own topics to investigate*" is indeed a rare event with 79% of teachers and 80% of students saying that this happens very rarely or never.

Table 5.5: How teachers deal with Practical Work in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
5. I demonstrate experiments.	0 (10)	12 (13)	26 (32)	53 (27)	9 (29)
6. I give instructions to my students to follow when completing experiments.	0 (2)	1 (5)	6 (18)	64 (33)	29 (42)
7. I allow students to plan and do their own experiments.	7 (32)	33 (20)	40 (20)	20 (17)	1 (10)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.5 reports both teacher and student responses to items concerning practical work. It appears that teacher led experiments are the norm. Over 90% of teachers give instructions for students to follow at least once a week or more frequently and 62% demonstrate experiments with the same frequency. Students appear to have a slightly different perspective with 75% of them saying that they follow instructions about once a week or more while 56% of them report that they watch the teacher demonstrate experiments.

Table 5.6: Thinking about Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
In science students need to be able to:					
31. think and ask questions.	0 (3)	0 (10)	7 (21)	18 (27)	75 (39)
32. remember lots of facts.	2 (3)	41 (10)	38 (23)	17 (34)	3 (30)
33. understand and explain science ideas.	0 (3)	1 (12)	13 (26)	41 (30)	46 (28)
34. recognise the science in the world around us.	0 (6)	0 (16)	7 (24)	31 (27)	62 (27)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.6 shows that 75% of teachers say that in science students need to be able to think and ask questions *almost always* while only 39% of students think the same. Combining the two more frequent levels of this question reveals that 93% of teachers think that asking questions is important compared with 63% of students. Only 20% of the teachers think that students need to remember lots of facts *Very Often* or *Almost Always* compared with 64% of the students. In Q33, 87% of teachers think that students need to be able to understand and explain science ideas *Very Often* or *Almost Always* compared with 58% of students. For Q34 the differences even greater with 93% of teachers reporting that students need to be able to recognise the science in the world around us compared with only 54% of the students saying that this should happen *Very Often* or *Almost Always*.

Table 5.7: Teacher Feedback and Guidance in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
As a science teacher I…					
17. Tell students how to improve their work.	1 (11)	4 (15)	21 (21)	41 (31)	34 (23)
18. Give students quizzes that they self-correct so that they can see how they are going	8 (14)	26 (21)	35 (39)	26 (19)	6 (7)
19. Talk to students and give them feedback on how they are getting on in science..	1 (25)	13 (29)	42 (22)	32 (17)	13 (7)
As a science teacher I…	Almost never	Sometimes	Often	Very Often	Almost Always
26. Mark students work and give it back quickly.	1 (18)	16 (15)	29 (27)	29 (33)	26 (13)
27. Make it clear what students have to do to get good marks.	0 (7)	3 (11)	19 (20)	38 (29)	41 (34)
28. Use language that students easily understand.	0 (6)	1 (7)	13 (10)	39 (20)	48 (57)
29. take notice of students' ideas.	0 (8)	5 (8)	23 (13)	44 (28)	29 (22)
30. Show students how new work relates to what we have already done..	2 (9)	6 (12)	17 (21)	43 (33)	33 (25)
During science class:					
36. have enough time to think about what we are doing.	5 (7)	41 (26)	42 (32)	13 (22)	0 (12)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.7 reports the teacher's opinions about the kinds of guidance and feedback they give to help students. Again there are some disparities in the perceptions of teachers and of their students. Three quarters of teachers report that they tell students how to improve their work at least once a week while 54% of students report that this happens at this frequency. Both teachers and students appear to largely agree on the frequency that quizzes are given and they also agree about the use of language in the science classroom. There are major differences between the frequency with which teachers report taking notice of students' ideas (73%) *Very Often* or *Almost Always* compared with the frequency of students' response at a level of 50%. The same may also be said for the frequency with which new work is related to work already done with 76% of teachers reporting that this happens *Very Often* or *Almost Always* compared with 58% of students.

The results reported in Table 5.8 reinforce the finding by Goodrum et al. (2000) that science is rarely linked with outside activities. Excursions seem to be a rarity with 98% of teachers reporting that this happens *Once a term* or *Never* and 99% report that having a visiting speaker is a very rare event. There is some discrepancy between the 67% of teachers and 83% of students who report that they participate in practical work outside of the school classroom *Once a term* or *Never*.

Table 5.8: Links with Years 7, 8 and 9 Science Outside the Classroom

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class:					
9. I provide learning experiences for students to learn about scientists and what they do.	3 (19)	43 (24)	35 (30)	17 (19)	3 (8)
In science we:					
11. Participate in practical work outside in the schoolyard, the beach or bush.	10 (49)	57 (34)	29 (12)	3 (3)	1 (1)
12. Have excursions to the zoo, museum, science centre, or places like that.	16 (56)	82 (40)	1 (3)	0 (0)	1 (1)
13. Listen to visiting speakers who talk to them about science..	49 (73)	50 (21)	1 (4)	0 (1)	1 (1)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.9 reports the frequency with which technology is used to do science work. It would appear that this happens relatively rarely with about one third of teachers reporting that it happens about *Once a week* or *Nearly every lesson* and 28% reporting that they plan for students to use computers at the same level of frequency. It was noted earlier that there was a major increase in the frequency of students reporting computer use compared with that reported by Goodrum et al. (2000). A higher proportion of students report using computers to do these things once a term or less or never than do the teachers.

Table 5.9: Computer Use in Science in Years 7, 8 and 9

	% Response				
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
In my science class I plan for students to…					
14. use computers to do their science work.	6 (29)	22 (24)	45 (22)	23 (16)	5 (9)
15. Look for information on the Internet at school.	3 (23)	29 (23)	35 (26)	26 (20)	8 (8)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.10 shows that 25% of teachers perceive their students as enjoying science and 28% being curious *Very Often* or *Almost Always*. Students report somewhat lower levels of excitement and curiosity and higher levels of boredom.

Table 5.10: Enjoyment and Curiosity in Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
During science lessons I feel students…					
35. get excited about what we do.	0 (25)	28 (40)	48 (18)	22 (11)	3 (7)
37. are curious about the science we do.	3 (19)	23 (33)	47 (22)	25 (15)	3 (10)
38. are bored.	9 (16)	82 (40)	7 (14)	2 (12)	0 (17)

(N) shows the % Response from Student Pre-Intervention questionnaire

The results in Table 5.11 show that 9% of teachers report thinking that students *Almost Never* think science is too hard compared with 37% of students. It would appear that

94% of teachers think that their students *Almost Never* or only *Sometimes* find science too easy. This compares with 76% of students.

Table 5.11: Perceived Difficulty and Challenge of Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
During science lessons I feel students…					
39. don't understand the science we do.	9 (28)	75 (48)	15 (13)	1 (6)	0 (6)
40. find science too easy.	41 (35)	53 (41)	6 (14)	0 (6)	0 (4)
41. fnd science challenging.	0 (10)	22 (35)	48 (28)	29 (17)	2 (11)
42. think science is too hard.	9 (37)	62 (37)	23 (12)	5 (7)	1 (7)

(N) shows the % Response from Student Pre-Intervention questionnaire

Table 5.12 reports that 41% of teachers think that the science students learn at school is relevant to their future while 19% of students do *Very Often* or *Almost Always* and 35% report that it will be useful in their every day life compared with only 19% of students. It would also appear that 48% of teachers report that science helps students make decisions about health issues only *Sometimes* or *Almost Never* and compares with the 69% of students who report at the same level.

Table 5.12: Perceived Relevance of Science in Years 7, 8 and 9

	% Response				
	Almost never	Sometimes	Often	Very Often	Almost Always
The science we learn at school:					
21. is relevant to my students' future.	0 (20)	19 (39)	41 (23)	33 (11)	8 (8)
22. is useful in my students' every day life.	1 (17)	24 (41)	41 (23)	28 (12)	7 (7)
23. deals with things my students are concerned with.	2 (33)	38 (35)	46 (20)	15 (7)	0 (4)
24. helps my students make decisions about their health.	1 (35)	47 (34)	35 (17)	16 (10)	2 (4)
25. helps my students understand environmental issues.	1 (11)	28 (29)	40 (29)	28 (19)	4 (12)

(N) shows the % Response from Student Pre-Intervention questionnaire

The teacher questionnaire asked respondents to rank five roles in order from 1-most important to 5-least important. Table 5.13 shows that teachers appear to rate their role as facilitators of students' learning highly with 90% of the teachers ranking it first or second. The second most highly ranked role is to help students understand science with 87% of the teachers ranking it first or second. Assessing and reporting students' learning outcomes are ranked fourth and fifth respectively while the role of teaching students is ranked third.

Table 5.13: Multiple-response table of what teachers construct their roles to be

	% Ranking				
Rank	1	2	3	4	5
Role is to teach students.	9	14	55	10	12
Role is to report student outcomes to relevant stakeholders.		2	4	17	77
Role is to facilitate students' learning	50	40	11		
Role is to assess students' learning outcomes		3	17	71	9
Role is to help students understand science.	43	44	13	1	

This ranking order is of major interest if examined in light of the results presented for questions 1-42 above. One might ask how teachers construct themselves as facilitators of students' learning if they are directing them how to carry out or demonstrating experiments, rarely exposing them to science outside of the classroom or getting them to copy notes from the blackboard, overhead projector or data projectors.

5.1.2 Responses to the Open-Ended Questions

Four open-ended questions were asked of the teachers covering their likes and dislikes of science in their class, how science could be improved and what they thought of the declining numbers of students taking science beyond the compulsory years of school.

Table 5.14 is a multiple-response table presenting the results of the question which asked of teachers "What are the things that you really like about the way you teach science and the way students learn in your science class?" Responses were coded according to the category of answer. A total of 210 comments were made with no more than three being received from any one teacher. An average of 2.1 comments per teacher was made.

Table 5.14: Multiple-response table of what teachers like about science

	Count	% of cases
Focus on science being student centred and involving students	49	48.5
Practical work, experiments, hands-on work	44	43.6
Relevance to students lives/world	42	41.6
Students asking questions and students initiating discussion	29	28.7
Individualising Learning/ catering for individual difference	16	15.8
Mentions positive attitudes (enthusiasm)	15	14.9
Students working in groups and interacting with their friend	10	9.9
Having access to Internet in the classroom	4	4.0
Time to discuss ideas and theories	1	1.0
Total	210	100

The most common response made by 48.5% of teachers focused on the fact that science was student-centred. The second most common class of comments made by 43.6% of teachers focused on practical work in the science laboratory. The relevance of science to students' lives was the third most common type of response made by 41.6% of the teachers. The latter two classes of comments are somewhat surprising given the fact that student-initiated practical work was rare and the fact that students do not perceive the relevance of science to their lives to be very high.

Table 5.15 presents the multiple response categories of the question which asked of teachers "What are the things, if any, that you don't like about the way you teach and the way students learn in your science class?" A total of 199 responses from the 101 teachers were received at an average of 1.97 comments per teacher. The most common class of response received from 43.6% of the teachers related to the time constraints experienced during science classes and time associated with preparation and clear up. A further 33.7% mentioned their dissatisfaction with the need to adopt teacher-centred approaches that were driven, in part, by the necessity to cover the curriculum and to achieve the outcomes specified in various syllabuses, an issue raised by 29.7% of teachers. Almost a quarter of the teachers mentioned student behaviour and lack of student interest in science as being problematic. Lack of confidence in using the technology was identified by 12.9% of the teachers as being something that was a problem for them and made such comments as “the students are more computer literate than I am".

Table 5.15: Multiple-response table of what teachers dislike about science

	Count	% of cases
Time constraints	44	43.6
Teacher centred approaches	34	33.7
Demands of covering the curriculum- focus on achieving outcomes	30	29.7
Student behaviour and discipline issues/ lack of student interest	25	24.8
Content and theory driven	17	16.8
Lack of resources, guest speakers, excursions etc.	16	15.8
Focus on assessment and meeting assessment deadlines	13	12.9
Lack of confidence/knowledge/use of technology	13	12.9
Prescribed reading from textbooks	7	6.9
Total	199	100

Table 5.16 presents the results of teachers’ responses when asked "How could your science class be improved (if any) so that students could learn more?”

The most common response made by 41.6% of teachers that they would appreciate access to improved resources, better equipment, access to and use of technology, and more out of class experiences. Student-centred approaches in conjunction with more interesting and challenging, relevant content were identified by 32.7% and 37.6% of teachers respectively. Almost 30% of teachers identified the need for more preparation time and curriculum time for science as ways of improving their science classes so that students could learn more. Only six comments were identified that called for more opportunities for professional development.

Table 5.16: Multiple-response table of how science classes could be improved

	Count	% of cases
Improved resources and equipment/access to and use of technology / more excursions	42	41.6
Make the content interesting, challenging and relevant	38	37.6
Make science more student-centred/foster investigations	33	32.7
More preparation time for lessons/ time for science	29	28.7
Smaller classes/minimise behaviour problems/streamed classes	18	17.8
More practical work, experiments, hands-on work	17	16.8
Engage students/make science more fun/interest	9	8.9
More opportunities for Professional Development	6	5.9
Students working in groups more often	5	5.0
Total	197	100

Table 5.17 presents the results of the final question that asked teachers to comment on the declining numbers of students undertaking senior science or moving on to university to study a science related subject.

Table 5.17: Multiple-response table of teachers' thoughts on the declining numbers in science

	Count	% of cases
Lack of well-paid jobs in science	45	44.6
Perceived difficulty (science is too hard)	42	41.6
Lack of relevance to students, boring content	40	39.6
Bad experiences in junior science, found it boring	25	24.8
Low profile in society	23	22.8
More options for students in subject selection	21	20.8
A worrying point/ sad/ disappointing etc.	13	12.9
Stereotypes associated with scientists and science subjects	4	4.0
Gender differences	1	1.0
Total	214	100

A total of 214 comments at an average of 2.12 comments per teacher were received. The three most common classes of response related to the lack of well-paid jobs in science with 44.6% of teachers making comments of this kind, 41.6% said that they thought students perceived science to be too difficult and 39.6% thought that the science they had to teach lacked relevance for students. Almost 25% of the teachers thought that students had had bad experiences in junior science or found it boring and did not wish to prolong the agony.

6 RESULTS IV: TEACHERS' RESPONSES POST-INTERVENTION

A total of 35 questionnaires were received from teachers who had implemented the intervention. This represents a return rate of 35%. This was disappointing compared with the 60% return rate of their students. The fourth and fifth research questions to be asked are "How have teachers' responses to the items changed compared with the pre-intervention questionnaires?" and "What was their reaction to the intervention?"

In this section, comparisons are presented in the same way as for Results II to highlight where changes have occurred in the response patterns of teachers who supplied data on both the pre- and post-intervention occasions. An exhaustive statistical analysis is not provided. Rather, comparisons are presented to highlight the differences between the pre-and post-intervention data. This is done in a similar way to Results II with the post-intervention results presented as response percentages together with pre-intervention response percentages in the brackets for comparison.

As before, the Wilcoxon signed-rank test is again used to compare the pattern of distributions of the pre-intervention and post-intervention variables. In order to protect against significant differences that occur by chance in the comparisons of the 42 items of the teacher questionnaire, the Bonferroni approach is again adopted to reduce the probability at which significance is indicated by a factor of 42. That is, instead of accepting a probability value of 0.05 to indicate that the difference in response pattern is significant, a far more conservative value of (0.05/42) or 0.0012 is adopted below which the difference in response pattern indicates a significant change from the pre- to the post-intervention occasion. It should be noted here that with 35 responses from teachers on the pre- and post-intervention occasions, the Wilcoxon signed-rank test is a relatively crude statistical procedure for detecting change. In this section of results, the actual probabilities are presented in each of the tables of results and probability values lower than 0.0012 are indicated by * and if less than 0.0001 by **. Those probabilities between 0.0012 and 0.006 may have become significant had the full 101 post-intervention questionnaires been received.

6.1.1 Responses to Rating-Scale Items on the Teacher Questionnaire

In each of the tables presented below, the Teachers' Response percentages are presented together with their response percentages on the pre-intervention occasion enclosed in brackets for comparison. The p-value is presented in the right hand column of the table to compare the pattern of distributions of the respondents on the pre- and post-intervention occasion. Table 6.1 presents the results for the items that deal with the learning activities found in science classrooms.

Table 6.1: Learning Activities by teachers—Dealing with Content in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
1. students copy notes that I give them.	6 (4)	14 (1)	20 (11)	34 (49)	26 (36)	0.002
2. I give my students the opportunity to work out explanations.	3 (0)	3 (1)	17 (11)	40 (44)	37(45)	0.77
3. I provide opportunities for my students to explain their ideas.	3 (0)	0 (1)	9 (4)	37 (29)	51 (66)	0.431
4. my students read a science textbook.	3 (4)	20 (8)	23 (16)	29 (57)	20 (18)	0.006
8. I provide opportunities for class discussions.	0 (0)	0 (1)	14 (6)	40 (31)	46 (49)	0.244
10. students work in groups.	0 (0)	0 (0)	6 (8)	57 (57)	37 (35)	0.296
In my science class I plan for students to…						
16. investigate to see if their ideas are right.	6 (3)	6 (29)	54 (35)	31 (26)	3 (8)	0.449
As a science teacher I…						
20. allow students to choose their own topics to investigate.	23 (21)	23 (58)	26 (15)	26 (5)	3 (1)	0.194

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

The Wilcoxon signed rank test results show that there is no significant difference between the pattern of pre- and post –intervention responses. Two sets of results, however, have changed markedly for the respondents from the pre- to post-occasion. There has been a marked reduction in the frequency that students are given notes to copy (p=0.002) and also a slightly less marked reduction in the frequency that students read a textbook (p=0.006).

There were marginal reductions in the frequency with which students were given the opportunity to work out explanations and to explain their ideas. These reductions were accompanied by marginal increases in the frequency with which students were given the opportunity to engage in class discussions, work in groups, investigate to see if their ideas were correct and allowed to choose which topics they wished to investigate.

Table 6.2 reports responses to items concerning practical work in the secondary science classroom. Practical work continued to occur relatively often and there was a marked reduction in the frequency with which teachers reported that they demonstrated experiments (p=0.005). There was little change in the frequency with which teachers reported allowing students to plan and conduct their own experiments and no overall change in the response pattern for teachers giving instructions for students to follow when completing experiments.

Table 6.2: How teachers deal with Practical Work in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
5. I demonstrate experiments.	11 (0)	14 (12)	20 (26)	51 (53)	3 (9)	0.005
6. I give instructions to my students to follow when completing experiments.	3 (0)	0 (1)	6 (6)	54 (64)	37 (29)	1.000
7. I allow students to plan and do their own experiments.	26 (7)	14 (33)	40 (40)	20 (20)	0 (1)	0.200

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

Table 6.3 shows that there has been little change in the pattern of responses from teachers related to what they think students need to be able to do in science. In all items, there are as many changes to teachers' responses in the positive direction as there are in the negative direction resulting in no significant differences in the pattern of responses from the pre- to the post-intervention occasion. This contrasts with the finding for students where significant reductions were found for all four items.

Table 6.3: Thinking about Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
In science students need to be able to:						
31. think and ask questions.	0 (0)	0 (0)	0 (7)	31 (18)	69 (75)	1.000
32. remember lots of facts.	0 (2)	20 (41)	63 (38)	17 (17)	0 (3)	0.124
33. understand and explain science ideas.	0 (0)	0 (1)	14 (13)	43 (41)	43 (46)	0.499
34. recognise the science in the world around us.	0 (0)	0 (0)	6 (7)	37 (31)	57 (62)	0.782

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

Table 6.4 reports changes in the kinds of guidance and feedback teachers give to students in science for the pre- and post-intervention occasion. There has been a marked reduction in the frequency with which teachers report that they give students self-corrected quizzes to see how they are going (p=0.004) and reductions also in how often they tell students how to improve their work. There is little change in the pattern of teachers' responses on telling students how they are getting on in science.

Table 6.4 also shows that there has been a marked reduction in the rate at which teachers report marking students' work and give it back quickly (p=0.007) and a reduction in teachers telling students what they have to do to get good marks. There are also reductions in the frequency with which teachers report that they use language that students can understand, take notice of students' ideas, and in telling students how new work relates to that which they have already done. There has been an increase in the frequency with which teachers report that they have enough time to think about what they are doing.

Overall, these results are encouraging with some bordering on significant findings for the impact of the project.

Table 6.4: Teacher Feedback and Guidance in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
As a science teacher I…						
17. tell students how to improve their work.	6 (1)	3 (4)	14 (21)	49 (41)	29 (34)	0.405
18. give students quizzes that they self-correct so that they can see how they are going	26 (8)	31 (26)	26 (35)	17 (26)	0 (6)	0.004
19. talk to students and give them feedback on how they are getting on in science..	9 (1)	14 (13)	31 (42)	34 (32)	11 (13)	0.903
As a science teacher I…	Almost never	Sometimes	Often	Very Often	Almost Always	
26. mark students work and give it back quickly.	3 (1)	20 (16)	49 (29)	23 (29)	6 (26)	0.007
27. make it clear what students have to do to get good marks.	3 (0)	6 (3)	23 (19)	40 (38)	29 (41)	0.037
28. use language that students easily understand.	3 (0)	0 (7)	23 (13)	40 (39)	34 (48)	0.346
29. take notice of students' ideas.	3 (0)	0 (5)	40 (23)	40 (44)	9 (29)	0.384
30. show students how new work relates to what we have already done..	9 (2)	9 (6)	31 (17)	29 (43)	23 (33)	0.021
During science class:						
36. have enough time to think about what we are doing.	3 (5)	29 (41)	37 (42)	20 (13)	11 (0)	0.028

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

Table 6.5 presents a picture of teacher responses in linking science to what happens outside the classroom. While students still rarely reported undertaking excursions, and a significantly lower proportion of them report rarely leaving the laboratory or classroom to do practical work, teachers report marginal differences in the frequencies with which these things happen. The only result that markedly changes is the frequency with which teachers report engaging with excursions. Here, there is a slight increase away from *Never* or *Once a term or less* towards *Almost once a month* (p=0.007).

Table 6.5: Links with Years 7, 8 and 9 Science outside the Classroom

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class:						
9. I provide learning experiences for students to learn about scientists and what they do.	11 (3)	26 (43)	26 (35)	26 (17)	11 (3)	0.356
In science we:						
11. participate in practical work outside in the schoolyard, the beach or bush.	23 (10)	20 (57)	43 (29)	14 (3)	0 (1)	0.301
12. have excursions to the zoo, museum, science centre, or places like that.	51 (16)	43 (82)	6 (1)	0 (0)	0 (1)	0.007
13. listen to visiting speakers who talk to them about science.	63 (49)	37 (50)	0 (1)	0 (0)	1 (1)	0.071

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0012$, ** $p < 0.0001$.

Table 6.6 shows the results for the frequency of computer use in science classes on the pre- and the post-intervention occasions as reported by teachers. There is a highly significant change in the pattern of teachers' responses.

Table 6.6: Computer Use in Science in Years 7, 8 and 9

	% Response					Sig. p
	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson	
In my science class, I plan for students to…						
14. use computers to do their science work.	3 (6)	0 (22)	14 (45)	40 (23)	43 (5)	0.00007**
15. look for information on the Internet at school.	3 (3)	0 (29)	17 (35)	54 (26)	26 (8)	0.00009**

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0012$, ** $p < 0.0001$.

On the post-intervention occasion, only 3% of teachers (c.f. 28%) reported using a computer to do science work *Once a term* or *Never* ($p < 0.0001$) and 83% report that they plan for students to use them at least once a week compared with 28% their pre-intervention response. A similar pattern is evident for the frequency of planning to use the Internet with only 3% saying *Never* or *Once a term or less* which is down from 32%

on the pre-intervention occasion. During the intervention 84% of teachers planned to use them at least once a week compared with 34% on the pre-intervention occasion. This result is also highly significant ($p < 0.0001$).

These results represent a highly significant change in the pattern of computer use from the pre- to the post-intervention occasion.

Table 6.7 shows that 86% of teachers feel that their students (c.f. 91% on the pre-intervention occasion) are bored in science *Almost Never* or *Sometimes* in contrast to the 49% of students who report the same level of boredom. In addition, 32% (36%) of teachers feel that their students are seldom curious about the science they do and 35% (25%) feel that their students appear to get excited *Very Often* or *Almost Always* while doing the astronomy. At least the excitement level is moving in the right direction.

Table 6.7: Enjoyment and Curiosity in Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
During science lessons, I feel students…						
35. get excited about what we do.	9 (0)	26 (40)	31 (48)	29 (22)	6 (3)	0.317
37. are curious about the science we do.	6 (3)	26 (33)	37 (47)	29 (25)	3 (3)	0.710
38. are bored.	6 (9)	80 (82)	9 (7)	3 (2)	6 (0)	0.963

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0012$, ** $p < 0.0001$.

Table 6.8 shows that there is little change in teachers' perceptions that their students don't understand science, find it easy only *Sometimes* or *Almost Never*, find science challenging or think that it is too hard.

Table 6.8: Perceived Difficulty and Challenge of Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
During science lessons I feel students…						
39. don't understand the science we do.	6 (9)	80 (75)	6 (15)	9 (1)	0 (0)	0.518
40. find science too easy.	46 (41)	49 (53)	6 (6)	0 (0)	0 (0)	0.637
41. find science challenging.	3 (0)	26 (22)	29 (48)	37 (29)	6 (2)	0.605
42. think science is too hard.	11 (9)	60 (62)	23 (23)	0 (5)	6 (1)	0.268

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

The results reported in Table 6.9 show that 20% of teachers (c.f., 41%) report that science is relevant *Very Often* or *Almost Always*, while 37% (c.f., 35%) report it useful to students *Very Often* or *Almost Always*. There is no overall change in teachers' perception that science deals with things that their students are concerned with or that it helps students understand environmental issues. One finding has changed significantly for the worse with teachers believing that science helps students make decisions about their health only *Sometimes* or *Almost Never*, 71% (c.f., 48%) of the time ($p < 0.0012$).

Table 6.9: Perceived Relevance of Science in Years 7, 8 and 9

	% Response					Sig. p
	Almost never	Sometimes	Often	Very Often	Almost Always	
The science we learn at school:						
21. is relevant to my students' future.	6 (0)	31 (19)	43 (41)	20 (33)	0 (8)	0.400
22. is useful in my students' every day life.	11 (1)	31 (24)	20 (41)	34 (28)	3 (7)	0.234
23. deals with things my students are concerned with.	11 (2)	31 (38)	37 (46)	17 (15)	3 (0)	1.000
24. helps my students make decisions about their health.	34 (1)	37 (47)	17 (35)	11 (16)	0 (2)	0.0003*
25. helps my students understand environmental issues.	14 (1)	37 (28)	23 (40)	26 (28)	0 (4)	0.048

(N) shows the % Response on pre-intervention questionnaire, * p < 0.0012, ** p < 0.0001.

The post-intervention teacher questionnaire asked respondents to rank eight roles in order from 1-most important to 8-least important. Five roles were supplied as for the pre-intervention questionnaire. Teachers were asked to add up to three more roles and to rank them all from 1-most important to 8-least important. The teachers added 20 additional roles and ranked them from 1 to 8. These roles had little impact on the ranking of the original five roles for which pre-post comparisons are presented in Table 6.10.

Table 6.10: Multiple-response table of what teachers construct their roles to be

	% Ranking					Sig. p
Rank	1	2	3	4	5	
Role is to teach students.	9 (9)	17 (14)	37 (55)	20 (10)	12 (12)	0.034
Role is to report student outcomes to relevant stakeholders.	6 (0)	3 (2)	0 (4)	9 (17)	83 (77)	0.095
Role is to facilitate students' learning	40 (50)	31 (40)	20 (11)	6 (0)	3 (0)	0.238
Role is to assess students' learning outcomes	3 (0)	9 (3)	6 (17)	49 (71)	35 (9)	0.099
Role is to help students understand science.	43 (43)	37 (44)	14 (13)	3 (1)	3 (0)	0.559

(N) shows the % Response on pre-intervention questionnaire, * $p < 0.0012$, ** $p < 0.0001$.

Table 6.10 shows that teachers still appear to rate their role as facilitators of students' learning highly with 71% of the teachers ranking it first or second compared with 90% on the pre-intervention occasion. The second most highly ranked role is to help students understand science with 80% (c.f. 87%) of the teachers ranking it first or second. Assessing and reporting students' learning outcomes are still ranked fourth and fifth respectively while the role of teaching students is ranked third. Overall, there is no significant change in the ranked positions of any of these roles from the pre- to post-intervention occasion.

This ranking order remains of major interest when examined in light of the results presented for questions 1-42 above. One can continue to ask how teachers can construct themselves as facilitators of students' learning if they are continuing to direct how students should carry out experiments, or worse, demonstrate them, rarely expose them to science outside of the classroom or get them to copy notes from the blackboard, overhead projector or data projector. One can only hypothesise that the teachers construct reasons for conducting science education in these ways.

6.1.2 Responses to the Open-Ended Questions

Table 6.11 is a multiple-response table presenting the results of the question which asked of teachers "What are the things that you really like about the way you taught the astronomy and the way students learned in your science class?" Responses were coded according to the category of answer. A total of 62 comments were made with no more than three being received from any one teacher. An average of 2.01 comments per teacher was made.

Table 6.11: Multiple-response table of what teachers liked about the astronomy

	Count	% of cases
Technology aspects, Internet access in the classroom, using the telescope, activities on the CD-ROM	17	49
Focus on science being student centred and involved students making decisions about what they were to do, individualising the learning, catering for individual difference	15	43
Practical work, experiments, hands-on work	8	23
Mentions positive attitudes (enthusiasm)	8	23
Relevance to students lives/world	4	11
Aspects of the T-guide and SW - format of the lessons, hands on structure	4	11
Students asking questions and students initiating discussion	1	3
Students working in groups and interacting with their friend	1	3
Having lessons ready to teach	1	3
Having a variety of activities	1	3
Being involved in using a new programme Practical Astronomy	1	3
Mentions negative aspects	1	3
Total	62	100

The most common class of responses related to the authentic use of technology in science with 49% of teachers mentioning general or specific aspects about its use. For example, a number of teachers commented, "it was good to actually see how technology can be used in real ways in science" and "learning how to, and actually taking, control of the telescope had a positive impact on my students."

The second most common response made by 43% of teachers focused on the fact that the astronomy programme was student-centred and involved students making decisions about what they were to do. The third most common class of comments made by 23% of teachers focused on practical and hands-on work in the science laboratory. A further 23% of teachers made comments about the positive attitudes that seemed to have been engendered during the intervention.

Table 6.12 reports the results of what teachers found to be negative aspects of the astronomy programme. The most common response in this category made by 31% of teachers related to the difficulties schools encountered negotiating the tortuous path through departmental bureaucracy to get firewall ports opened so that they could access the telescope from within their school network. Queensland was the only jurisdiction where the relevant internet port was opened in the firewall for participating schools without any trouble.

Table 6.12: Multiple-response table of what teachers disliked about astronomy

	Count	% of cases
Difficult access technology, firewall issues, lack of computers, access to computer rooms	11	31
Lack of time prior to starting to look through materials, plan, organise information etc'	9	25
Lack of teacher confidence/knowledge/use of technology	6	18
Student behaviour and discipline issues/lack of student interest	3	9
Went for too long	3	9
Programme involved lot of teacher prep working out what you were doing on the run	2	6
Too student centred-felt like I was not teaching them	2	6
Language in Student Workbook too difficult. Reading levels too high	2	6
Extensive teacher prep carried out by teachers – comment relates to all topics – not just astronomy	2	6
Did not like students having a workbook	2	6
Content and theory driven	1	3
Teacher centred approaches	1	3
Making materials relate to low ability/weaker students	1	3
Hard to assess/grade students, would like more objective assessment	1	3
Too much time spent in students learning software and not enough time spent learning astronomy.	1	3
Did not really like SkyGlobe-prefer Win stars	1	3
Difficulties in booking telescope time. Booking sessions filled quickly, bad weather	1	3
Technology skills sometimes too advanced for students- they tended to get lost	1	3
Total	47	100

The second most common class of response made by 25% of teachers related to the lack of preparation time to digest the resource materials. A further 18% of teachers mentioned their lack of confidence in using the technology.

Two comments by teachers in different schools related to a surprising and unanticipated issue that students should not have access to the Student Workbooks. The remainder of comments related to specific aspects such as the time spent learning how to use the software tools, preference for other software, and the fact that the programme was too student centred with the teacher saying that s/he felt that "I was not teaching them".

Table 6.15 presents the results of the multiple response analysis based on the question about how things could be improved. The most common class of comment related to the specific issue of the reading age of materials and the amount of student reading required (26%). An associated class of comment related to the need for simpler worksheets (20%). Two comments related to teachers' positive experiences and that nothing should be changed.

The remainder of the comments related to highly specific issues and were made by three or fewer teachers. For example, three comments called for more access to professional development in the area of astronomy in the curriculum. A number of comments related to highly specific aspects such as including the entire set of student learning materials in the teachers' guide, providing writing space in the student workbook for students to put in their answers, or to the quality of the binding of the student workbook.

Table 6.15: Multiple-response table of how science classes could be improved

	Count	% of cases
Cut down on student reading in textbook, simplify language	9	26
Need simpler worksheets/ projects such as orbits of Earth and Moon	7	20
More opportunities for Professional Development	3	9
Change PowerPoint slideshows-too long, text appear at once. Allow teachers to stop and control the pace	3	9
Separate Student Workbooks for the different Year Levels	3	9
Simplify materials/software - make it more user friendly	3	9
Add resources for teachers-OHP, links to astronomy-education sites, extension activities	3	9
The DET could help with Firewall issues and technical difficulties	2	6
Cut down on student writing	2	6
Nothing should be changed/ no changes/well done	2	6
More preparation time for lessons/ time for science	1	3
Improved resources and equipment/access to and use of technology, more excursions	1	3
Include further activities and worksheets in the textbook	1	3
Put activities in Student Workbook on CD-ROM so can be adapted to suit class	1	3
Clearer instructions for students in Student Workbook	1	3
More time on astronomy and less time on students' learning to use software	1	3
Provide more areas in Student Workbook for students to record/write their responses	1	3
Put all material into the Teachers' Guide contained in the Student Workbook	1	3
More demonstrations on how to make materials/devices needed for practical activities in PD day	1	3
Books - Covers fell off, ring binding came apart	1	3
Total	47	100

6.1.3 Responses to specific evaluation questions

This final section of results from teachers seeks to report their reactions to specific components of the materials.

Table 6.16 reports the results of teachers' responses to statements made about specific aspects of the programme. Teachers were asked to respond on a forced choice Likert scale from *Strongly Disagree* to *Strongly Agree*.

For all of the items, teachers agreed or strongly agreed at the 75% or higher level. The one item that scored at the 75% level of agreement was the statement that “Involvement has inspired me to apply technology to other science topics.” With this one item, 25% of teachers disagreed. It can be seen that more than 85% of teachers *agreed* or *strongly agreed* that the materials were worthwhile, they enjoyed taking part, found technology use in astronomy valuable, and aided in their own learning and teaching.

More than 80% of teachers thought that the online telescope, the technology and using the internet encouraged student motivation and learning. These results are almost wholly positive for the majority of the teachers providing post-intervention questionnaires.

Table 6.16: Likert scale items tapping teachers’ reactions to components of the programme

	% Response			
	Strongly Disagree	Disagree	Agree	Strongly Agree
54. The suite of materials implemented was worthwhile	3	9	63	26
55. I enjoyed taking part in the project.	0	11	49	40
56. I found the use of technology in the astronomy lessons valuable.	0	11	40	49
57. Involvement has inspired me to apply technology to other science topics.	0	25	66	9
58. The on-line Internet work encouraged student motivation.	6	17	49	29
69. The on-line Internet work encouraged student learning.	6	11	71	11
60. The on-line telescope work encouraged student motivation.	3	9	49	40
61. The on-line telescope work encouraged student learning.	3	14	31	51
62. The technologies and materials used in the project aided my teaching.	0	6	49	46
63. The technologies and materials used in the project aided my learning as a teacher.	0	14	46	40
64. The technologies and materials used in the project aided student learning.	0	14	60	26
65. This project has developed my knowledge and understanding of astronomy.	0	14	31	54

Table 6.17 reports the results of teachers’ levels of satisfaction with the components supplied to them as part of the project. It can be seen that more than 75% of the teachers are *moderately satisfied* or *very satisfied* with the relevance of the project to syllabus

outcomes, the Teachers' Guide, and the help that they received both within the school and through the professional development and from Charles Sturt University.

A more modest proportion of more than 60% of the teachers are *moderately satisfied* or *very satisfied* with the depth of content covered for the year levels taught, the Student Workbook coverage, the technology for the students, the help given to students within the school to use the technology, and the help that they were able to give the students to access and use the technology.

A small proportion of teachers seem to be *not at all satisfied* with anything apart from the school help they received in learning to access and use computer programs. The item that drew the highest level of non-satisfaction is the workbook and materials supplied for students with 17% of teachers expressing the view that they were not at all satisfied. A further 11% of teachers were not at all satisfied with the depth of content covered for the year levels that they taught.

Table 6.17: Level of satisfaction with aspects of the programme.

	% Response			
	Not at all satisfied	Slightly satisfied	Moderately satisfied	Very satisfied
66. Satisfaction with relevance of the project content to syllabus outcomes for science.	3	20	57	20
67. Satisfaction with depth content covered for year level(s) taught.	11	26	46	17
68. Satisfaction with info in the Teacher Guide.	3	17	49	31
69. Satisfaction with Student Workbook and materials for students.	17	17	40	26
70. Satisfaction with technology for students.	9	26	46	20
71. Satisfaction with help I got in learning to access and use computer programs in school.	0	23	43	34
72. Satisfaction with help I was given to access and use computer programs Professional Development, and help from CSU.	3	14	37	46
73. Satisfaction with help students given learning access and use computer programs in school.	6	29	49	17
74. Satisfaction with help I gave students to access and use computer programs in school.	9	26	40	23

Table 6.18 presents the results for the series of items that asked teachers the extent to which they used the various components constructed for the project. It can be seen that

the teacher guide, student workbook and planetarium software were the most heavily used components. These were used by more than 80% of the teachers at least once or twice a week. E-mail, the communication Forum and the information searching utility constructed for the project were the least frequently used items. These were used by less than approximately one quarter of the teachers more than once or twice per week.

Some items were used surprisingly infrequently given the central nature of these components to achieving the educational outcomes of the project. These included the PowerPoint slideshows, the resource links on the Internet web site, the weather information system and the image processing software all of which were used by more than half of the teachers only once or twice or not at all. The communication Forum was not used at all by 69% of the teachers. Despite the fact that teachers had to email the observation request of their class to the university when making a booking for time, 75% of teachers said that they used it *once or twice* or *not at all*.

Table 6.18: The extent to which components were used.

	% Response			
	Not at all	Once or twice	Once or twice a week	Daily
75. Extent used: The Teachers Guide	6	20	40	37
76. Extent used: The Student Workbook	6	9	43	43
77. Extent used: The resource links on the web site	6	54	29	9
78. Extent used: The information searching utility on the web site	35	43	20	3
79. Extent used: The weather links	14	46	37	3
80. Extent used: The image processing software	12	26	51	11
81. Extent used: The planetarium software (SkyGlobe)	12	0	74	14
82. Extent used: The PowerPoint slideshows	3	54	40	3
83. Extent used: The communication Forum	69	20	11	0
84. Extent used: Email (user supplied)	29	46	23	3

Table 6.19 presents the results of the analysis of the final statements seeking teachers' agreement or disagreement about the usefulness of the various components of the project. It can be seen that 77% *Agreed* or *Strongly Agreed* that the Teachers' Guide

was useful, and 60% expressed the same levels of agreement about the Student Workbook.

Table 6.19: Usefulness of the various components

	% Response			
	Strongly Disagree	Disagree	Agree	Strongly Agree
85. The Teachers Guide was extremely useful.	0	23	60	17
86. The Student Workbook was extremely useful for students.	9	31	37	23
87. The CD-ROM was extremely useful.	3	9	60	29
88. The DEST Web site was extremely useful.	0	20	54	26
89. The on-line telescope session was motivating.	0	3	43	54
90. Communicating with other science teachers was satisfying.	3	11	77	9
91. I would recommend this approach to teaching astronomy to science teachers.	0	11	69	20

A higher proportion, 89% *Agreed* or *Strongly Agreed* about the usefulness of the CD-ROM and 80% of the teachers were in agreement with the usefulness of the web site. This latter result is somewhat surprising given the figures reported in Table 6.18 on the extent to which components of the website were used. A surprising 86% of the teachers *Agreed* or *Strongly Agreed* that communicating with other science teachers was satisfying. This also is a surprisingly high level of agreement given the paucity of use of the communication forum and email. Perhaps they communicated with their peers at school.

Almost all teachers providing post-intervention data *Agreed* or *Strongly Agreed* that using the on-line telescope was motivating and 89% of teachers would recommend this approach to teaching astronomy to other science teachers.

Table 6.20 presents the results of the multiple response analysis asking teachers to identify the benefits for their students. A total of 69 comments were given at an average of 2.2 comments per teacher.

The most often reported benefit made by 67% of teachers is the motivation engendered and the interest developed by their students. Another 40% of the teachers' comments noted the relevance to students' interests, the student-centred learning and the variety in the learning experiences. Another 35% of teachers mentioned the benefits and enjoyment of the hands-on activities and controlling the telescope with a further 20% linking the taking of pictures and controlling the telescope as being of benefit.

Table 6.20: Multiple-response table - Benefits to the students

	Count	Column %
Motivated students to learn scientific ideas/astronomy, created interest and enthusiasm in students. Gave students interest and understanding for study of astronomy.	23	67
Gave students more options/learning experiences, student centred learning, relevant to students' interests	14	40
Practical activities/ hands on/actually controlling the telescope was fun	12	35
Having access to and using technology/ICTs	9	26
Taking pictures with and controlling the CSU Remote Telescope	7	20
Provided more opportunities for student questioning, developed technological skills, enabled students to research	3	9
Mentions negative aspects eg students not easily motivated	1	3
Total	69	100

Table 6.21 presents the results of the analysis of teachers' comments in relation benefits for them. A total of 61 comments were made at an average of 1.97 per teacher.

The most common response made by 55% of teachers related to improved content knowledge for them and a greater confidence to teach astronomy in the future. The second most often mentioned benefit for 38% of teachers was seeing how the technology was used in integrated ways to support the teaching and learning in science. A closely related topic for another 23% was in using a different teaching style. That is to say, the comments related to a move from transmission of content to facilitation of understanding. The teaching resources helped another 23% of teachers through cutting down on their preparation time.

The next two groups of comments related to increased teacher motivation and seeing the enthusiasm in their students as they learned the astronomy using the resources of the project. Some comments relating to the links to the syllabus, meeting parents at the observation night, and achieving some measure of integration with mathematics were made by individual teachers.

Table 6.21: Multiple-response table - Benefits to me, the teacher

	Count	Column %
Improved teacher content knowledge, resources and information, more confidence in teaching astronomy to other/future classes	19	55
Using technology/ integration of technology throughout. Having access to the CSU Remote Telescope	13	38
Experience of employing a different teaching style	8	23
Having a Teacher Guide, Student Workbook and practical ideas cut down on planning time	8	23
Seeing the enthusiasm of students learning	5	14
Teacher motivation increased became more interested in astronomy	5	14
The links to outcomes that were provided from syllabus	2	6
Involved students in more independent work which gave the teacher more time to help individual students	1	3
The observation night allowed for teacher/parent communication	1	3
Being able to link science to other areas such as maths	1	3
Total	63	100

Table 6.22 presents the results of the analysis of teachers' comments about suggested improvements. A total of 39 comments were made at an average of 1.25 per teacher.

One class of comments related to the Student Workbook made by 23% of teachers. A second class of comments made by 18% of teachers related to technical and software aspects and ranged from firewall issues to clearer instructions on how to use the software. Professional development, issues related to the observation night, and factors related to the length of the program were each nominated by 15% of teachers.

Table 6.22: Multiple-response table - Suggested improvements

	Count	Column %
Simplify Student Workbook-too much detail for lower classes, reading level for students too high, simpler version for Year 7 students, Student Workbooks for individual year levels,	8	23
Technical aspects- connection was too slow, firewall issues. Provide clear instructions on how to use the computer software	6	18
Additional professional development/ in-service days. More technical support for online activities	5	15
Making decisions about whether or not an observation night goes ahead due to weather. More options for booking telescope time. Cancellation of night-notifying the school as early as possible, Have one class at an observation night as opposed to several	5	15
Too long. Questionnaires were too long/ too difficult. PowerPoint presentations too long.	5	15
Teacher related factors eg would have re-sequenced the lessons, organising the observation night better. Taking photos with telescope much earlier than they did. More access to computers within the school	4	12
Nothing no change	3	9
Prefer to follow normal school program-use these as extension. Clearly identify the outcomes.	2	6
Have all of the material in the Teacher-guide and no Student Workbook	1	3
Total	39	100

Table 6.23 presents the results of the analysis of teachers' additional comments. A total of 33 comments were made at an average of 1.06 per teacher.

The most common class of comments were positive ones made by 45% of teachers about their experiences, willingness to be involved in the future and the support they received, etc. Negative comments were made by 27% of teachers and one surprising one from a Queensland teacher about the content not matching that State's outcomes. This was despite the fact that all other Queensland teachers had no problems in this area.

Table 6.23: Multiple-response table – Additional Comments

	Count	Column %
Positive comments made - very worthwhile, great experience, Thanks, grateful for being involved, job well done by CSU, would like to be involved in the programme in the future, Good support for teachers who had little astronomical content knowledge. Observation night resulted in most students and their parents turning up. Observation night was enjoyable. The PD day was necessary to help implement the programme. It was a programme that was flexible/ could be adapted.	15	45
Negative comments - Too long, condense the course. Too much teacher prep required. Difficulties engaging their class, found that they were hard to motivate. The programme does not match Year 8 or 10 outcomes for Queensland. Technical difficulties with computers/ network/ accessing technology at school. Ongoing bad weather- negative impacts.	9	27
Constructive comments - More spaces for students to write in the Student Workbook. Simplify Student Workbook. Additional Professional Development. Would like a more simplified printed version of how to control the telescope. Language in the Student Workbook needs to be easier- for 7, 8 and 9 levels.	5	15
Personal comments - Needed ongoing peer support/support from other staff members. There was a steep learning curve for teachers through teaching the programme. Liked to know going to be involved with it earlier (HoS made decision). Would have liked physical access to telescopes as it would make experience more real for students.	4	12
Total	33	100

Constructive comments were made by 15% of teachers about what to do to improve the materials. A few teachers made personal comments about the difficulties they had encountered such as the steepness of the learning curve for them while another stressed the need for collegial support during implementation.

7 RESULTS V: STUDENTS' KNOWLEDGE OF ASTRONOMY

This chapter presents the results of the Astronomy Diagnostic Test (ADT). The instrument was used to assess the level of students' astronomy knowledge, their alternative scientific conceptions about astronomical phenomena and the cognitive complexity of their explanations employing the Structure of the Observed Learning Outcome (SOLO) Taxonomy developed by Biggs and Collis (1982).

The first section of the knowledge results present students' knowledge in questions that are related to the content of the Primary school curriculum in relation to the causes of day and night, the movement of the Earth and Moon about the Sun, the phases of the Moon and the causes of the seasons. A total of 11 items in the ADT constitute the probes into students' knowledge of these phenomena. The maximum score achievable is thus 11. The second section presents the results of the same post-intervention test items. The third section reports students' alternative scientific conceptions in relation to these 11 items on both the pre- and post intervention occasions. The final section reports the cognitive complexity of students' explanations.

The Ns for females and males for each of the educational jurisdictions who supplied valid data are presented in Table 7.1. A total of 1992 students in years 7, 8 and 9 supplied valid data. The "year" to which students have been assigned is determined by the first year of high school. That is, Year 8 students in Queensland, the first year of high school in that state, have been recoded as Year 7 students.

Table 7.1: Breakdown of Ns by year of high school, gender and state or territory

		State or Territory				Total
		Australian Capital Territory	New South Wales	Queensland	Victoria	
Year 7	female	27	231	201	312	**771**
	male	38	107	215	145	**505**
	Group Total	*65*	*338*	*416*	*457*	***1276***
Year 8	female		196	89	24	**309**
	male		83	88	32	**203**
	Group Total		*279*	*177*	*56*	***512***
Year 9	female		70		17	**87**
	male		90		27	**117**
	Group Total		*160*		*44*	***204***
	Table Total	**65**	**777**	**593**	**557**	**1992**

7.1 Students' astronomical knowledge

This first section of results presents the students' astronomical knowledge on the 11 items of the *Astronomy Diagnostic Test* that relate directly to the outcomes of the primary curriculum in each State and Territory represented in this study. The analysis of the pre- intervention results is immediately followed by the analysis of the post intervention results. The impact of the intervention is tested using analysis of variance with repeated measures on the occasion of testing procedures.

7.1.1 Pre-intervention astronomical knowledge

Table 7.2 presents means, standard deviations and Ns for the analysis for students' pre-intervention astronomical knowledge as it relates to the outcomes of the primary curriculum in each State and Territory represented in this study. The maximum score possible is 11.

Table 7.2: Means, standard deviations and Ns by Gender and State – pre-intervention scores

State		Year of School						Table Total
		Year 7		Year 8		Year 9		
		female	male	female	male	female	male	
ACT	Mean	2.04	2.05					2.05
	σ	1.45	1.84					1.68
	Count	27	38					65
NSW	Mean	1.54	1.79	2.57	3.63	2.43	3.13	2.32
	σ	1.33	1.36	1.79	1.93	2.12	1.91	1.81
	Count	231	107	196	83	70	90	777
Queensland	Mean	1.74	1.96	2.00	3.16			2.07
	σ	1.35	1.60	1.34	2.13			1.64
	Count	201	215	89	88			593
Victoria	Mean	1.91	1.74	1.63	2.00	2.71	3.63	1.97
	σ	1.41	1.54	1.64	1.41	1.61	1.80	1.53
	Count	312	145	24	32	17	27	557
Group	Mean	1.76	1.87	2.33	3.17	2.48	3.25	2.14
	σ	1.38	1.56	1.68	2.02	2.03	1.89	1.69
	Count	771	505	309	203	87	117	1992

Table 7.2 shows that the mean scores for students in the first year of high school (Year 7) are not high. This result might be interpreted to mean that the outcomes of primary science education as they relate to the Earth in Space are not being achieved for the majority of students whether they are female or male in the States and Territory in which this study took place. There is also evidence that the study of astronomy in junior high school science has some effect, but it is not great. This is shown by the general upward trend in mean scores in the States or Territory in question from Year 7, through Year 8 to Year 9.

The differences from year to year, by gender and across jurisdictions evident in Table 7.2 could be tested with Analysis of Variance procedures but this is beyond the scope of this project and will not be reported.

7.1.2 Post-intervention astronomical knowledge

Table 7.3 presents means, standard deviations and Ns for the analysis of students' post-intervention astronomical knowledge on the same metric as the pre-intervention results. Again, the maximum score possible is 11. A total of 1251 students supplied data on the post-intervention occasion.

Table 7.3: Means, standard deviations and Ns by Gender and State – post-intervention scores

State		Year of School						Table Total
		Year 7		Year 8		Year 9		
		female	**male**	**female**	**male**	**female**	**male**	
ACT	Mean	2.30	2.00					2.13
	σ	1.59	1.62					1.60
	Count	20	27					47
NSW	Mean	2.44	2.42	3.45	5.31	3.91	3.79	3.31
	σ	1.51	1.63	2.14	2.42	3.06	2.65	2.31
	Count	207	86	172	77	65	90	697
Queensland	Mean	2.51	3.09	2.55	3.88			2.91
	σ	2.14	2.21	1.52	2.14			2.13
	Count	164	155	67	66			452
Victoria	Mean	1.90	1.22			2.67	2.25	1.68
	σ	1.26	1.00			1.15	1.75	1.28
	Count	21	23			3	8	60
Group	Mean	2.43	2.64	3.18	4.57	3.85	3.66	3.05
	σ	1.78	2.00	2.03	2.42	3.00	2.61	2.22
	Count	412	291	239	143	68	98	1251

Table 7.3 shows that there was an increase in mean scores for each year in all but a few cells. The significance of the increases was tested using Analysis of Variance with repeated measures on the occasion of testing. The outcomes of the analysis are reported in the following section.

7.1.3 Pre/Post-intervention astronomical knowledge analysis

In order to avoid comparisons amongst jurisdictions, the only independent variables that are employed to investigate any learning effects which may be attributed to the intervention are Year level and gender. The N for this analysis is limited to the 1168 students who supplied valid data on both the pre- and post-intervention occasions in Years 7, 8 and 9.

Table 7.4 Tests of Within-Subjects Contrasts

Source	Type III Sum of Squares	df	Mean Square	F	Sig. p	Partial Eta Squared
OCCASION	321.864	1	321.864	137.287	.000	.105
OCCASION * YEAR	6.694	2	3.347	1.428	.240	.002
OCCASION * GENDER	1.044	1	1.044	.445	.505	.000
OCCASION * YEAR * GENDER	16.230	2	8.115	3.461	.032	.006
Error(OCCASION)	2738.336	1168	2.344			

Table 7.4 presents the results of the repeated measure analysis. There is a significant main effect due to the occasion of testing (F=137.287, df = (1, 1168), p < 0.00001). There is a small effect size of 0.105 that can be attributed to the occasion of testing.

The Occasion x Year of School x Gender significant interaction was explored graphically and is shown in Figure 7.1 below. The interaction is probably due to the fact that females increased their mean score more than males only at the Year 9 level compared with students in Year 7 and Year 8.

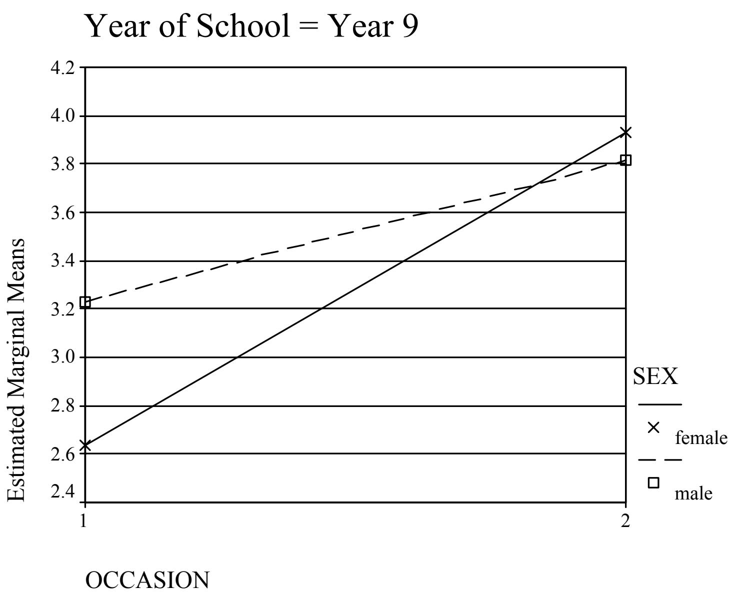

Figure 7.1: Occasion x Year of School x Gender interaction

Table 7.5 presents the results of the between subjects effects. The table shows that there is a significant main effect due to the Year in which students were enrolled (F=84.917, df= (2, 1168), p < 0.00001), to Gender (F=23.656, df= (1, 1168), p < 0.00001) and a significant interaction between the Year of enrolment and Gender ($F=12.035$, $df= (2, 1168)$, $p < 0.00001$). The effect size due to year of enrolment in high school is small at 0.127.

Table 7.5: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	14214.899	1	14214.899	2912.530	.000	.714
YEAR	828.894	2	414.447	84.917	.000	.127
GENDER	115.457	1	115.457	23.656	.000	.020
YEAR * GENDER	117.474	2	58.737	12.035	.000	.020
Error	5700.543	1168	4.881			

The significant interaction between Gender and Year of Enrolment was explored graphically and is shown in Figure 7.2 below. The interaction is probably due to the fact that the difference between the mean scores for females and males is greater in the Year 8 group than for either of the Year 7 or Year 9 female and male students.

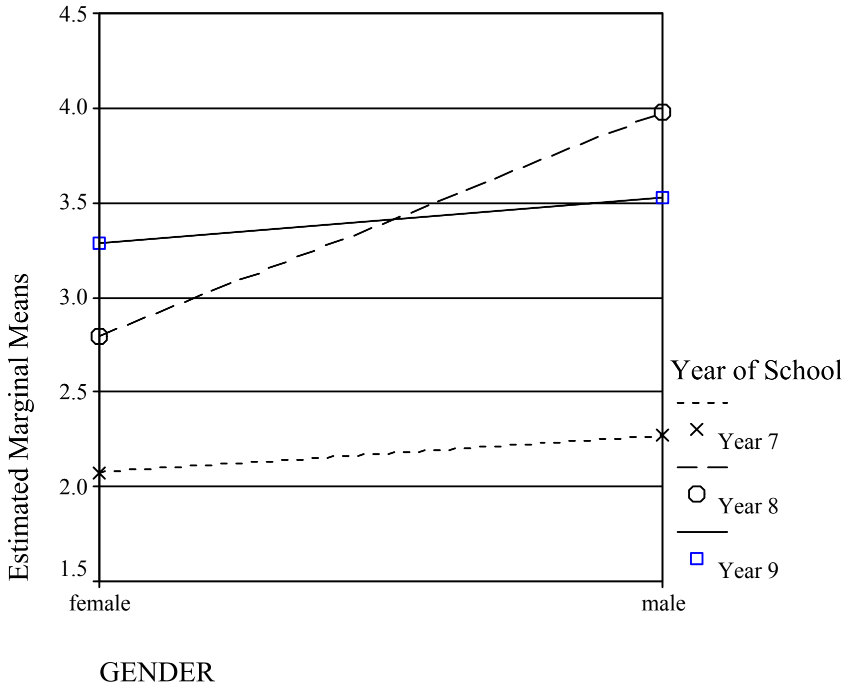

Figure 7.2: Year of School x Gender interaction

These data can be explored at much greater depth. For the purposes of this report, however, the data presented above are sufficient to demonstrate that there has been a significant learning effect that could be attributed to the intervention. There are interesting interactions that have been explored briefly but not exhaustively and which may be in part due to the integrity of implementation in each class within each school within each State or Territory. Further analyses will be undertaken at a later date and reported in due course.

7.2 Students' alternative conceptions of astronomical phenomena

This section reports the incidence of alternative conceptions that the 1,992 students who supplied valid data on the pre-intervention occasion hold about the causes of day and night, the orbit of the Earth and Moon about the Sun, phases of the Moon and the causes of the Earth's seasons. The Tables 7.6 through 7.9 show the raw count of the number of times that a particular alternative conception was detected and the percentage of the students who supplied a response on the pre-intervention occasion.

7.2.1 Pre-intervention alternative conceptions

Table 7.6 shows that 29% of all students believe that the Sun always rises in the east and sets in the west and, that 27% believe that the Sun is always directly overhead at noon each day. The fact that 12.8% of students believe that day and night is caused either by the Earth going around the Sun or the Sun going around the Earth in a single day is of concern.

Of greater concern is the fact that 73.8% of students hold alternative or incomplete conceptions about the causes of day and night. None of the alternative conceptions listed below refer to the rotation of the Earth as the prime cause for day and night.

Table 7.6: Multiple response table for alternative conceptions about Day & Night

	Count	% of students
Day & Night: The Sun always rises in the east and sets in the west.	578	29.0
Day & Night: The Sun is directly overhead noon every day.	538	27.0
Day & Night: Earth orbits Sun makes night/day. Earth orbits Sun daily.	133	6.7
Day & Night: caused by the Sun going around the Earth.	122	6.1
Day & Night: is equivalent to the seasons.	50	2.5
Day & Night: Moon blocks sunlight at night. Moon orbits the Earth daily.	42	2.1
Day & Night: Doesn't show half of the Earth lit with other half in darkness.	4	0.2
Day & Night: The Sun goes around the Earth in less than a year.	3	0.2
Total	1470	73.8

The alternative conceptions evident in the orbital paths of the Earth, Moon and Sun system are quite varied. The results presented in Table 7.7 show that the most common alternative conception is that the Sun goes around the Earth, a view held by 17.2% of students. A further 7.1% of students had the Earth and Moon orbiting the Sun together so that the Moon was always on the far side of the Earth from the Sun. A variation of this latter conception is evident in 4.8% of responses where the Sun, Earth and Moon all follow the same path in their celestial dance. In total, just over one third of students could not adequately explain the orbits of the Earth and Moon about the Sun.

Table 7.7: Multiple response table for alternative conceptions about Orbits of Earth and Moon

	Count	% of students
Orbit: Earth rotates at centre of system Sun goes round the Earth.	343	17.2
Orbit: Moon and the Earth orbit the Sun together	142	7.1
Orbit: Sun & Moon go around Earth in same orbital path.	95	4.8
Orbit: Earth orbits the Sun by day and the Moon by night.	46	2.3
Orbit: The Moon goes around the Earth in a single day.	24	1.2
Orbit: Sun, Moon, Earth go around in same orbit.	20	1.0
Total	670	33.6

Table 7.8 presents the alternative conceptions for the almost two thirds of students who cannot adequately explain why the Moon goes through a cycle of phases or explain the phase at which a total solar eclipse happens.

The table shows that one third of students believe that a total solar eclipse can only happen at full-Moon because then, and only then, is it big enough to cover the Sun. Shadow effects either by the Earth or clouds is used by another 15.9% to explain phases.

Table 7.8: Multiple response table for alternative conceptions about Phases of the Moon

	Count	% of students
Phases: Eclipse of Sun happens at full Moon – only then BIG ENOUGH to cover the Sun	667	33.5
Phases of Moon caused by shadow from the Earth.	223	11.2
Phases caused by cloud/Clouds blocking light reaching the Moon.	93	4.7
Phases caused by amounts of sunlight shining on Moon.	88	4.4
Phases caused by distance of the Moon from Earth and Sun	78	3.9
Phases caused by Sun covering Moon.	59	3.0
Phases: Moon orbits the Sun.	50	2.5
Phases caused by Sun orbiting Moon.	22	1.1
Phases: Light reflected from Earth lighting the bit of Moon we see.	9	0.5
Phases: Different countries see different phases of the Moon on same day	8	0.4
Phases: The Moon makes light the same way the Sun does.	2	0.1
Total	1299	65.3

Table 7.9 reports the results of the analysis of students' alternative conceptions on what causes the seasons. A total of 53.8% of students provided responses that did not adequately explain the phenomenon. Table 7.9 shows that the Earth's distance from the Sun the most common alternative conception held by 45.8% of students.

Table 7.9: Multiple response table for alternative conceptions about the Seasons

	Count	% of students
Seasons are caused by the Earths' distance from the Sun.	912	45.8
Seasons: Sun on one side Earth hot for 6 months other side colder.	69	3.5
Stars come out first at night. Relies on what they see.	35	1.8
Seasons: One side of the Sun is cooler than the other.	19	1.0
Seasons: Clouds in winter block light coming from the Sun weakening it	18	0.9
Seasons: Sun is hot in summer, cool in winter.	16	0.8
Total	1598	53.8

7.2.2 Post-intervention alternative conceptions

In this section, students' alternative conceptions about the same astronomical phenomena are reported. A total of 1196 students provided valid responses. In the text, when a percentage response is presented for the post-intervention occasion, the percentage figure for the same pre-intervention item is presented in brackets.

Table 7.10 shows that 6.5% (29%) of all students believe that the Sun always rises in the east and sets in the west. This is a marked reduction in the pre-intervention belief. Little change is evident in the belief that the Sun is always directly overhead at noon each day by 25% (27%) of students. The fact that 10.6% (12.8%) continue to believe that day and night is caused either by the Earth going around the Sun or the Sun going around the Earth in a single day is of concern.

Though a significant reduction, the fact that 53.1% (73.8%) of students continue to hold alternative or incomplete conceptions about the causes of day and night is of concern.

Table 7.10: Multiple response table for post-intervention alternative conceptions about Day & Night

	Count	% of students
Day & Night: The Sun is directly overhead noon every day.	316	25.0
Day & Night: The Sun always rises in the east and sets in the west.	82	6.5
Day & Night: Earth orbits Sun makes night/day. Earth orbits Sun daily.	80	6.3
Day & Night: is equivalent to the seasons.	66	5.2
Day & Night: caused by the Sun going around the Earth.	55	4.3
Day & Night: The Sun goes round Earth/Orbit alternative explanation	49	3.9
Day & Night: Moon blocks sunlight at night. Moon orbits the Earth daily.	22	1.7
Day & Night: Doesn't show half of Earth lit with other half in darkness.	1	0.1
Day & Night: The Sun goes around the Earth in less than a year.	1	0.1
Total	672	53.1

The alternative conceptions evident in the orbital paths of the Earth, Moon and Sun system have reduced quite markedly. On the post-intervention occasion the total alternative conceptions have dropped to 18.2% (33.6%).

The results presented in Table 7.11 show that the previously held most common alternative conception that the Sun goes around the Earth is now held by 7.0% (17.2%) of students. A further 7.5% (7.1%) of students representing a small increase have the Earth and Moon orbiting the Sun together so that the Moon is always on the far side of the Earth from the Sun. The variation of this latter conception is now evident in 0.2% (4.8%) of responses where the Sun, Earth and Moon all follow the same path.

Table 7.11: Multiple response table for post-intervention alternative conceptions about Orbits of Earth and Moon

	Count	% of students
Orbit: Moon and the Earth orbit the Sun together	95	7.5
Orbit: Earth rotates at centre of system Sun goes round the Earth.	89	7.0
Orbit: Moon orbits the Sun.	23	1.8
Orbit: Sun & Moon go around Earth in same orbital path.	15	1.2
Orbit: Earth orbits the Sun by day and the Moon by night.	8	0.6
Orbit: The Moon goes around the Earth in a single day.	6	0.5
Orbit: Sun, Moon, Earth go around in same orbit.	3	0.2
Total	239	18.8

Table 7.12 presents the post-intervention alternative conceptions for the 43.8% (65.3%) of students who cannot adequately explain why the Moon goes through a cycle of phases or explain the phase at which a total solar eclipse happens.

Table 7.12: Multiple response table for post-intervention alternative conceptions about Phases of Moon

	Count	% of students
Phases: Eclipse of Sun happen at full Moon BIG ENOUGH to cover the Sun	319	25.2
Phases of Moon caused by shadow from the Earth.	126	9.9
Phases caused by distance from Earth/Sun	45	3.6
Phases caused by cloud/Clouds block light reaching the Moon.	32	2.5
Phases: Light reflected from Earth lighting the bit of Moon we see.	15	1.2
Phases caused by amounts of sunlight shining on Moon.	8	0.6
Phases caused by Sun covering Moon.	6	0.5
Phases caused by Sun orbiting Moon.	3	0.2
Phases: Different countries see different phases of the Moon on same day	1	0.1
Total	555	43.8

Table 7.12 shows that 25.2% (33.5%) of students still believe that a total solar eclipse can only happen at full Moon. Shadow effects, either by the Earth or by clouds, are used by another 12.4% (15.9%) to explain phases of the Moon. Some 0.7% (4.1%) of the students continue to believe that the phases are caused by the Sun either orbiting the Moon or actually covering it.

Table 7.13 reports the results of the analysis of students' alternative conceptions on what causes the seasons. A total of 39% (53.8%) still cannot adequately explain the phenomenon. Table 7.13 shows that the Earth's distance from the Sun remains the most common alternative conception held by 33.2% (45.8%) of students. There is, however, a marked reduction in the proportion of students, 1.7% (c.f. 8%) using other explanations for the causes of the seasons.

Table 7.13: Multiple response table for post-intervention alternative conceptions about the Seasons

	Count	% of students
Seasons: are caused by the Earths' distance from the Sun.	472	37.3
Seasons: One side of the Sun is cooler than the other.	10	0.8
Seasons: Sun on one side Earth hot for 6 months other side colder.	6	0.5
Seasons: Clouds in winter block light coming from the Sun weakening it	2	0.2
Seasons: Sun is hot in summer, cool in winter.	2	0.2
Total	492	39

7.3 SOLO analysis of students' reasons for their astronomical knowledge

This section of results presents an analysis of the cognitive complexity of students' explanations for why they chose a particular answer. The Structure of the Observed Learning Outcome (SOLO) Taxonomy (Biggs & Collis, 1982) is employed to provide a framework for examining the reasons.

Students' responses were coded according to the complexity of their response. If students' provided a reason that was unrelated to the question or simply re-stated the question as an answer, it was coded as "1" for a pre-conceptual response. If one unit of information that was related to the question was provided then it was coded as "2" for a uni-structural response. A multi-structural response was coded as "3" when students provided multiple units of information related to the question but which were not related together. A relational response was coded as "4" when students related the multiple units of information together. Although no extended abstract responses were detected, these would be coded as "5" if the relational response contained further information that went beyond the information required to provide a different perspective on the question.

7.3.1 Pre-intervention SOLO analysis

The first section of the SOLO results present the distributions of students' responses to questions that are related to the content of the Primary school curriculum in relation to the causes of day and night, the movement of the Earth and Moon about the Sun, the phases of the Moon and the causes of the seasons.

Table 7.14: Analysis of pre-intervention SOLO responses provided by students

	% SOLO Response					Total %
Question:	**No response**	**Pre-conceptual**	**Uni-structural**	**Multi-structural**	**Relational**	
1. Day & Night	8.6	6.0	52.0	33.0	0.4	100
2. Orbit of Earth, Moon, Sun	21.6	9.9	19.5	48.5	0.5	100
3. Phases of Moon	37.4	7.6	40.6	14.3	0.1	100
4. Seasons	40.2	5.6	41.6	12.6	0.1	100
5. Position of Sun at noon	34.7	14.5	48.2	2.4	0.2	100
6. Phase of Moon at total eclipse	35.8	8.3	53.8	2.2		100
11. Seasons, circular orbit	53.7	7.7	37.1	1.5		100
13. Location of setting Sun	64.5	7.6	27.0	0.9		100
17. Closest to most distant	60.3	15.4	12.6	11.7		100
23. Position in orbit of crescent Moon	66.3	8.8	24.3	0.6		100
24. Shape of full Moon rising and 6 hours later	73.0	6.3	20.5	0.2		100
Total N						1992

A total of 11 items in the ADT constitute the probes into students' ability to explain these phenomena. In total, 1,992 students provided data that could be interpreted and classified on the pre-intervention occasion.

Table 7.14 presents the analysis of the 11 items showing the percentage of the 1,992 students at each SOLO level. The results show that few students are operating at a multi-structural level. That is, when a reason is volunteered, the majority of students operate at uni-structural or pre-structural levels. The item for explaining the orbits of the Earth, Moon and Sun in relation to each other is the best answered question with 48.5% of students advancing multiple reasons but with only 0.5% of students relating these causes together.

Table 7.14 also shows that 85.6% of students have little idea what causes the phases of the Moon, and 87.3% have little or no idea what causes the seasons as shown by Q4. With Q11, only 1.5% of students can, at best, offer a multi-structural response.

The latter questions have an artificially high non-response rate due to the fact that teachers reported that students did not have the time to finish within the allocated time. Students were asked to leave blank any to which they did not know the answer and not to "guess".

7.3.2 Post-intervention SOLO analysis

The second section of the SOLO results present the distributions on the post-intervention occasion of students' responses to questions that are related to the content of the Primary school curriculum in relation to the causes of day and night, the movement of the Earth and Moon about the Sun, the phases of the Moon and the causes of the seasons.

A total of 11 items in the ADT constitute the probes into students' ability to explain these phenomena. In total, 1,266 students provided data that could be interpreted and classified on the pre-intervention occasion.

Table 7.15 presents the analysis of the 11 items showing the percentage of the 1,266 students at each SOLO level.

The Wilcoxon signed-rank test is used to compare the pattern of distributions of the pre-intervention and post-intervention SOLO responses for each variable. In order to protect against significant differences that occur by chance in the comparisons of the 11 items of the teacher questionnaire, the Bonferroni approach is again adopted to reduce the probability at which significance is indicated by a factor of 11. That is, instead of accepting a p-value of 0.05 to indicate that the difference in response pattern is significant, a more conservative p-value of (0.05/11) or 0.004545 is adopted below which the difference in response pattern indicates a significant change from the pre- to the post-intervention occasion.

In this section of results, the actual probabilities are presented in each of the tables of results and probability values lower than 0.004545 are indicated by * and if less than 0.001 by **.

The results show that a larger proportion of students are operating at multi-structural levels. That is, when a reason is volunteered, fewer students operate at uni-structural or pre-structural levels.

Table 7.15 shows that significantly higher proportions of students now have some ideas of what causes the phases of the Moon, the seasons as shown by Q4 and Q11, the orbits of the Moon about the Earth and these about the Sun, and the order of objects from the closest to most distant.

The latter questions still have an artificially high non-response rate due to the fact that teachers reported they again did not have the time to finish within the allocated time. Students were again asked to leave blank any questions to which they did not know the answer and not to “guess”.

Table 7.15: Analysis of post-intervention SOLO responses provided by students

Question:	% SOLO Response: No response	Pre-conceptual	Uni-structural	Multi-structural	Relational	Sig p
1. Day & Night	10.2	4.5	48.9	36.3	0.1	0.203
2. Orbit of Earth, Moon, Sun	23.0	7.4	11.8	57.7		0.0044*
3. Phases of Moon	32.4	8.0	35.0	24.6	0.1	<0.0001**
4. Seasons	35.5	5.1	35.6	23.7		<0.0001**
5. Position of Sun at noon	35.2	13.6	46.3	4.7	0.2	0.842
6. Phase of Moon at total eclipse	36.7	8.9	46.8	7.4	0.2	0.540
11. Seasons, circular orbit	49.0	8.2	37.5	5.3	0.1	0.0038*
13. Location of setting Sun	60.6	7.6	29.8	2.1		0.014
17. Closest to most distant	54.9	17.5	10.0	17.5		<0.0004**
23. Position in orbit of crescent Moon	61.6	8.0	28.4	2.1		0.026
24. Shape of full Moon rising and 6 hours later	65.9	7.7	25.0	1.4		<0.0001**
Total N						1266

7.4 Summary

The results in this section have shown significant learning effects in terms of the content knowledge acquired about the causes of day and night, the orbits of the Earth and Moon, the causes of phases of the Moon and the seasons.

There are also important reductions in the incidence of students' alternative conceptions about the causes of these astronomical phenomena.

The analysis of the SOLO responses has also demonstrated that there are significant improvements in students' ability to explain their reasons for these phenomena with evidence that students are attempting to present increasingly complex reasons.

This latter development is essential if students are to build the many increasingly sophisticated conceptual models to explain the many scientific phenomena they will encounter.

8 RESULTS VI: VIGNETTES FROM VISITS TO SCHOOLS

In this, the final chapter of results, four vignettes are described that will give the reader an understanding of the different teaching approaches adopted and the reactions from students as they experienced a variety of elements from the project. What is evident from these vignettes is the variation in implementation “integrity” across the settings.

Two of the schools were in the country and two were metropolitan. One was an all-girls’ school while the other three were co-educational. Two schools are private schools and two are state schools. In all cases, school names have been changed and teachers referred to as Mr L or Ms O etc. The letters used bear no relationship to the teachers’ actual names.

The vignettes presented here have been chosen for a number of reasons and highlight the importance of the teacher involved in different ways. The first vignette shows how students, despite the best efforts of their teacher, can quickly cut through to the heart of the issue. The second vignette shows how one teacher controls what, and how, his students learn and how this can stifle creativity and interaction within the science class. The third vignette is designed to show how a laissez-faire approach by a head of department has created problems for teachers implementing the programme and how the students have reacted, and perhaps succeeded, despite what is happening within the science department. The fourth vignette is perhaps the most encouraging yet it illustrates how problems within schools can remove an obviously good science teacher from the classroom.

In their totality, the vignettes present a disparate picture of how science is taught in schools. Some of the issues raised by these vignettes will be taken up in the discussion.

8.1 Country High School

The atmosphere at Country High School was very friendly. Students came up and asked if the researcher needed help or required directions to the front office. There, I was welcomed by the school secretary who phoned the science teacher. Mr Science Teacher arrived and introduced me to the school principal who was also very welcoming. Mr Science Teacher took me straight to his science classroom where the project was being implemented with three Year 8 classes. He was teaching all three classes.

The walls were bare apart from one poster showing the orbits of the planets. It was not a very big science laboratory. There was a blackboard at the front, a teacher's bench with a sink and students sat at normal desks. On the two side walls there were cupboards where science equipment was stored. On top of these cupboards were sinks and gas outlets. There were no computers present in this room.

The bell rang and Year 8 students began to appear outside the science laboratory. I went outside with Mr Science Teacher. Students were very chatty. They kept staring and smiling at me, perhaps trying to work out who I was. Mr Science Teacher asked students to line up, insisting they be quiet before entering the science lab. Students entered lab and took their seats immediately.

Mr Science Teacher took his place at the front of the classroom behind the teacher's bench. He asked the boys to remove their hats and began with housekeeping things. On the blackboard were notes presumably from a previous lesson, as they were unrelated to astronomy.

Mr Science Teacher introduced me and spoke to the students about why I was in their class. Mr Science Teacher then commenced the lesson by asking students to open their Student Workbooks to page xx. They were doing the project that dealt with drawing ellipses.

Mr Science Teacher had both a Student Workbook and the Teachers' Guide open on the bench. He asked the class to read the project and explained that they would be drawing ellipses today. Once Mr Science Teacher introduced what they were going to be doing. I asked for four volunteers to interview outside in the courtyard. The majority of students put their hand up with some making noises as though they really wanted to be chosen. Mr Science Teacher began by asking me if two girls and two boys would be suitable. I agreed that this would be fine. He chose them and we went outside to set up for the first interview.

During each of the interviews, students had their backs to the science laboratory, which was about 20 metres away. The researcher was facing the laboratory and so could see what was going on through the windows. Students did not leave their seats during the lesson. Mr Science Teacher seemed to spend most of his time at the front of the room.

After each of the interviews, the researchers walked back with groups to their science laboratory to wait for the next group of students to interview and, while waiting would look at what the students were doing. Students were still in their desks, working by themselves. They had boards and string and looked like they were making ellipses. There was not much talking.

Each time the researcher returned, the majority of the class wanted to be interviewed, with some pleading that Mr Science Teacher should choose them next. There were two young men who always put their hand up. Mr Science Teacher told them not to bother putting their hands up as they would not be going to be interviewed as a result of their behaviour and lack of completed work from previous lessons.

8.1.1 The first and subsequent interviews with students

The students were a bit hesitant at first when they came out to speak to me. I set up the equipment, and broke the ice by speaking to them about general things. One of the males made the comment about it being "*really cool*" that they were going to be taped.

Once I had introduced myself and told them that anything they said on tape would be private and confidential they seemed more at ease. Before saying too much, they sought reassurance that Mr Science Teacher would not be hearing the tapes. I replied that this was to be the case and that it was purely for our purposes at the University to find out how the programme was going, what they liked and what they disliked about it. This appeared to make them much more comfortable and they opened up a little more.

During the first interview, it was clear that the students were excited about the astronomy but disappointed with the way it was being taught. They made negative remarks about the way in which Mr Science Teacher did things and gave examples. One of the students said, "*He means well but he just really hasn't got it. He has no idea.*"

Many of the students made comments in this and subsequent interviews that much of the time Mr Science Teacher talks to them "*like we were his Year 11 students*" and "*he explains things we don't understand*." Or, if he did use language they could understand, it was too in-depth for them. They commented a number of times that Mr Science Teacher finds it "*hard to relate to us [them].*"

In this and subsequent interviews, it was apparent that students were excited by the practical activities that they had been doing such as going out onto the oval and stepping out the distances between the planets. The telescope night was no exception in generating excitement because of the activity in their doing things, though there was to be a major disappointment for them.

All groups, without exception, brought up the issue about their telescope night and all made similar comments about their feelings of disappointment. They said that Mr Science Teacher led them to believe that they were the ones who were going to take the pictures with the telescope. They were excited about this because they had been doing research about the pictures they wanted to take of their different objects.

When it came to their observation night, they said, "*All of us were crammed into one room.*" They would go up to take their picture and instead of them getting control, they had to tell Mr Science Teacher what they wanted to take a picture of and had to watch him press the buttons to control the telescope and manipulate the telescope's cameras, badly, as it turned out, and "*that was it*". In one student's words that reflected the sentiment of their group, he said "*Why bother, I mean…it was all a waste of time getting ready for that."* It was a major disappointment for them.

Apart from this, comments about the programme were very positive. One of them said, "*It's heaps better then what the Year 8s did last year. I spoke to some of them and they said they did nothing like this."*

It was also evident that they thought the program should run again next year for Year 8 but hoped that it might be taught better. Some students commented and complained about still having to write notes in their school science notebooks even though things were already in their astronomy Student Workbook.

When each of the group interviews ended, the majority of students appeared to be disappointed about having to go back to class. Some made the comment… "O*h, do we have to go back? Can't we stay out here with you for a bit longer? It's boring in there"* or similar.

The overall impression of these interviews from each of classes was that the students saw many benefits of being involved in the programme and thought many of the things were very worthwhile. They, however, were turned off in some cases by their teacher not letting them take control or have a say in their learning. Students wanted to be more involved and to take control of what they were doing. As one student explained, "*Sitting in the classroom in front of one little laptop in the dark, watching a slideshow*" and their teacher pressing the mouse button did not engage them or interest them. They wanted to assume responsibility, to work it out for themselves or with each other.

The researcher was left with the impression that the science lessons in this school were very teacher directed and brief observations of some of the lessons support this. Mr Science Teacher did a lot of telling, that is telling the students what to do, what to get out, how to do it, etc. There did not seem to be much student-centred learning happening.

8.1.2 The interview with Mr Teacher

In talking with Mr Science Teacher later, he said he thought that the whole experience with the astronomy was very worthwhile. He indicated that he lacked some knowledge when it came to some of the technology components that were involved. He also said that the image processing, planetarium software and activities were taught in the students' computer lessons by the computer teacher. On the observation night, they had had a few hiccups with the technology where the computer linked to the telescope had disconnected. Perhaps this was why he had been taking the images – perhaps he was safeguarding the computer.

From speaking to both Mr Science Teacher and the students, the classes appeared to cover a range of activities that involved both practical and outside activities. Work seemed to be individual or a whole class approach. There did not seem to be much "group" work happening.

Mr Science Teacher also said that organising the observation night required a lot more preparation than organising an ordinary excursion did. He also said that the Student Workbook was very useful but that he would have liked more space in it for students to be able to write about what they were doing. He also suggested that some of the information could be blanked out and that students could write this in as part of the lesson.

Mr Science Teacher described how he brought his laptop and data projector into the science class on a number of occasions so that students could view the slideshows. He said that he ran the slideshow all lesson. He did this to show them the different software applications. From this comment, the researcher gathered the impression that Mr Science Teacher thought this worked well and that the students appreciated this.

From the students' perspective, however, they said they "*hated it*" and thought, "*It was boring*." Perhaps Mr Science Teacher saw them being quiet through these lessons and thought that they were listening and interested when really, they were tuned out, bored and perhaps sleeping, as one student had confessed.

8.1.3 Summary

Overall, the researcher was left with the impression that Mr Science Teacher felt happy with how things were going in his science classes and believed that students were also happy with how the lessons were going. He appeared not to be aware of the fact that the students wanted to have more control or that they did not always understand his explanations.

The researcher's impression of Mr Science Teacher was that he very much liked to be in control. He appeared to plan everything and to follow the plan to the letter. Mr Science Teacher made one telling comment *"I think I would be much more comfortable doing this next year now that I have more of an idea of what it involves."* It is perhaps expected that, when confronted with something new and technologically demanding, the pedagogy will revert to a teacher-centred approach. The solution in Mr Science Teacher's case would perhaps be to allow a longer lead-time and to provide more professional development opportunities covering a range of matters.

8.2 Metro Girls High School

Mr Master, the head of the science department, met the researcher in the foyer. Everyone seemed very busy and preoccupied with whatever they were doing to get ready for the start of the teaching day. Very few paid attention to us. Mr Master introduced me to the Principal who was in a meeting with two other staff members. It was a very quick "*Hello and thank you for coming*" etc. The project had been running for some weeks when the visit was undertaken and occurred after the students had had their scheduled observation night, one of which was significantly delayed by bad weather. The project was being conducted with year 7 students.

8.2.1 Group interview with teachers

The visit began with a group interview of the science teachers in their staffroom. Mr Master had asked all of the teachers involved in the project to attend the interview. Despite this, only three of them could make it.

All of the teachers were very friendly and made me comfortable though Mr Master seemed to dominate by always answering first and seemed to make longer comments. He talked more than the two female staff members did. Towards the middle of the interview, Ms C started saying a lot more. Ms Q remained very reserved and quiet throughout the session and when she did say something, it was generally very brief.

They all seemed very positive about the programme. They left me in no doubt that they liked the idea of having a Teachers' Guide and Student Workbook since this significantly cut down on planning time. They also commented on the feedback that they had received from the University on the students' pre-intervention Astronomy Diagnostic Test results and said that they intended to use the post-intervention test as one of their assessment items. As Mr Master said, "*It saves us from doing it*."

Although they commented on having all of the materials which cut down on their planning, the researcher was still left with a strong impression that the teachers felt under-prepared and would have like more time to go through some of the projects before starting with the students.

They had *apparently* chosen the projects together in a team meeting but the researcher was left with the impression that it was more Mr Master who had selected the content through which they would work. It was clear from comments that he did the projects first with his class and then the others would do them afterwards. He also passed on resources he had developed and gave the science staff his input/feedback about the project. For example, Mr Master started image processing with his class and found that many students were getting lost and were not sure what to do. Mr Master made up an overhead with steps on it that outlined what certain things did and instructions on what to do when processing certain images. Mr Master gave the overhead to the other teachers so that they could also use it when carrying out the image processing lessons. This was despite the fact that there was a PowerPoint slideshow illustrating how to process images and which could have been accessed by all students on the school network.

All of the teachers commented on the technology used. Ms C said that parents had told her that they were very proud of their daughters. Seeing them on the observation night controlling the telescope and getting the images was hard to believe. As one reportedly said, "*It is hard to believe that my child is capable of using such a powerful instrument- such opportunities weren't available to us in my days at school*."

Important connections were made with parents by inviting them to the observation nights. The observation nights were very positive for students and motivating with the exception of Ms Q's class. She said that the students were very excited about it and were looking forward to it. There was a big "*positive build up."* However, when it came to their night, it was postponed due to bad weather. This happened to them on two further occasions and their night was moved to early Term 4 after the holidays. Ms Q said that the students were disappointed and things started to get very drawn out as all of the other classes had had their nights and they were missing out. This had a negative effect on the class where "*they were getting sick of missing out*" for the remainder of the unit making the students loose interest and motivation.

The teachers seemed very positive about the whole experience. One thing that they did not like was collecting all of the notes - consent forms, observation night permission notes etc. They made the comment that it would be great if everything was just on the one form so that could collect just one form as opposed to 3 or 4. They did not like having to do too much administrative work.

8.2.2 Interviews with students

Mr Master had organised for me to go in to his class. The science laboratory was a very old looking lab. It had the teacher's bench out the front. There was a blackboard and overhead projector screen, which was pulled down. The overhead projector sat in the middle of the room, set up, plugged in and facing the middle of the screen. Even though this was set up ready to use, it was not used while the researcher was there.

The classroom was very well "decorated" with students' work. Along the side-benches were scale models of the planets that students had made. The back of the classroom had six large freestanding dividers/display boards. On either side of these were research projects written and illustrated by the students.

The class sat in groups of six. One of the groups was interviewed within the science class. Mr Master started the lesson by standing at the front of the class and telling students to turn to Project 13 on measuring the distance between the Moon and Earth. He gave them a run down on what they would be doing. Then he got the girls to carry the equipment outside. He had enough equipment for each group to carry out the activity. The interview with the group began in the classroom.

They made the comment that this was the first lesson that they had been outside to do practical work and said that they do not get to do practical things very often. As one said, "*We usually sit and copy notes from the overhead.*"

The students were quite emphatic that they did not enjoy copying notes from the overhead projector and that they seemed to be doing this all the time in science. They commented further that they were still doing this even with this astronomy subject so that they had things to go into their science books.

Even though the students did not like this "*copying notes from the overhead*" aspect of their science class such, they did not "*blame*" the teacher or make any comments that they did not like Mr Master's teaching. They all seemed to like Mr Master. One is left with the suspicion that many of them probably had a crush on him, the novelty of having a young male teacher in an all-girls' school.

After this short interview, the researcher remained with the class to observe the activity as they struggled with simple mathematics and tried to make sense of what they had to do.

Towards the end of the lesson, Mr Master told the students to show me their work that was around the classroom and encouraged them to explain things to me. He suggested that they stand near their work while the researcher walked around and asked each group some questions.

It was obvious that they felt it was "*their*" work. They had ownership of it and liked, and enjoyed showing the researcher "*their projects*" or "*their scale models*" or "*their research report"* etc. The curtains even had little planets, moons and stars painted or printed on them.

8.2.3 Summary

Even though there were many "good things" happening, e.g., Mr Master's classroom looked visually appealing and the students appeared to have ownership over their work, the class sat in groups and went outside to do the practical activity together. There appeared to be little differentiation of the curriculum. It was lock step for the whole class. The researcher was left with the feeling that the majority, if not all of the lessons, were teacher directed.

The evidence for "a teacher-directed class" was circumstantial and formed from observations of the students' behaviour. For example, when girls were sitting in their groups writing answers in their science notebook based on the outside activity, there was no interaction or talking within or amongst groups. Girls came in and followed Mr Master's instructions- "*Sit down and write in your answers from outside*" or variations like that. The girls appeared to wait for Mr Master's instructions before beginning anything. It was like this the whole time the researcher was in the room and from the reactions of the students, this seemed normal. It was apparent that they were very dependent on their teacher and in a way relied on him giving them the information or telling them what was required or what he expected of them in everything they did. Perhaps it was not surprising that the students sought guidance in the image processing tasks and that Mr Master had developed the overhead projector films.

8.3 Beachside High School

The researcher spent a day at Beachside High School. All teacher interviews were conducted in the science staffroom and the Year 7 student interviews were held just outside the staffroom.

The researcher was not invited to spend time with a class. Visits, however, were made to the empty science and computer laboratories where students were located for the "astronomy" lessons. Their walls were bare. There were no posters or work on display. Regular science equipment was on the bench tops around the lab. There were benches with stools where student sat during class. In the computer rooms, computers were set up side by side and it looked as though there would be enough equipment for one computer per student in a class.

8.3.1 Interviews with teachers

The head of science (Mr Head) was very enthusiastic and was all for participating in the project. He always had positive things to say and seemed very excited about everything that the teachers had been doing. Despite Mr Head's enthusiasm, the researcher felt that not all of the science teachers who were involved in the project shared the same enthusiasm. From talking to all but one of the teachers involved, the researcher felt that Mr Head neglected to take into consideration what other staff members thought about being involved in this project. There is evidence to suggest that Mr Head made the decision on doing the project and told the teachers that they would be teaching an astronomy unit in Term 3 giving them little information in the process about what it involved and only telling them that it was astronomy and that they would have access to a remote telescope.

One of the teachers, Mr N had already planned two units for term 3 which he had to put on hold in order to participate in the astronomy. He said that if he had known they were doing the astronomy he would have spent the time preparing for that. Some of the teachers may have felt a bit more comfortable if they had known, in advance, about what the astronomy involved and had not just been "told" that this was what they would have to do in Term 3 with the result that they had to find out what it involved closer to the time for teaching it.

From talking to the teachers, it was clear that they all lacked confidence in this area and had not had any training or experience with astronomy prior to the professional development day. One had a chemistry background, two in biology and the other was a Physical Education teacher who also had qualifications in agriculture. Mr Head had a physics degree and taught senior physics. He, however, was not involved in teaching the program to the Year 7 students.

Mr N said that he felt that he "*lacked the content knowledge*" and that he would have liked "*more professional development before starting to teach the unit*." He spent time working through the lessons and projects so that he would feel comfortable with teaching them. He also helped some of the other teachers with what and how to do things. He said that he always worked through lessons prior to doing them with his students so that he could learn and be sure that he was prepared when it came to teach.

The way in which the teachers covered the astronomy seemed to focus heavily on the technology side of things. All classes spent the majority of their time in the computer room working on image processing and using the planetarium software. Classes did not seem to do any of the design, make and build practical activities in the Student Workbook such as measuring the distance between Moon and Earth.

There was some ill feeling evident between some of the teachers. This surfaced in the interview with Ms O and Mr T. Ms O complained about one of the teachers, Mr G, who was not interviewed because he was off doing other things and generated the impression that he was avoiding the researcher. Three science classes ran concurrently with Mr G taking one of them. Apparently, on a number of occasions Mr G split his class and sent one half to join Ms O's class in one of the computer laboratories and the other half was sent to join the other science class in another computer laboratory. During these sessions, while Mr G was in one or other of the rooms, he sat at a computer doing his own things or did work in another part of the room while Ms O or Mr T were left to move around helping all of students, his included.

Ms O was also disturbed that Mr G did not help out with organising the observation nights and what "*really put the icing on the cake*" for her was that he didn't show up to any of the observation nights because he had "training" to attend and that was more important. Mr Head appeared oblivious to this and felt everything was running smoothly and that the astronomy was going really well.

All teachers commented on problems that they had been having in accessing the computer laboratories with issues related to the timetable. Some commented on teachers always "jumping in" and getting the "good" computer laboratories with the newer, faster machines while they were always stuck in the older laboratories where computers were slow and where there were network problems.

Despite the fact that there was the issue of not being informed about the program early and there were problems with certain staff members, the teachers were all really enjoying the experience of being involved. All said that they would like to do this again because next time they "*would know what to expect and would have more time to prepare*." The teachers felt, however, that there were mixed reactions from students with some "*really getting into it*" and others who were "*just not interested*."

8.3.2 Interviews with students

Students from the classes of Mr N and Mr T were interviewed. The teachers sent groups to speak to the researcher with the interviews being conducted outside near the science laboratories and science staff room.

There were groups of students that really got into the program. Some had formed an astronomy club. Others did not enjoy lessons with one of the groups clearly saying that they were "*sick of always working on the computers*" and wanted to experience the other "practical" activities they had read about in the Student Workbook.

If teachers took the students to the computer laboratory every lesson then perhaps the students cannot be blamed for feeling that way. Perhaps they were getting too much of the same thing. Perhaps they needed greater balance and variety in the approach. Later in the interview, this same group of students said that they had really enjoyed the lessons where each group had to give a PowerPoint presentation on the objects they had to research and which they were going to image with the telescope. The reasons they gave for liking this activity so much was that it was different, all of the group presentations were different, and they were not in the computer room doing what they would normally be doing. They had to go to the library to do research, conduct research on the Internet and work together as a group to build their presentation. They said they argued, discussed and compromised "*a lot*" as they constructed their slideshow presentations.

8.3.3 Summary

Maybe the teachers decided to focus on the image processing/technology side of things because they were not confident with teaching the astronomy concepts present in the majority of the other activities. There seems to be quite a bit of evidence for this conclusion scattered through their comments about the lack of time to familiarise themselves with the projects.

The more mature teachers seemed to rely on the two younger teachers Mr T and Ms O in setting up and organising the telescope nights. Mr N commented on "*how quick they picked things up*" and how they were "*able to run through simulation sessions*" online and show him how it all worked with little difficultly. Mr N was grateful having them around for support when it came to certain aspects of the technology.

The student interviews left the researcher with the impression that the teachers had relinquished some control when teaching and gave students opportunities for them to investigate while doing image processing. Perhaps the downfall was that the image processing was the main focus of all activity while students, through access to the Student Workbook, could see that there were many other activities being left out which may have interested them more. The result for some of them was that they were not engaged.

There were students for whom the astronomy struck a real chord and an astronomy club was formed. Mr Head appeared to be the instigator of this. There was an interesting outcome for their club and one which was highly motivating for them. Students in this group were given the opportunity to control a telescope at a local restaurant that had purchased it as a marketing ploy but no one there knew how to work it until a serendipitous visit by a staff member created the contact. Now the school has access to a sophisticated telescope on loan by the restaurant in return for supplying students to guide patrons on weekend evenings.

8.4 Town High School

This was the last of the schools visited as part of the qualitative data collection phase. On arrival at this large high school, the school secretary called for Mr D who guided me to the science staffroom. Mr D sent a message to the students that he had organised for me to interview. They were being collected from other subjects as they did not have a science period that day. The students had been drawn from different work groups in Mr D's classes.

The researcher was only able to speak with this one group of seven students. The group was too large. One of the students dominated the others and seldom allowed them to finish what they were saying without interrupting. The situation was less than ideal.

Apart from one short interval, Mr D was present for the entire interview. This also was less than ideal as the researcher felt that students appeared more constrained compared with what might have happened if he had not been there.

8.4.1 Student interview with teacher present

One Year 7 female in the group seemed to be regarded as the leader. The other students always deferred and listened to her opinion and comments attentively. She tried to interrupt others as they spoke and, in some ways, intimidated them. They could say something only if she did not have anything to say but if what they said stirred something in her, they deferred to her interruption unless the researcher asked politely if the student would mind finishing what they had been saying.

The students commented positively about everything except for when they had casual teachers for a few of the lessons. They said in a somewhat disparaging way that these teachers did not know anything about the astronomy. They all seemed to regard Mr D highly and obviously liked him as a teacher.

Out of all of the groups that the researcher had interviewed, these students were probably exposed to more student-centred activities in their science classes. They were actually involved in doing the practical activities within their groups. This was made clear in the interview with many comments "*we did this* and "*we did that*" where the "this" and "that" covered many different topics and projects. They described in great detail the disaster scenario of what would happen to them and their town if an asteroid were to hit 200km away. The problem scenario had been set up by Mr D and they did their research and modelling using the Internet and one of the spreadsheets supplied with the Teachers' Guide to create maps of the impact on the countryside.

They had a say in what and how they did things. In groups, they had built the equipment to measure the diameter of the Sun, with Mr D acting as the "*guide on the side*" and not telling them or showing them how to do everything. Students displayed the devices that they had made, and demonstrated how they worked. They were genuinely proud of what they had done and were able to describe in detail how they had made them. Groups also seemed to be working on different things at the same time, For example, one group had finished building their device and had automatically moved on to the next part of the activity to measure the diameter of the Sun and do all of the mathematics that that involved.

At the time of the interview, students had not done any of the technology related things such as image processing, telescope control or using the planetarium software for planning their observation night, but they did say that they thought they were starting this soon. Mr D said that there had been difficulties in accessing computer laboratories and since computer classes had priority within the school, he had started with the practical activities. He said that this had turned out to be beneficial and the students "*had really got into it.*"

Students had not had their online telescope night either but Mr D had told them about it and had told them that he had booked it for them giving them the date and time. A few students said that this was a bad night, a Friday, and that there would probably be a number of them who could not come back to school. They sounded very disappointed by this. They offered reasons for not being able to attend such as in coming from a split family they had to go to the other parent's house at the weekend, while others had sporting commitments with some having to travel to remote venues.

Mr D appeared very accommodating and the researcher suspects that he was very flexible in his teaching. He was very approachable and took his time in providing feedback throughout the interview. He said that he had been really enjoying the program and felt that *"it allowed astronomy to be covered in a very hands-on and practical* *way."* Students were engaged, loved the activities and were "*on task most, if not all, of the time.*"

Mr D started the program by doing his own motivational activity with the students where they did some research on rockets and how they worked. Mr D thought that this would get students involved and excited about the rest of the unit and would make it more relevant for them. For example, "*here they were down on Earth and one way of getting into space was in a rocket*". So he had the students do some research and then had a lesson out on the oval where Mr D and the students launched water rockets. Other class groups from different year levels came, watched and applauded. This then led into the next lesson, which was on the Moon.

Mr D talked about how the students loved the activities and especially the one that involved cratering on the Moon. He described how this practical activity worked with students doing controlled experiments, improving their experimental design as they went along and taking many measurements on the diameter and depth of the impact craters created in flour using devices (Vernier callipers) that they had never seen before.

Mr D talked about how the students really "*got into*" the activities, how they hated it when they were not able to do the astronomy when Mr D had a few lessons where he was acting Deputy Principal and casual teachers were employed to replace him. During this period, the astronomy was not covered by the casual teachers because, as the students highlighted disparagingly earlier, the replacement knew nothing about astronomy.

Lack of time on the class appeared to be the major problem for Mr D. The researcher was left with the impression that if he had more time to spend on the unit then the students would have probably achieved a great deal more.

He later confided about why he had been assigned elsewhere for that time without being specific about the problems within the school. He also spoke a bit more about all of the interruptions that the school has and how this takes away from teaching time making it hard to fit everything in and get through units.

He also talked about how the girls in his class read the Student Workbook but found it difficult to build things from the diagrams. They relied more on the words and some help from him as well as the males in the class who went straight for the diagrams and/or pictures as opposed to using the written text.

He also confessed that he had found it hard to get the other science staff interested in the astronomy project except for one other who had intended to participate but who had had to take sick leave. He also said that this was the case with most things at the school.

8.4.2 Summary

This group of students and their science teacher were the most interesting to interview from the perspective of the type of science that appeared to be happening within the school and especially in Mr D's classes. It appeared to be student-centred, problem-focused and investigative with students working in their groups to achieve a common goal.

They appeared to be given responsibility for their learning and it also appeared that they assumed that responsibility gladly as evidenced by their excited, though often interrupted by the dominant female student, descriptions of what was happening both in their classes and outside in the playground with their model building and mathematics investigations.

Later in the school term the classes did come back to school for their observation night with their parents but not on the Friday night because that night was cloudy. An email informed us that the session was a great success.

9 DISCUSSION AND CONCLUSIONS

The Eye Observatory Remote Telescope Project developed and field tested curriculum materials targeting astronomy in Years 7, 8 and 9 and involved students learning how to use an astronomical telescope remotely over the Internet.

A quasi-experimental mixed-method research design was employed to evaluate the effectiveness of the curriculum materials and ascertained the impact of using the Charles Sturt University Remote Telescope on students' attitudes, motivation and knowledge of some astronomical phenomena. The research design allowed comparisons to be made with data collected by Goodrum et al. (2000) and reported in The Status and Quality of Science and Science Teaching in Australian Schools prepared for the Department of Education, Science and Training. The same student questionnaire was employed to collect data in the current project. A teacher questionnaire was developed based upon the student instrument that allowed some comparisons between students and teachers responses.

The intervention designed for this project comprised a Teachers' Guide, a Student Workbook, a CD-ROM, a web-site, a communication Forum, and access to, and use of, the Charles Sturt University Remote Telescope. Prior to schools implementing the project materials, a series of professional development days were held in the Australian Capital Territory, New South Wales, Queensland and Victoria for participating teachers. Prior to schools implementing the project, teachers administered two instruments to collect data from students.

The first of these assessed students' astronomical knowledge while the second attempted to gauge their thoughts and feelings about the science they experienced in school. Different teachers implemented different parts of the learning materials depending on the year to which they taught the content and the time that they have available.

During the course of this teaching/learning process students and their teachers planned to take control of the telescope located at Charles Sturt University, Bathurst, New South Wales. Students also learned how to process astronomical images with software supplied on the CD-ROM. While doing this technical aspect of their course, they also undertook, in varying degrees, practical and research activities related to the science syllabus astronomy content in their State or Territory.

At the observation night, the students used the telescope to acquire the images of astronomical objects that interested them and on which they had conducted some research to convince their peers that their object should be imaged. At the conclusion of their observation session, these images were e-mailed directly to the science teacher. In class, students processed their particular images for display to their peers.

At the conclusion of this intervention, teachers completed the post-intervention questionnaire and administered the two instruments to their students. The return rate of post-intervention instruments from students was approximately 60% while only 30% of teachers returned their questionnaire and information about the materials that they had covered during the project.

9.1 Summary of pre-intervention findings

Analysis of the *Secondary School Science Student Questionnaire* completed by students prior to the intervention and compared with the results reported in Goodrum et al. (2000) revealed that little has changed in the perspectives of students towards the science they experience in high school. One notable exception to this general finding was a major increase in the use of information and communication technologies (computers) in school science. Compared with the data collection period of Goodrum et al. (2000) undertaken in 1999, there has been almost a quadrupling of ICT use in science reported by the students.

Analysis of the *Astronomy Diagnostic Test* results supplied by over 2000 students in the first three years of high school reveals that the intended outcomes of primary science curricula as they relate to The Earth and its Surroundings are not being met. That is to say, this project found that a very large proportion of students could not adequately explain the causes of day and night, the phases of the Moon, the causes of Earth's seasons or describe how to the orbits of the Earth and Moon relate to the Sun.

The mean score for Year 7 students was 1.8 items correct out of a possible maximum score of 11. There was a large range in the scores obtained by students with 96% of students scoring 5 or less out of 11 and only 1.8% scoring more than 6 out of 11.

The “lack of impact” of the teaching of the topics on astronomy indicated by State and Territory syllabuses in the junior secondary school on Year 8 and 9 students using “traditional” approaches can be discerned from the mean scores of 2.6 and 2.9 out of 11 respectively. There was also a large variation in the scores obtained by students in Years 8 and 9 with 90% of students scoring 4 or less out of 11 in Year 8 and 90% scoring 5 or less out of 11 in Year 9.

The analysis of students' alternative conceptions data reveals that large proportions of students in Years 7, 8 and 9 of junior high school hold alternative scientific conceptions about such things as the causes of day and night, the phases of the Moon and the Earth's seasons.

Astronomy is a premier science in Australia. The results of this study indicate that the teaching of the topic of astronomy in the junior secondary school as far as content knowledge is concerned, is not satisfactory. The results obtained from Year 7 students indicate that the teaching of astronomy in the primary school is also in a parlous state. These findings indicate that there is a need for professional development of both primary school teachers and of junior secondary science teachers.

The *Secondary School Science Teacher Questionnaire* results reveal that there is a disparity in the perceptions of teachers of science about what they say goes on in their science classroom and what students report they experience. For example, the copying of notes given by the teacher is reported by 68% of students to happen in *nearly every* *lesson* while 36% of teachers claim that this is the case, and while 21% of teachers say they *never* "allow students to choose their own topics to investigate" 61% of students report that this never happens.

A large proportion of students (60%) report that they enjoy the practical activities and 36% thought that their science classes could be improved by having more practical and hands-on work. These two results are almost identical with those reported in Goodrum et al. (2000). These figures compare, however, with the 17% of teachers who thought that their classes could be improved by having more practical or hands-on work and the 44% of teachers who said that they liked this aspect of science. If there appears to be one thing that could improve the perception of students towards science, it would be the inclusion of more practical activities. This obviously needs to be resourced adequately within schools with the provision of laboratory assistants and time for teachers to prepare the materials.

In summary, little has changed in science education since Goodrum et al. (2000) gathered their results in 1999. Students continue to complain about the pedagogy they experience and teachers continue to complain about their lack of resources and access to professional development. It is also clear that primary school teachers are ill-equipped to deliver the outcomes of the science syllabuses that are related to astronomy.

9.2 Summary of post -intervention findings

The post-intervention data supplied by students in the *School Science Student Questionnaire* reveal that it is possible to address many of the problems identified by Goodrum et al. (2000) and confirmed by the current study on the pre-intervention occasion. By implementing a practical approach to the teaching of astronomy in junior high school science and involving the use of a remotely controlled telescope, significant changes were achieved in many problematic areas, though not all.

There were highly significant gains in students' astronomy content knowledge as measured by the same 11 items on the pre-intervention occasion from the Astronomy

Diagnostic Test. There were also significant gains in students' ability to explain various astronomical phenomena. A marked reduction was evident in the number of alternative scientific conceptions held by students as well as a marked reduction in the proportion of students holding each of these.

The *Secondary School Science Student Questionnaire* post-intervention questionnaire completed by almost 1200 students revealed some interesting changes. There was a significant reduction in the proportion of students reporting that they copied notes the teacher gave them and in the proportion of students who indicated that they read a science textbook at least once a week or more. There were significant reductions in the proportion of students reporting that they watched the teacher do experiments or doing them by following the teacher's instructions. There were also interesting reductions in the reporting of teacher feedback and guidance given to students with a significantly smaller proportion of students reporting that their science teacher told them how to improve their work. There were also small but significant changes in the proportion of students reporting where practical work was done with more of it being done outside the classroom.

Consistent with the project content, there was a highly significant increase in the use of computers to do science work and in searching the Internet for information. In total, there were significant changes in 37 of the 45 Likert-scale items. It should also be noted here that a very conservative protection against chance significant findings was implemented where a probability level of 0.0011 was necessary before a finding was deemed to be *significant.* Thus, it is likely that all of the 37 items have indeed shown significant changes from the pre- to the post-intervention occasion.

Students provided responses to open ended questions in the *Secondary School Science Student Questionnaire*. On the pre-intervention occasion, 59% of students commented about their liking for doing experiments while on the post-intervention occasion 24% made the same remark. This major reduction could, perhaps, be attributed to the amount of practical work in which the students engaged during the intervention.

On the post-intervention occasion 31% mentioned that they enjoyed using computers to do science, a topic that was not raised by students in the pre-intervention questionnaire. Thus, the response patterns on the post-intervention questionnaire had changed markedly from that of the pre-intervention questionnaire.

There was great variety in the amount of material chosen to be covered by teachers. Some, for example, chose only those projects necessary to learn how to control the telescope, take images and process them and covered this amount of content in four weeks. Others chose to immerse their students in the content covering projects from each of the main chapters in the Student Workbook according to student interest over almost an entire school term. One school in particular was notable for the fact that the Year 7 classes involved completed 23 of the 31 possible projects during the entire school term. Further analyses of any differential impact due to the depth of treatment needs to be undertaken.

The *Secondary School Science Teacher Questionnaire* administered on the post-intervention occasion demonstrated that there remained major differences in the perceptions of students and their teachers as to what was happening within their classrooms.

Qualitative data supplied at the interviews by both teachers and students indicated that they had enjoyed the astronomy content. It was apparent in some of the schools that the students had developed ownership of what they had done, what they had built and what they had found out. It was also apparent that the engagement students expressed depended very much on their teacher. In some cases, the students were highly critical of their science teacher and the way in which the material had been implemented.

9.3 Discussion

Astronomy is one of Australia's premiere sciences. We possess world-class instruments in both the optical and radio wavebands with facilities such as the Anglo- Australian Observatory, the Mount Stromlo and Siding Spring Observatory, the Australia

Telescope Compact Array, and the classic 64-metre dish at Parkes. Australia's astronomers are well renowned all over the world with Professor Ron Ekers of the Australia Telescope National Facility the current President of the International Astronomical Union.

It is against these accomplishments in the professional world of astronomy that the performance of students in Years 7, 8 and 9 in our schools could be judged. If this were the case, then our schools are failing. This simple conclusion, however, has to be juxtaposed with other research that details how science education is failing in other areas not only in astronomy. The current research project has revealed many interesting findings five years on from when Goodrum et al. (2000) collected their data. Perhaps the most significant finding of the pre-intervention investigation is that little has changed in the perspectives of students about the way they are taught science and what they experience in the classroom. The only major difference over this five-year period that was found by the current project was an increase in the use of information and communication technologies in the science classroom.

The intervention has demonstrated that significant changes can be made to students' perceptions of science education, knowledge of content, alternative scientific conceptions and ability to explain scientific phenomena when highly motivating devices and sound curriculum content are introduced.

Professional development of science teachers remains a key issue. There were many positive comments from those who engaged with the project content about how they had enjoyed the professional development and learned how to integrate computers into their science teaching. In this respect, the technology played a key role as a learning tool. The telescope played a secondary key role as a motivational device to engage students with the promise of control that, though not always delivered by their teachers, when achieved ensured their continued engagement with the curriculum content.

Given the disparity of implementation integrity, the outcomes of this project have nonetheless been highly significant. If it was at all possible to achieve a higher level of implementation integrity across jurisdictions and given professional development support, then learning outcomes for students may be significantly greater.

One comment by a teacher underscores the impact of the materials developed for this project - "*I was amazed. They [the students] actually enjoyed learning science*."

9.4 Reccomendations

Recommendation 1: It is recommended that the Commonwealth and educational jurisdictions continue to promote the importance of science education in schools.

Students come to high school with high expectations of science being a subject that they will enjoy. The majority are soon disappointed. Yet, it is to science that Australia must turn if the problems of salinity, global warming and energy production amongst the many are to be overcome. Scientific literacy is a key component of the education of our youth to develop in them the critical capacities required of informed and educated citizens who contribute to achieving the greater good and to improving the human condition.

Recommendation 2: It is recommended that the Commonwealth and educational jurisdictions make haste in implementing all recommendations made in the *Status and Quality of Teaching and Learning of Science in Australian Schools.*

The current study was undertaken because of the Chief Investigator's interest in the findings of the Goodrum et al. (2000) report to DETYA. It stimulated the author to ask a number of questions about how changes could be made to the ways in which science was taught in high schools. The outcomes of the present report have found that little has changed overall in the science classrooms of Australia's junior high schools. As one focus group member was quoted as saying in the Goodrum et al. (2000: p 85) report about what is actually happening in science teaching and learning "*Everything from brilliant to appalling*."

The current study found the same thing. The vignettes included in this report serve as examples of the "brilliant to appalling" range of science teaching in our schools. The recommendation made here will require significant funding of jurisdictions and of science teacher education in our universities.

Recommendation 3: It is recommended that the Commonwealth and educational jurisdictions provide the support of ongoing professional development to help science teachers teach science in ways that promote improved learning outcomes.

It is clear from comments made by teachers in this study that they were unaware of alternatives on how to teach students in deep and meaningful ways. They appeared to lack many of the information technology pedagogical skills required to use computers in their classrooms. In this sense, the current study had made unrealistic assumptions about the level of technological literacy they possessed despite the fact that large amounts of money have been invested in professional development in the past by educational jurisdictions to equip teachers with the necessary skills.

This study sought to contextualise the use of technology as an educational tool to address the science of astronomy. Further professional development is required that will contextualise further the use of the technology not only to achieve learning outcomes for the students but also to engage them with the tools of the emerging mode of production. Teachers, schools, systems and the society cannot afford to be left behind in this increasingly complex world. The “objects” of this investment are the future members of the society, the students in our schools.

Recommendation 4: It is recommended that the Commonwealth and educational jurisdictions provide further funding to investigate the impact on student learning outcomes from using remote and robotic telescopes in Years 10, 11 and 12.

This study has shown the value of employing access to a remote telescope as a motivational device to engage students. The instrument used was the Charles Sturt University Remote Telescope. In the short period of time that the intervention was implemented in participating schools by teachers, significant changes in students’ attitudes and performance were achieved, though not all for the better. Nonetheless, significant improvements to students’ content knowledge, reduction in alternative conceptions and improvement in their ability to explain certain phenomena were detected. With access to the research grade Faulkes Telescope at Siding Spring Observatory by Australian students and teachers, it is essential that adequate professional development be implemented for science teachers and that curriculum resources be developed that target the science curriculum of the educational jurisdictions.

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APPENDICES

APPENDIX A

Sample letters

A-1 Sample letter to school principal

A-2 Sample letter to teachers

A-3 Sample letter to parents

A-4 Sample letter to students

A- 1 Sample letter to school principal

May 1, 2004

Dear ,

Associate Professor David McKinnon through the Department of Education, Science and Training and Charles Sturt University is conducting an Australia wide study called:

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9.

There will be two co-investigators: Dr Des Wilsmore and Ms Lena Danaia. Dr Wilsmore was a school principal with the NSW Department of Education and Training. Ms Danaia is undertaking her PhD study in this area. All members have the required "Clearance to Work with Children" documentation. This can be supplied if required. It has already been supplied to the central offices of the various States and Territory Departments of Education and the Ethics in Human Research Committee at Charles Sturt University. Charles Sturt University, The NSW Department of Education and Training, and the ACT Department of education and Youth affairs have granted ethics approval. The Charles Sturt University ethics number is 2003/2004. A photocopy of this clearance is supplied in this package.

The investigation involves implementing a package of science learning materials in Years 7, 8 or 9 dealing with astronomy over a maximum of one school term but more normally in a period of 6-8 weeks. Classes of students will use the package during their normal science classes and access the Charles Sturt University (CSU) Remote Telescope during evenings selected by the teacher and students.

The study seeks to investigate, by questionnaire and interview, the knowledge developed by, and the attitudes towards, the educational materials in particular and science education in general. Further, the study will involve post-intervention interviews of a small number of student focus groups lasting approximately 20 minutes and with participating teachers lasting 30 minutes. Observations will be carried out in a small number of schools to assist with triangulation.

It is hoped that the information gained from this study will improve the teaching of astronomy in secondary schools and improve teachers' and students' knowledge and skills in the use of Information and Communications Technologies (ICTs) as a learning tool in the science classroom. Additionally, it will engage both teachers and students in an exciting on-line learning/teaching program where students and teachers learn how to, and actually take, control of the CSU Remote Telescope from their computers. Students and teachers may explore the telescope web-site at http://www.csu.edu.au/telescope .

Enclosed in this package are copies of the Ethics clearances, a description of the methodology to be employed and a Consent Form for you to sign and return to us.

We have already been in contact with science teachers at your school and they have indicated their willingness to participate in the project subject to your approval. We have been supplying them with email updates as to the progress of materials development and ethics applications.

If you agree to your school participating please sign and return the Consent Form (Principal) to A/Prof D McKinnon.

We are keenly aware this is a particularly busy time of year in your school but we ask that you select, where possible, classes across the first three years of high school where the teachers and students are prepared to participate in the study. This may be all or only one of the classes in a particular year level through to all classes in all year levels. We anticipate, however, that 3-5 classes per school may choose to become involved.

As part of the contract from the Department of Education, Science and Training (DEST), professional development release money can be supplied for the replacement of participating teachers on a day and location yet to be decided.

If you have any queries about the questionnaire or consent forms please contact Associate Professor David McKinnon, on 02 63 384235 or by e-mail dmckinnon@csu.edu.au .

Thank you again for your ongoing support and thank you for your anticipated prompt attention to the Consent Form.

Yours sincerely,

David H. McKinnon

Project Director

A- 2 Sample letter to teachers

Mr/Ms..........Given........................Last
Name of School
Street
Town/city......State.......area code

Associate Professor David McKinnon
School of Teacher Education
Charles Sturt University
Bathurst. 2795
Ph: 02 6338 4235
email: dmckinnon@csu.edu.au

Dear Mr/Ms.........……………Last name

My name is David McKinnon. I am an Associate Professor with the School of Teacher Education at Charles Sturt University (CSU) and am conducting this study from the Bathurst Campus. The title of this study is:

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9.

PURPOSE OF THE STUDY

Recent studies reveal strong evidence to suggest that many science teachers are isolated from effective professional development (PD), and that there is a lack of teachers comfortable in teaching astronomy in secondary schools. It is hoped that through your contributions to this study we will be able to improve professional development for science teachers involving on-line approaches leading to better outcomes and attitudes towards astronomy in particular, and science in general, for students.

This study is being conducted with the approval of the relevant Education Departments, the Department of Education Science and Training in Canberra, and the Charles Sturt University Ethics Committee. All information collected will remain strictly confidential. No identities will be revealed to any person or authority outside of the research team. There will be two co-investigators: Dr Desmond Wilsmore and Ms Lena Danaia. Dr Wilsmore was a school principal with the NSW Department of Education and Training. Ms Danaia is undertaking her PhD study in this area. All members have the required "clearance to work with children" documentation. It has already been supplied to the central offices of the various States and Territory Departments of Education.

We would like to invite you and your class to take part in this study and the associated intervention to assist in the teaching of astronomy in secondary schools. It will improve your knowledge and skills in the use of Information and Communications Technologies (ICTs) as a learning tool in the science classroom. Additionally, it will engage both teachers and students in an exciting on-line learning/teaching program where students and teachers learn how to, and actually take, control of the CSU Remote Telescope from their computers.

I would like myself, or my co-investigators, to interview you, several other volunteer members of the science staff and three groups of students (about four in each group) from Years 7, 8 and/or 9. It would also assist if you could complete a survey and mail it to us in the supplied rely-paid envelope. With your permission we would also observe the use of ICTs by your students and/or yourself as you implement the package. Please find attached a copy of the surveys for your information and perusal.

Your participation and that of your students is purely voluntary. You are free to withdraw at any time. If you agree to participate in this study please sign the attached Consent Form (Teachers) and return it to us with your completed survey.

You will be funded to attend a professional development day that will be scheduled prior to the start of the intervention.

Yours sincerely,

David H. McKinnon

Project Director

A- 3 Sample letter to parents

Plain language statement

Associate Professor David McKinnon
School of Teacher Education
Charles Sturt University
Bathurst. 2795
Ph: 02 6338 4235 email: dmckinnon@csu.edu.au

Dear Parent,

My name is David McKinnon. I am an Associate Professor in the Faculty of Education at Charles Sturt University (CSU). The title of this study is:

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9.

PURPOSE OF THE STUDY

Recent research studies suggest that students in secondary school are disappointed with the way science is taught. Only a few choose to study science in years 11 and 12. In addition, there is an expected shortage of science teachers in the near future. This study will enliven one part of the science curriculum in junior high school. The study will involve your child in the study of astronomy. In it, they will learn how to control a sophisticated astronomical telescope and electronic cameras over the Internet. They will use the system to image things like the Moon, planets, stars, clusters of stars and galaxies. They will learn how to analyse the pictures they have taken in practical and motivating settings.

The study is being conducted with the approval of the relevant Education Departments, the Department of Education Science and Training in Canberra, and the Charles Sturt University Ethics Committee. All information collected will remain strictly confidential. No names will be revealed to any person or authority. I would like to invite your child to take part in this study.

I would like myself, or my co-investigators, to interview your child. There will be two co-investigators: Dr Desmond Wilsmore and Ms Lena Danaia. Dr Wilsmore was a school principal with the NSW Department of Education and Training. Ms Danaia is undertaking her PhD study in astronomy education. All members have the required “clearance to work with children” documentation provided by an Approved Screening Agency.

Your child's participation is purely voluntary and they are free to withdraw at any time. If you agree to your child taking part in this study please complete the Consent Form (Parents) attached and return to your child’s teacher.

Your child will be involved in providing some information about what they know about astronomy, what they thought of the activities and educational experience. We will interview a small number of students at each school. The interview will take about twenty minutes.

Yours sincerely,

David H. McKinnon

Project Director

A- 3 Sample letter to students

Letter to Students

Plain language statement

Associate Professor David McKinnon
School of Teacher Education
Charles Sturt University
Bathurst. 2795
Ph: 02 6338 4235 email: dmckinnon@csu.edu.au

Dear Student,

My name is David McKinnon. I am an Associate Professor with the School of Teacher Education at Charles Sturt University. I am conducting this study from the Bathurst Campus. The title of this study is:

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9.

PURPOSE OF THE STUDY

Recent research studies suggest that students in secondary school are disappointed with the way science is taught. Not many students choose to study science in years 11 and 12. This project will enliven one part of the science curriculum in junior high school. The study will involve you in the study of astronomy. In it, you will learn how to control a special telescope and electronic cameras over the Internet. You will use the system to take pictures of things like the Moon, planets, stars, clusters of stars and galaxies. You will learn how to analyse the pictures you have taken in interesting ways.

This study is being conducted with the approval of the Education Departments in your State or Territory, the Department of Education Science and Training in Canberra, and the Charles Sturt University Ethics Committee. All information collected will remain strictly confidential. No names will be revealed to any person or authority.

I would like to invite you to take part in this study.

I would like one of my colleagues or myself to interview you and some other students. There will be two co-investigators: Dr Desmond Wilsmore and Ms Lena Danaia. Dr Wilsmore was a school principal with the NSW Department of Education and Training. Ms Danaia is undertaking her PhD study in astronomy education. Interviews will be about twenty minutes. You will also be asked to fill in a questionnaire about what you know and what you learn.

Your taking part is purely voluntary. You are free to withdraw at any time. If you agree to take part in this study, please complete the form attached and return it to your teacher.

Yours sincerely,

David H McKinnon

Project Director

APPENDIX B

Questionnaires

B-1 Student pre-intervention Survey

B-2 Student post-intervention Survey

B-3 Teacher pre-intervention Survey

B-4 Teacher post-intervention Survey

B-5 Astronomy Diagnostic Test

B-1 Student pre-intervention Survey

SECONDARY SCHOOL SCIENCE STUDENT QUESTIONNAIRE

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9

(Pre-test Student Questionnaire)

We are interested in what you think about science lessons at school and what you know about astronomy.

On the following pages are some questions. There are no right or wrong answers. We are asking for your ***personal*** opinion. Please answer these questions as honestly as you can.

Student Name ______________________ School: ______________________

City/Town: ______________________ State/Territory: ______________________

<u>Background Information</u>

(a) I am in Year

(Tick which year)

☐ 7

☐ 8

☐ 9

(b) I am

(Tick only ONE of these.)

☐ Female

☐ Male

There are no right or wrong answers. Please read each sentence carefully. Say what you think by putting a circle around the number that is right for you. If you make a mistake, put a cross over it, and then circle the right number

There is a short answer section at the end. Write your answers in the spaces provided. Please write neatly.

Look carefully at the top of each page to see how to choose or write your answer.

How often do these things *happen* in your science class?

In my science class…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
1. I copy notes the teacher gives me.	1	2	3	4	5
2. I work out explanations in science with friends or on my own.	1	2	3	4	5
3. I have opportunities to explain my ideas.	1	2	3	4	5
4. I read a science textbook.	1	2	3	4	5
5. I watch the teacher do an experiment.	1	2	3	4	5
6. we do experiments by following instructions.	1	2	3	4	5
7. we plan and do our own experiments.	1	2	3	4	5
8. we have class discussions.	1	2	3	4	5
9. we learn about scientists and what they do.	1	2	3	4	5
10. we do our work in groups.	1	2	3	4	5

In science we…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
11. do practical work outside in the schoolyard, the beach or in the bush.	1	2	3	4	5
12. have excursions to the zoo, museum, science centre, or places like that.	1	2	3	4	5
13. we have visiting speakers who talk to us about science.	1	2	3	4	5
14. use computers to do our science work.	1	2	3	4	5
15. look for information on the Internet at school.	1	2	3	4	5
16. investigate to see if our ideas are right.	1	2	3	4	5

My science teacher…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
17. tells me how to improve my work.	1	2	3	4	5
18. gives us quizzes that we mark to see how we are going.	1	2	3	4	5
19. talks to me about how I am getting on in science.	1	2	3	4	5
20. lets us choose our own topics to investigate.	1	2	3	4	5

How often are these things *true* for your science class?

The science we learn at school…	Almost never	Some-times	Often	Very Often	Almost Always
21. is relevant to my future.	1	2	3	4	5
22. is useful in every day life.	1	2	3	4	5
23. deals with things I am concerned about.	1	2	3	4	5
24. helps me make decisions about my health.	1	2	3	4	5
25. helps me understand environmental issues.	1	2	3	4	5

My science teacher…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
26. marks our work and gives it back quickly.	1	2	3	4	5
27. makes it clear what we have to do to get good marks.	1	2	3	4	5
28. uses language that is easy to understand.	1	2	3	4	5
29. takes notice of students' ideas.	1	2	3	4	5
30. shows us how new work relates to what we have already done.	1	2	3	4	5

In science, we need to be able to…	Almost never	Some-times	Often	Very Often	Almost Always
31. think and ask questions.	1	2	3	4	5
32. remember lots of facts.	1	2	3	4	5
33. understand and explain science ideas.	1	2	3	4	5
34. recognise the science in the world around us.	1	2	3	4	5

During science lessons…	Almost never	Some-times	Often	Very Often	Almost Always
35. I get excited about what we do.	1	2	3	4	5
36. we have enough time to think about what we are doing.	1	2	3	4	5
37. I am curious about the science we do.	1	2	3	4	5
38. I am bored.	1	2	3	4	5
39. I don’t understand the science we do.	1	2	3	4	5
40. I find science too easy.	1	2	3	4	5
41. I find science challenging.	1	2	3	4	5
42. I think science is too hard.	1	2	3	4	5

The following questions use codes SD=Strongly Disagree, D= Disagree, S=Sometimes, A=Agree, SA=Strongly Agree. Circle the one the describes best the situation for you.

43. I enjoy science ***in general***.	**SD**	**D**	**S**	**A**	**SA**
44. I enjoy the science we do at ***this school***.	**SD**	**D**	**S**	**A**	**SA**
45. I enjoy the science we do in ***this class.***	**SD**	**D**	**S**	**A**	**SA**

Please write answers to these questions below in the spaces provided.

46. What are the things that you really like about science in your class?

47. What are the things that you don't like about science in your class?

48. How could your science class be improved so that you could learn more?

49. Based on my experience in science lessons, I believe the purpose of learning science is….

Thank you for filling in this questionnaire about your experiences in science.

B-2 Student post-intervention Survey

SECONDARY SCHOOL SCIENCE STUDENT QUESTIONNAIRE

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9

(Post-test Student Questionnaire)

We are interested in what you think about science lessons at school and what you know about astronomy.

On the following pages are some questions. There are no right or wrong answers. We are asking for your ***personal*** opinion. Please answer these questions as honestly as you can.

Student Name ______________________ School: ______________________

City/Town: ______________________ State/Territory: ______________________

Background Information

(a) I am in Year
(Tick which year)

☐

☐

☐

(b) I am
(Tick ONE of these.)

☐ Female

☐ Male

There are no right or wrong answers. Please read each sentence carefully. Say what you think by putting a circle around the number that is right for you. If you make a mistake, put a cross over it, and then circle the right number

There is a by short answer section at the end. Write your answers in the spaces provided. Please write neatly.

Look carefully at the top of each page to see how to choose or write your answer.

Think about your experiences in science over the past few weeks. Please answer the questions below.

How often did these things happen in your science class?

In my science class…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
1. I copied notes the teacher gave me.	1	2	3	4	5
2. I worked out explanations in science with friends or on my own.	1	2	3	4	5
3. I had opportunities to explain my ideas.	1	2	3	4	5
4. I read science and other astronomy textbooks.	1	2	3	4	5
5. I watched the teacher do experiments.	1	2	3	4	5
6. we did experiments by following instructions.	1	2	3	4	5
7. we planned and did our own experiments.	1	2	3	4	5
8. we had class discussions.	1	2	3	4	5
9. we learned about scientists and what they do.	1	2	3	4	5
10. we did our work in groups.	1	2	3	4	5

In science we…	Never	Once a term or less	Almost once a month	About once a week	Nearly every lesson
11. did practical work outside in the schoolyard (or the beach or in the bush).	1	2	3	4	5
12. had excursions outside the school (e.g., to the museum, science centre, or places like that.)	1	2	3	4	5
13. we had visiting speakers who talked to us about science.	1	2	3	4	5
14. used computers to do our science work.	1	2	3	4	5
15. looked for information on the Internet at school.	1	2	3	4	5
16. investigated to see if our ideas were right.	1	2	3	4	5

My science teacher…					
17. told me how to improve my work.	1	2	3	4	5
18. gave us quizzes that we marked to see how we were going.	1	2	3	4	5
19. talked to me about how I was getting on in science.	1	2	3	4	5
20. let us choose our own topics to investigate.	1	2	3	4	5

How often were these things *true* for your science class?

Overall, the science we learned at school…	Almost never	Some-times	Often	Very Often	Almost Always
21. is relevant to my future.	1	2	3	4	5
22. is useful in every day life.	1	2	3	4	5
23. dealt with things I am concerned about.	1	2	3	4	5
24. helped me make decisions about my health.	1	2	3	4	5
25. helped me understand environmental issues.	1	2	3	4	5
My science teacher...					
26. marked our work and gave it back quickly.	1	2	3	4	5
27. made it clear what we had to do to get good marks.	1	2	3	4	5
28. used language that was easy to understand.	1	2	3	4	5
29. took notice of students' ideas.	1	2	3	4	5
30. showed us how new work related to what we have already done.	1	2	3	4	5

In science we need to be able to…	Almost never	Some-times	Often	Very Often	Almost Always
31. think and ask questions.	1	2	3	4	5
32. remember lots of facts.	1	2	3	4	5
33. understand and explain science ideas.	1	2	3	4	5
34. recognise the science in the world around us.	1	2	3	4	5
During these science lessons…					
35. I got excited about what we were doing.	1	2	3	4	5
36. we had enough time to think about what we were doing.	1	2	3	4	5
37. I was curious about the science we did.	1	2	3	4	5
38. I got bored.	1	2	3	4	5
39. I didn’t understand the science we did.	1	2	3	4	5
40. I found the science too easy.	1	2	3	4	5
41. I found the science challenging.	1	2	3	4	5
42. I though the science was too hard.	1	2	3	4	5

The following questions use codes SD=Strongly Disagree, D= Disagree, S=Sometimes, A=Agree, SA=Strongly Agree. Circle the one the describes best the situation for you.

43. I enjoy science ***in general***.	**SD**	**D**	**S**	**A**	**SA**
44. I enjoy the science we do at ***this school***.	**SD**	**D**	**S**	**A**	**SA**
45. I enjoyed the science we did in ***this class.***	**SD**	**D**	**S**	**A**	**SA**

Please write answers to these questions below in the spaces provided.

46. What are the things that you really liked about the science in your class over the past 6-8 weeks?

47. What were the things that you didn't like about the science in your class over the past 6-8 weeks?

48. How could your science class be improved so that you could learn more?

49. Based on my experience in the science lessons on astronomy, I now believe the purpose of learning science is…

Thank you for filling in this questionnaire about your experiences in this science unit on Astronomy.

B-3 Teacher pre-intervention Survey

2004 SECONDARY SCHOOL SCIENCE QUESTIONNAIRE

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9

(Pre-occasion Teacher Questionnaire)

We **guarantee** to you the **absolute confidentiality** of your responses to the items in this and other questionnaires. Once your responses on the pre-test have been matched with your responses on the post-test, all identifying information relating the responses to an individual will be destroyed. We are interested only in the aggregated data beyond the end of the project. No identifying information will ever be published.

Consequently, we ask that you identify yourself by giving your name, school name, town/city, the educational jurisdiction, the type of school and your gender. Your name and school are the most important identifying features that will allow us to match your pre-occasion responses with your post- occasion responses. Please ensure that these details are completed.

(Please Print)

Name ____________________ School: ____________________

City/Town: ____________________ ____________________

Type of School: (please tick)
- ☐ Government School
- ☐ Catholic Systemic School
- ☐ Catholic Independent School
- ☐ Independent School

State/ Territory:
- ☐ Australian Capital Territory
- ☐ New South Wales
- ☐ Queensland
- ☐ Victoria

Tick **all** years to whom you are going to teach the astronomy.
- ☐ 7
- ☐ 8
- ☐ 9

I am (Tick one ONLY.)
- ☐ Female
- ☐ Male

There are no right or wrong answers. We seek your opinion. Please tell us what you think.

Please read each sentence carefully then say what you think by putting a circle around the number that is right for you or by giving a short answer in the spaces provided at the end of the questionnaire.

If you would like to change a response, put a cross over it, then circle the new response.

Look carefully at the top of each section to see how to choose or write your answer.

Your Background and experience (Please Print)

Please provide information on the science qualification(s), if any, that you hold.

Please provide information on the teaching qualifications that you hold. **(Please Print)**

Have you undertaken any formal units at university/courses/professional development activities in astronomy?(Please circle) ....**Yes / No**

If **Yes**, please tell us what you have done. **(Please Print)**

Please provide information on the science subjects in which you have taught.		
Name of the Course/Subject	**Grade level of students**	**Year(s) Taught**
Example: **Biology**	**Year 11**	**2003 and 2004**

How often do these things happen in your science class?

In my science class…	**Never**	**Once a term or less**	**Almost once a month**	**About once a week**	**Nearly every lesson**
1. students copy notes that I give them.	1	2	3	4	5
2. I give my students the opportunity to work out explanations in science with peers or individually.	1	2	3	4	5
3. I provide opportunities for my students to explain their ideas.	1	2	3	4	5
4. my students read a science textbook.	1	2	3	4	5
5. I demonstrate experiments.	1	2	3	4	5
6. I give instructions to my students to follow when completing experiments.	1	2	3	4	5
7. I allow students to plan and do their own experiments.	1	2	3	4	5
8. I provide opportunities for class discussions.	1	2	3	4	5
9. I provide learning experiences for students to learn about scientists and what they do.	1	2	3	4	5
10. students work in groups.	1	2	3	4	5

In my science class I plan for students to…	**Never**	**Once a term or less**	**Almost once a month**	**About once a week**	**Nearly every lesson**
11. participate in practical work outside in the schoolyard, the beach or bush.	1	2	3	4	5
12. have excursions to the zoo, museum, science centre, or places like that.	1	2	3	4	5
13. listen to visiting speakers who talk to them about science.	1	2	3	4	5
14. use computers to do their science work.	1	2	3	4	5
15. look for information on the Internet at school.	1	2	3	4	5
16. investigate to see if their ideas are right.	1	2	3	4	5
As a science teacher I…					
17. tell students how to improve their work.	1	2	3	4	5
18. give students quizzes that they self-correct so that they can see how they are going.	1	2	3	4	5
19. talk to students and give them feedback on how they are getting on in science.	1	2	3	4	5
20. allow students to choose their own topics to investigate.	1	2	3	4	5

How often are these things true for your science class?

The science I teach at school…	**Almost never**	**Some-times**	**Often**	**Very Often**	**Almost Always**
21. is relevant to my students' future.	1	2	3	4	5
22. is useful in my students' everyday life.	1	2	3	4	5
23. deals with things that my students are concerned with.	1	2	3	4	5
24. helps my students make decisions about their health.	1	2	3	4	5
25. helps my students understand environmental issues.	1	2	3	4	5
As a science teacher I…					
26. mark students work and give it back quickly.	1	2	3	4	5
27. make it clear what students have to do to get good marks.	1	2	3	4	5
28. use language that students easily understand.	1	2	3	4	5
29. take notice of students' ideas.	1	2	3	4	5
30. show students how new work relates to what we have already done.	1	2	3	4	5

In science I think students need to be able to…	**Almost never**	**Some-times**	**Often**	**Very Often**	**Almost Always**
31. think and ask questions.	1	2	3	4	5
32. remember lots of facts.	1	2	3	4	5
33. understand and explain science ideas.	1	2	3	4	5
34. recognise the science in the world around us.	1	2	3	4	5
During science lessons I feel students…					
35. get excited about what we do.	1	2	3	4	5
36. have enough time to think about what we are doing.	1	2	3	4	5
37. are curious about the science we do.	1	2	3	4	5
38. are bored.	1	2	3	4	5
39. don't understand the science we do.	1	2	3	4	5
40. find science too easy.	1	2	3	4	5
41. find science challenging.	1	2	3	4	5
42. think science is too hard.	1	2	3	4	5

A teacher has many tasks to perform, many roles to fulfil and many pressures placed upon them. Below are only five of these roles. We are interested in your perception of these tasks/ roles/pressures. All are important facets of a teacher's job. From your perspective, please ***RANK*** in order from 1 to 5 the following five roles from your perception as a science teacher in order of importance. Use 1= highest level of personal importance to 5= lowest level of personal importance.

My role as a science teacher is to…	**Rank**
43. teach students.	
44. report student outcomes to relevant stakeholders.	
45. facilitate students' learning.	
46. assess students' learning outcomes.	
47. help students understand science.	

Please write answers to these questions below in the spaces provided.

48. What are the things that you really like about the way you teach science and the way students learn in your science class?

49. What are the things, if any, that you don't like about the way you teach and the way students learn in your science class?

50. How could your science class be improved (if any) so that students could learn more?

51. What are your thoughts on the declining number of students pursuing the sciences in Years 11 and 12 and at University? Why do you think this is so?

Thank you very much for completing this survey!

B-4 Teacher post-intervention Survey

2004 SECONDARY SCHOOL SCIENCE QUESTIONNAIRE

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7 to 9

(Post-occasion Teacher Questionnaire)

We are interested to see if their have been any changes in your perspectives about the teaching of science in general, and in the teaching of astronomy in particular. Specifically, we are interested in your reactions to the Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9 and the way in which it was presented by you to your students.

We ask you again to complete the questionnaire, and at the end of it to detail your reactions to the project.

(Please Print)

Name ____________________ School: ____________________

City/Town: ____________________ ____________________

Type of School: (please tick)

- ☐ Government School
- ☐ Catholic Systemic School
- ☐ Catholic Independent School
- ☐ Independent School

State/ Territory: (please tick)

- ☐ Australian Capital Territory
- ☐ New South Wales
- ☐ Queensland
- ☐ Victoria

Tick **<u>all</u>** years to whom you taught the astronomy.

- ☐ 7
- ☐ 8
- ☐ 9

I am (Tick one ONLY.)

- ☐ Female
- ☐ Male

Did you attend the Professional Development day at the start of the Project? (please tick)

- ☐ Yes
- ☐ No

There are no right or wrong answers. We seek your opinion. Please tell us what you think.

Please read each sentence/statement carefully then indicate what you think by putting a circle around the number that is right for you or by giving a short answer in the spaces provided at the end of the questionnaire.

If you would like to change a response, put a cross over it, then circle your new response.

Look carefully at the top of each section to see how to choose or write your answer.

In relation to you, and your students', experiences with *The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 & 9,* please circle the response below that best describes what happened.

How often did these things happen in your science class?

In my science class…	**Never**	**Once a term or less**	**Almost once a month**	**About once a week**	**Nearly every lesson**
1. students copied notes that I gave them.	1	2	3	4	5
2. I gave my students the opportunity to work out explanations in science with peers or individually.	1	2	3	4	5
3. I provided opportunities for my students to explain their ideas.	1	2	3	4	5
4. my students read science textbooks.	1	2	3	4	5
5. I demonstrated experiments.	1	2	3	4	5
6. I gave instructions to my students to follow when completing experiments/investigations.	1	2	3	4	5
7. I allowed students to plan and do their own experiments.	1	2	3	4	5
8. I provided opportunities for class discussions.	1	2	3	4	5
9. I provided learning experiences for students to learn about scientists and what they do.	1	2	3	4	5
10. students worked in groups.	1	2	3	4	5

In my science class I planned for students to	**Never**	**Once a term or less**	**Almost once a month**	**About once a week**	**Nearly every lesson**
11. participate in practical work outside in the schoolyard.	1	2	3	4	5
12. have excursions to the museum, science centre, or places like that.	1	2	3	4	5
13. listen to visiting speakers who talk to them about science.	1	2	3	4	5
14. use computers to do their science work.	1	2	3	4	5
15. look for information on the Internet at school.	1	2	3	4	5
16. investigate to see if their ideas were right.	1	2	3	4	5
As a science teacher I…					
17. told students how to improve their work.	1	2	3	4	5
18. gave students quizzes that they self-corrected so that they could see how they were going.	1	2	3	4	5
19. talked to students and gave them feedback on how they were getting on in science.	1	2	3	4	5
20. allowed students to choose their own topics to investigate.	1	2	3	4	5

Overall, the science I taught at school…	**Almost never**	**Some-times**	**Often**	**Very Often**	**Almost Always**
21. was relevant to my students' future.	1	2	3	4	5
22. was useful in my students' everyday life	1	2	3	4	5
23. dealt with things that my students were concerned with.	1	2	3	4	5
24. helped my students make decisions about their health.	1	2	3	4	5
25. helped my students understand environmental issues	1	2	3	4	5
As a science teacher I…					
26. marked students work and gave it back quickly.	1	2	3	4	5
27. made it clear what students had to do to get good marks.	1	2	3	4	5
28. used language that students could easily understand.	1	2	3	4	5
29. took notice of students' ideas.	1	2	3	4	5
30. showed students how new work related to what we had already done.	1	2	3	4	5

In science I think students need to be able to…	**Almost never**	**Some-times**	**Often**	**Very Often**	**Almost Always**
31. think and ask questions.	1	2	3	4	5
32. remember lots of facts.	1	2	3	4	5
33. understand and explain science ideas.	1	2	3	4	5
34. recognise the science in the world around us.	1	2	3	4	5
During the science lessons I felt students					
35. got excited about what we did.	1	2	3	4	5
36. had enough time to think about what we were doing.	1	2	3	4	5
37. were curious about the science we did.	1	2	3	4	5
38. got bored.	1	2	3	4	5
39. didn't understand the science we did.	1	2	3	4	5
40. found the science too easy.	1	2	3	4	5
41. found the science challenging.	1	2	3	4	5
42. thought the science was too hard.	1	2	3	4	5

In the first questionnaire we asked you to rank five roles that a science teacher has to perform. Below are these five roles. We are interested in your perception of these tasks/roles/pressures. All are important facets of a teacher's job. We provide three additional spaces for you to add roles/tasks/pressures and to include them in your ranking of the original five. From your perspective, please ***RANK*** the list accordingly with your additions in order of importance. Use 1= highest level of personal importance to 8= lowest level of personal importance.

My role as a science teacher is to…	**Rank**
43. teach students.	
44. report student outcomes to relevant stakeholders.	
45. facilitate students' learning.	
46. assess students' learning outcomes.	
47. help students understand science.	
48.	
49.	
50.	

Please write answers to these questions below in the spaces provided.

51. What were the things, if any, that you really liked about the way you taught science over the past few weeks and the way students learned in your science class?

52. What were the things, if any, that you don't like about the way you taught science over the past few weeks and the way students learned in your science class?

53. How could we improve the astronomy materials (if any) so that students could learn more?

The following questions relate specifically to your evaluation of the project: *The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 & 9.*

When answering the questions below please think about **both** your, and your students', experiences with the project.

Please indicate your response to each statement/question below by circling the appropriate number to indicate the extent to which you agree or disagree with the statement.

(Circle one number on each line).	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
54. The suite of materials implemented was worthwhile.	1	2	3	4
55. I enjoyed taking part in the project.	1	2	3	4
56. I found the use of technology in the astronomy lessons valuable.	1	2	3	4
57. Involvement in this project has inspired me to apply technology to various other science topics and situations.	1	2	3	4

Please indicate the extent to which you think…	**Not at all**	**Slight Extent**	**Moderate extent**	**Great Extent**
58. the on-line Internet work encouraged student motivation.	1	2	3	4
59. the on-line Internet work encouraged student learning.				
60. the on-line telescope work encouraged student motivation.	1	2	3	4
61. the on-line telescope work encouraged student learning.				
62. the technologies and materials used in the project aided my teaching.	1	2	3	4
63. the technologies and materials used in the project aided my learning as a teacher.	1	2	3	4
64. the technologies and materials used in the project aided student learning.	1	2	3	4
65. this project has developed my knowledge and understanding of astronomy.	1	2	3	4

Please indicate your level of satisfaction related to…	**Not at all satisfied**	**Slightly satisfied**	**Moderately satisfied**	**Very satisfied**
66. the relevance of the project content to syllabus outcomes for science.	1	2	3	4
67. the depth at which the content of the project was covered for the year level(s) I taught.	1	2	3	4
68. the information in the Teacher Guide.	1	2	3	4
69. the Student Workbook and materials with which students worked.	1	2	3	4
70. the technology at school with which my students worked.	1	2	3	4

Please indicate your level of satisfaction related to…	**Not at all satisfied**	**Slightly satisfied**	**Moderately satisfied**	**Very satisfied**
71. the help ***I*** was given in learning how to access and use the computer programs/applications within the school.	1	2	3	4
72. the help ***I*** was given in learning how to access and use the computer programs/applications on the PD day, online help from CSU etc.	1	2	3	4
73. the help students were given in learning how to access and use the computer programs/applications by the school.	1	2	3	4
74. the help ***I*** was able to give students in learning how to access and use the computer programs/application.	1	2	3	4

To what extent did you <u>use</u> the resources provided by this project?	**Not at all**	**Once or twice**	**Once or twice a week**	**Daily**
75. The Teachers' Guide	1	2	3	4
76. The Student Workbook	1	2	3	4
77. The resource links on the web site	1	2	3	4
78. The information searching utility on the web site	1	2	3	4
79. The weather links	1	2	3	4
80. The image processing software	1	2	3	4
81. The planetarium software (SkyGlobe)	1	2	3	4
82. The PowerPoint slideshows	1	2	3	4
83. The communication Forum	1	2	3	4
84. Email (user supplied)	1	2	3	4

Please indicate your response to each statement/question below by circling the appropriate number to indicate the extent to which you agree or disagree with the statement.

(Circle one number on each line).	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
85. The Teachers' Guide was extremely useful.	1	2	3	4
86. The Student Workbook was extremely useful for students.	1	2	3	4
87. The CD-ROM was extremely useful.	1	2	3	4
88. The DEST Web site was extremely useful.	1	2	3	4
89. The on-line telescope session was motivating.	1	2	3	4
90. Communicating with other science teachers was satisfying.	1	2	3	4
91. I would recommend this approach to teaching astronomy to other science teachers.	1	2	3	4

Please write responses to these questions below in the spaces provided.

92. In your opinion, what were the main benefits of *The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 & 9…*

a) ***for students?***

b) ***for you?***

93. Were there any particular aspects of *The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 & 9*experience that you feel should have been handled differently or could be improved? If so, please explain.

94. If you have any additional comments about your experiences with *The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 & 9,* which you think would be important for us to know, please write them in the space below.

Please send with this completed questionnaire, the completed/photocopied Program that was handed to you in the folder on the professional development day.

Thank you very much for completing this survey!

B-5 Astronomy Diagnostic Test

Astronomy Diagnostic Test (ADT)

Southern Hemisphere Edition Version 1.01

The same quiz is used at the beginning and end of the course.

We ask for your name to see if there are any changes in responses to the survey questions. Please print your name, school, city/town neatly.

Student Name	____________	**School:**	____________
City/Town:	____________	**State/Territory:**	____________

Background Information

(a) I am in Year (Tick which year.)

☐ 7
☐ 8
☐ 9

(b) I am (Tick one ONLY).

☐ **Female**
☐ **Male**

Directions

The first four questions ask you to create a drawing to explain something that happens in space and then to write a few words to explain your drawing.

The rest of the questions ask you to tick a box beside what you think is the correct answer. <u>If you do not know, just leave the question blank.</u>

After each question, there is space for you to give the reason for your answer to the question. If you do not know, then leave the space blank.

You may tick only one box for each question. If you make a mistake, put a cross X over the tick. Place your tick in the new box.

Please be sure to tick a box for each question if you think you know the answer.

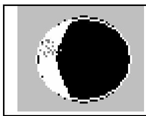
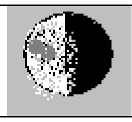
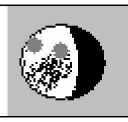
1a. Draw a picture of the Earth and the Sun in the space below to show why day-time and night-time happen. Include these labels: *The Earth*, *The Sun*, *day-time*, *night-time*

1b. Write a few words to explain your picture.

2a. Imagine you are out in space looking down on the Earth, the Moon and the Sun. Draw a picture to show how they would move. - Show their orbits. - Label each thing

2b. Write a few words to explain your picture.

3a. Janine looked for the Moon one week. Here is what she saw:

	Cloudy	Cloudy		cloudy		cloudy
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

Use drawings in the space below to show why she saw the Moon these different shapes.

3b. Write a few words to explain your picture.

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4. Draw pictures of the Earth and the Sun to show why Summer and Winter happen.

4b. Write a few words to explain your picture.

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5. As seen from your school, when will an upright flagpole cast *no shadow* because the Sun is directly above the flagpole?

- ☐ Every day at noon.
- ☐ Only on the first day of summer.
- ☐ Only on the first day of winter.
- ☐ On two days between beginning of spring and beginning of autumn.
- ☐ Never from my current location.

Please give the reason for your answer to this question?

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6. When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?

- ☐ Full
- ☐ At no particular phase
- ☐ First quarter
- ☐ New
- ☐ Last quarter

Please give the reason for your answer to this question?

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7. **Imagine that you are building a scale model of the Earth and the Moon. You are going to use a 30 cm basketball to represent the Earth and a 7 cm tennis ball to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?**
   - ☐ 7 cm
   - ☐ 15 cm
   - ☐ 90 cm
   - ☐ 9 m
   - ☐ 90 m

Please give the reason for your answer to this question?

8. **You have two balls of equal size and smoothness, and you can ignore air resistance. One is heavy, the other much lighter. You hold one in each hand at the same height above the ground. You release them at the same time. What will happen?**
   - ☐ The heavier one will hit the ground first.
   - ☐ They will hit the ground at the same time.
   - ☐ The lighter one will hit the ground first.

Please give the reason for your answer to this question?

9. **How does the speed of radio waves compare to the speed of visible light?**
   - ☐ Radio waves are much slower.
   - ☐ They both travel at the same speed.
   - ☐ Radio waves are much faster.

Please give the reason for your answer to this question?

10. Astronauts inside the Space Shuttle float around as it orbits the Earth because

- ☐ they are falling in the same way as the Space Shuttle.
- ☐ there is much less gravity inside the Space Shuttle.
- ☐ they are above the Earth's atmosphere.
- ☐ there is no gravity in space.
- ☐ more than one of the above.

Please give the reason for your answer to this question?

11. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?

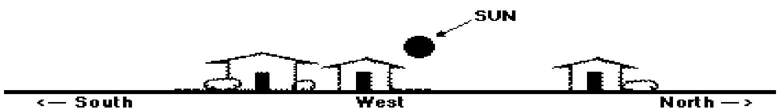
- ☐ We would still experience seasons, but the difference would be much MORE noticeable.
- ☐ We would still experience seasons, but the difference would be much LESS noticeable.
- ☐ We would no longer experience a difference between the seasons.
- ☐ We would continue to experience seasons in the same way we do now.

Please give the reason for your answer to this question?

12. **Where does the Sun's energy come from?**
    - ☐ The combining of light elements into heavier elements
    - ☐ The glow from molten rocks
    - ☐ The breaking apart of heavy elements into lighter ones
    - ☐ Heat left over from the Big Bang

Please give the reason for your answer to this question?

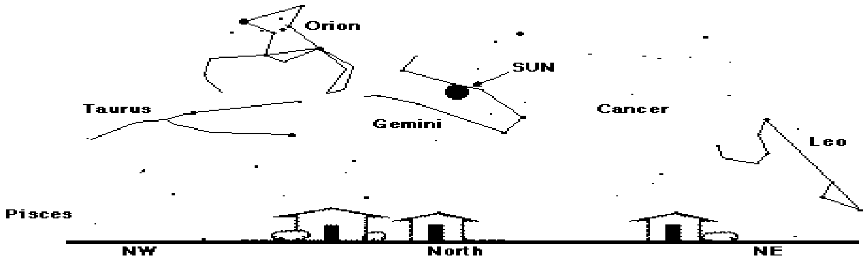
13. **On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?**
    - ☐ Farther south
    - ☐ In the same place
    - ☐ Farther north



Please give the reason for your answer to this question?

14. If you could see stars during the day, the diagram below shows what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?

- ☐ Cancer
- ☐ Taurus
- ☐ Gemini
- ☐ Leo
- ☐ Pisces



Please give the reason for your answer to this question?

15. Compared to the distance to the Moon, how far away is the Space Shuttle (when in space) from the Earth?

- ☐ Very close to the Earth
- ☐ About half way to the Moon
- ☐ About twice as far as the Moon
- ☐ Very close to the Moon

Please give the reason for your answer to this question?

16. As viewed from our location, the stars of the Southern Cross can be connected with imaginary lines to form the shape of a cross. To where would you have to travel to first observe a considerable change in the shape formed by these stars?

- ☐ Across the country
- ☐ South Africa
- ☐ The Moon
- ☐ Pluto
- ☐ A distant star

Please give the reason for your answer to this question?

17. Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

- ☐ Moon, Sun, Pluto, stars
- ☐ Moon, Pluto, Sun, stars
- ☐ Moon, Sun, stars, Pluto
- ☐ Sun, Moon, Pluto, stars
- ☐ Stars, Moon, Sun, Pluto

Please give the reason for your answer to this question?

18. Which of the following would make you weigh half as much as you do right now?

- ☐ Take away half of the Earth's atmosphere.
- ☐ Make the Earth spin half as fast.
- ☐ Take away half of the Earth's mass.
- ☐ Double the distance between the Sun and the Earth.
- ☐ More than one of the above

Please give the reason for your answer to this question?

19. A person is reading a newspaper while standing 2 m away from a table that has on it an unshaded 100-watt light bulb. Imagine that the table is moved to a distance of 4 metres. How many light bulbs in total would have to be placed on the table to light up the newspaper to the same amount of brightness as before?

- ☐ Three bulbs.
- ☐ One bulb.
- ☐ Two bulbs.
- ☐ Four bulbs.
- ☐ More than four bulbs

Please give the reason for your answer to this question?

20. According to modern ideas and observations, what can be said about the location of the centre of the Universe?

- ☐ The Milky Way Galaxy is at the centre.
- ☐ An unknown, distant galaxy is at the centre.
- ☐ The Sun is at the centre.
- ☐ The Universe does not have a centre.
- ☐ The Earth is at the centre.

Please give the reason for your answer to this question?

21. The hottest stars are what colour?

- ☐ Blue
- ☐ Red
- ☐ White
- ☐ Yellow
- ☐ Orange

Please give the reason for your answer to this question?

22. With your arm held straight, your thumb is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth is, what object could you use to just cover up the Sun?

- ☐ Your wrist
- ☐ A hair
- ☐ A strand of spaghetti
- ☐ Your thumb
- ☐ A pencil

Please give the reason for your answer to this question?

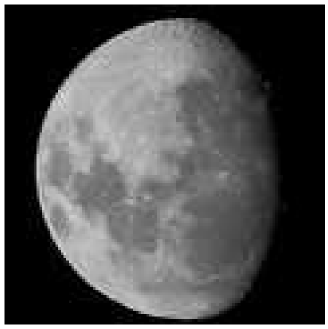
23. The diagram above shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture below when viewed from Earth?

- ☐ A
- ☐ B
- ☐ C
- ☐ D
- ☐ E

Please give the reason for your answer to this question?

24. You observe a full Moon rising in the east. How will it appear in six hours?

☐ A


☐ B


☐ C


☐ D


Please give the reason for your answer to this question?

25. Global warming is thought to be caused by the

☐ addition of carbon dioxide.

☐ destruction of the ozone layer.

☐ trapping of heat by nitrogen.

Please give the reason for your answer to this question?

26. In general, how confident are you that your answers to this survey are correct?

- ☐ Very confident
- ☐ Confident
- ☐ Not sure
- ☐ Not very confident
- ☐ Not at all confident (just guessing)

27. Which best describes the level of difficulty you expect (or **"experienced"** on post-intervention occasion**) from this course?**

- ☐ Extremely difficult for me
- ☐ Difficult for me
- ☐ Unsure
- ☐ Easy for me
- ☐ Very easy for me

Please give the reason for your answer to this question? ____________________

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THANK YOU for your responses.