

DAN07394

Perceptions, knowledge outcomes and experiences of students in junior secondary science: Impact(s) of using a remote telescope and associated curriculum materials.

Lena Danaia
Charles Sturt University

This research investigates the impact of an educational program, based on astronomy that involves using a remotely controlled telescope over the Internet and which employs five aspects of the *ideal* picture of science education (Goodrum, Hackling & Rennie, 2000), on students' perceptions of science at school and the knowledge outcomes generated. The program was introduced into 101 junior secondary science classes drawn from 30 schools located in four Australian educational jurisdictions. A concurrent nested mixed-method approach involving a quasi-experimental pre-test/post-test design complemented by qualitative techniques was used to investigate the data. Specifically, data were collected using: a perception questionnaire; an astronomy diagnostic test; and, semi-structured interviews with a sample of participants. Results show that students exhibited negative perceptions of science at school prior to the commencement of the program and knew little of the astronomical content knowledge that was supposed to be covered in primary school or in the first year of secondary school. The post-occasion data showed that there were highly significant differences in students' perceptions of science and in their knowledge of astronomical phenomena. The research recognises that the way in which science is implemented is crucial to the success of teaching and learning experiences in science education.

Introduction

In today's society, science plays an important role in every day life where developments are occurring at a rapid pace. Advances in science continue to have a major impact on society and the way people live. Countries have acknowledged that a well-educated and skilled workforce is vital for them to remain internationally competitive in the 21st century. It is therefore, imperative that members of society have a strong grounding in science so that they can follow such advancements and have the capacity to make informed decisions. Focus has been directed to the overwhelming importance of science education in schools and the fundamental role it must play in developing scientifically literate students.

During the last two decades, several countries have expressed widespread concerns about the science education delivered. Alarming are the declines in student interest and in the number electing to pursue the sciences in the post-compulsory years of schooling and at the tertiary level reported in Australia, Canada, Denmark, France, Germany, India, Ireland, Japan, Korea, Netherlands, New Zealand, Norway, Sweden, United Kingdom and the United States of America (Committee for the Review of Teaching and Teacher Education, 2003; Crawley III & Coe, 1990; Dekkers & de Laeter, 2001; Drury & Allen, 2002; Goodrum et al. 2000; Hackling, Goodrum & Rennie, 2001; Hassan & Treagust, 2003; International Bureau for Education, 2001; Lyons, 2006; Millar & Osborne, 1998; Speering & Rennie, 1996). It seems that as students progress through school a large proportion are disappointed with the science they experience. Furthermore, much of the science content offered in schools lacks relevance and fails to engage or interest students. In essence, it appears to alienate many.

There have been numerous requests and attempts from governments, science education bodies and relevant stakeholders to reform existing modes of science education to try and combat many of the concerns (e.g., American Association for the Advancement of Science [AAAS], 1990; Goodrum et

al. 2000; Millar & Osborne, 1998). Scientific literacy has been at the forefront of many of these reforms. Recommendations to turn away from traditional forms of instruction and support for adopting student-centred pedagogical approaches that focus on inquiry and practical investigation are generally endorsed. Despite changes in the objectives of science education and calls for reform there have not necessarily been corresponding changes in the implemented science curriculum (Goodrum et al. 2000). That is to say, the way science is taught at school and the content covered often continue to reflect traditional approaches.

Many of the persistent problems identified in school science education appear to be inter-related and are all critical factors inhibiting reform. Millar and Osborne (1998) link the declining number of students pursuing science in the post-compulsory years of school to the lack of relevance the science curriculum has in relation to students' interests and real life experiences. Furthermore, students' perceptions of, and attitudes toward, science are shaped by prior experiences which often inform their decision to undertake science subjects in the post-compulsory years of school (Hackling et al. 2000). Lyons (2006, p.606) advises that "negative school science experiences can be a significant and, in some cases, decisive, influence on students' enrolment deliberations." Additional factors that may deter the uptake of science in the post-compulsory years include the perceived difficulty associated with science subjects and the stereotypical image that many students possess in relation to scientists (Cleaves, 2005).

For a number of students the science they experience in junior secondary school lacks relevance to their everyday lives (Hackling et al. 2001). This lack of relevance and students' waning interest have been attributed to the transmissive way science is taught at school (Speering & Rennie, 1996). Furthermore, the transmissive or traditional pedagogies that tend to dominate science instruction are often employed as a consequence of teachers having to cover an overcrowded science curriculum within a specified timeframe to ensure that students are prepared for the norm-referenced assessment, which is generally given at the end of each topic (Goodrum et al. 2000; Osborne & Collins, 2000). All of these problems appear to be influential factors in determining students' further participation in science.

In Australia, the Department of Education Training and Youth Affairs (DETYA) commissioned a report into the Status and Quality of Teaching and Learning of Science in Australian Schools (Goodrum et al. 2000). The report set out to define an *ideal* picture of science education that epitomised the intended curriculum and to identify what was actually happening in both primary and secondary schools. The *actual* picture of teaching and learning in science was diverse but, on the whole, very disappointing. Many of the problems identified in science education in other countries were also evident in the Australian context. Several factors were identified that contributed to the difference between the intended and the implemented science curriculum and included things such as a lack of equipment and resources, time constraints associated with covering the curriculum and few opportunities for teacher professional development.

In light of the findings, recommendations were proposed to assist in closing the gap between the *ideal* and *actual* picture of teaching and learning in science in Australian schools. Similar to other countries, a central goal of these recommendations was to develop scientifically literate students and increase their capacity to make informed decisions about contemporary science issues in society. The recommendations spanned a number of areas and in particular, called for: state and national promotion of the importance of science education; more professional development opportunities; incentives to retain and attract science educators; an increase in funding for pre-service science teacher education courses; pre-service science teacher education courses that model appropriate pedagogies; the development of professional standards for science teaching; access to excellent facilities and resources; improved assessment mechanisms; and a national focus on science education (Goodrum et al. 2000). It was advised that action should be taken without delay

in implementing the recommendations. The final recommendation suggested that a review of the status and quality of science teaching and learning be conducted five years after the report to reflect on the implementation of such recommendations.

In 2003, the Department of Education Science and Training (DEST, formerly DETYA) funded The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9 (McKinnon, 2005). The Eye Observatory Remote Telescope Project emerged, in part, from the concerns identified and recommendations made in the Status and Quality of Teaching and Learning of Science in Australian Schools research report (Goodrum et al. 2000). Specifically, it related to a suggested action in the report that warranted the production of quality secondary science curriculum resources that integrated professional development (Goodrum et al. 2000).

The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9 was concerned with trialling and evaluating a set of teaching and learning resources based on astronomy that involved the use of a remotely controlled telescope and fostered student-centred forms of instruction (McKinnon, 2005). The learning resources include: a student workbook; teachers' guide; CD-ROM; access to and use of the Charles Sturt University Remote Telescope, website and forums. A professional development program is also incorporated within the program where teachers have the opportunity to access ongoing support throughout the implementation of the learning materials. Furthermore, five aspects of the *ideal* picture of science education were portrayed in the curricula and suggested teaching and learning experiences of The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9. The five themes are:

1. The 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, fulfilment, ownership of and engagement in learning, and mutual respect between the teacher and students.
5. Excellent facilities, equipment and resources support teaching and learning.

(Goodrum et al. 2000, p. vii)

The Practical Astronomy educational materials provide avenues for students to select and pursue projects in which they are interested. Assessment is carried out before, during and at the conclusion of the program. This provides feedback to the teacher on what students already know about various astronomical concepts and allows teachers and students to select projects that build on pupils' prior knowledge and address their alternative conceptions as well as monitor their emerging understandings of the concepts with which they are confronted. The educational materials provide the means by which certain astronomical concepts can be covered in-depth and make connections with other disciplines. The teaching and learning activities are based on student inquiry and lend themselves to collaborative group work. In addition, the use of technology is integrated throughout the educational materials and the project provides individual classes with exclusive access to highly specialised scientific grade equipment, such as the CSU Remote Telescope. Furthermore, teachers are supported through an ongoing professional development program.

Surprisingly, little research has been conducted on the impact of implementing science curricula characterised by the *ideal* picture of science on students' perceptions and knowledge outcomes in science. Given that The Eye Observatory Remote Telescope Project: Practical Astronomy for Years 7, 8 and 9 was created, partially, in response to such recommendations and considering the *ideal* (Goodrum et al. 2000) nature of the learning materials and the likely benefits of such curricula, one

would anticipate that investigating the impact of such curricula on students is of importance. Consequently, the purpose of this paper is to investigate the impact of such curricula on both students' perceptions of the science they experience at school and their knowledge outcomes.

It is important to assess students' knowledge and understanding of astronomical concepts given the large body of literature that indicates students often possess conceptions, which are at variance with the views currently accepted by the scientific community. From a very early age, children begin acquiring concepts about scientific phenomena through the process of their attempts to make sense of the world around them. Thus, it has been noted that the knowledge a learner brings to a classroom setting is a vital factor that needs to be considered by the teacher when planning what and how to teach components of the science education curriculum (Stead & Osborne, 1980). Ausubel (1968, p.vi) reinforces this by stating, "*the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him/her accordingly.*"

Method

The study took place in four educational jurisdictions located on the eastern side of Australia: the Australian Capital Territory; New South Wales; Queensland; and, Victoria. Opportunity sampling was employed to recruit participants in this research. In this type of sampling, participants are often accessible to the researcher and recruited through volunteering to participate in the research (Johnson & Christensen, 2004). It was necessary to employ this type of non-randomised sampling for practical reasons; that is, the study had a limited time in which it was to be completed and the research was conducted within an educational setting where class groups are already formed making it unrealistic for participants to be randomly selected and placed into groups. The schools involved in the study were drawn from both public (51.6%) and private (48.4%) educational sectors. A total of 30 schools agreed to participate in the research. The participants were 2016 junior secondary students of which 1277 were drawn from the first year of junior secondary school (Year 7), 520 from the second year (Year 8) and 219 from the third year of junior secondary school (Year 9).

The approach employed to carry out this research was a concurrent nested mixed-method approach (Creswell, 2003; Tashakkori & Teddlie, 2003) that involved adopting a quasi-experimental non-randomised pre-test/post-test design complemented by qualitative data (Bordens & Abbott, 2005; Cook & Campbell, 1979; Shadish, Cook & Campbell; 2002). Quasi-experimental research designs are suitable where random assignment of participants is not possible (Johnson & Christensen, 2004). Three data collection techniques were employed to gather information from participants. These included: questionnaires; a diagnostic test; and, semi-structured interviews. Questionnaire and test data were administered to, and collected from, participants on two occasions: both before and after their participation in the Practical Astronomy Program. In addition, semi-structured interviews were conducted with a sample of students drawn from six of the participating schools.

The Secondary School Science Questionnaire (SSSQ) was used to collect information from students regarding their perceptions of, and experiences in, junior secondary science classes. This questionnaire is a slightly modified form of the Secondary School Science Questionnaire used in *The Status and Quality of Teaching and Learning of Science in Australian Schools* research project (Goodrum et al. 2000). The questionnaire contains 45 rating-scale items, four open-response questions and a section at the beginning of the questionnaire that collects demographic information from respondents. In addition, three rating-scale items were added to the 42 items of the Goodrum et al. (2000) SSSQ that tapped respondents' enjoyment of science. The pre-occasion SSSQ is used to examine students' current perceptions of science at school. The post-occasion questionnaire is used to provide information on the impact of the program on students' perceptions of the science they experience at school during the intervention period. The original questionnaire was modified slightly on the post-occasion to focus participants' responses on their experiences within science

during the intervention period. To achieve this, a statement was introduced at the start of the questionnaire that asked students to concentrate on their experiences throughout the program. The 45 rating-scale questions were transformed into past tense to help students reflect. Three of the four open-response items were adapted to direct respondents to answer the questions based on their involvement in the science intervention.

The Astronomy Diagnostic Test (ADT) was used to collect information on students' knowledge and understanding of astronomical phenomena. The Astronomy Diagnostic Test Version 2.0 (ADT) created by The Collaboration for Astronomy Education Research (CAER, 1999) team, based in the United States, was released in June 1999 (Deming, 2002; Hufnagel et al. 2000). The test contained 21 multiple-choice items based on astronomical concepts that students are expected to cover in their elementary (primary) and secondary school science education (Hufnagel et al. 2000). The ADT was created to provide teachers with an assessment tool that could be used at the start of an introductory astronomy course to collect information on students' current astronomical understandings and which would allow teachers to mould the course to address the areas identified as being of most concern (Deming, 2002). The ADT could also be used at the conclusion of such a course to gather data on students' understanding and learning as a result of being involved in the course.

The Northern Hemisphere Version of the ADT was modified by O'Byrne (CAER, 2002), to create a version suitable to use with students in the Southern Hemisphere. The Northern Hemisphere Version described above was modified slightly by rewording three of the original 21 multiple-choice questions and changing certain diagrams to make them suitable to use with students located within the Southern Hemisphere. The ADT used in this study has been adapted from the Southern Hemisphere version. The 21 multiple-choice questions used in the original Southern Hemisphere ADT with one minor modification to an option remained the same for this rendition. It was however, recognised by the researcher that previous versions of the ADT failed to collect data on respondents' reasons for selecting certain answers. To address this, an additional section was created to accompany each of the tick-box questions that asked participants to give reasons or an explanation for their tick-box response. Adding this section provided a means to collect information on, and gain insight into, students' understanding of the concepts presented in each of the questions. In addition, four drawing-response items taken from John Dunlop's Astronomy Survey (Dunlop, 2000) were added to the beginning of this version of the Astronomy Diagnostic Test. The reason for incorporating the drawing-based questions stemmed from prior research in astronomy education that provided evidence to show that drawing-based responses tend to elicit more correct response rates from students drawn from primary and junior secondary school compared with multiple-choice responses seeking information on the same phenomena (Dunlop, 2000). The ADT was coded and analysed with respect to five dependent variables: knowledge about astronomy; alternative conceptions; non-responses; the complexity of explanations; and, the quality of responses (Danaia, 2006).

Interviews were conducted by the researcher in six schools with a selection of student participants. Pseudonyms were assigned to each school these included: Country, Metro, City, Town, Urban and Beachside High Schools. Two of the schools (Country and Town) were located in rural New South Wales, two (Metro and City) from metropolitan New South Wales and two (Urban and Beachside) were from metropolitan Queensland. All interviews were semi-structured where the researcher had a list of pre-prepared questions to guide the interviews. The interviews were conducted in small groups ranging from four to nine student participants. It was thought that conducting interviews in group situations would be more conducive in providing students with a supportive and comfortable environment with which they would feel safe in sharing their thoughts as opposed to an interview situation where they were on their own. Student interviews varied in length but averaged approximately 25 minutes each. The student interviews were conducted during normal science

lessons, where the researcher had permission to withdraw groups of students from their class and interview them in a neighbouring classroom or a nearby outside facility located within the school grounds. All interviews were taped and transcribed by the researcher. The interview data are used to gain insight into participants' thoughts and feelings about the experience and to depict student perceptions of what was happening in science during the intervention period.

Results

The results are presented in three sections. The first section, presents a summary of the findings from the pre/post-intervention occasion SSSQ. The second section, reports the pre/post-intervention results from the Astronomy Diagnostic Test. The third section, presents a summary of the findings from the student interview data. It is important to note that descriptive statistics are not presented in this paper for each of the scales for brevity reasons. This information can be obtained by contacting the author.

Secondary School Science Questionnaire Results

This first section of results presents the findings for both the pre- and post-occasion SSSQ. An exploratory factor analysis was computed on the 42 items from the SSSQ, which generated seven reliable and valid scales that measure students' perceptions of the science they experience at school (Danaia, 2006). The first of these scales comprised seven items that related to the *perceived relevance of science*. The second scale was interpreted as *difficulty in science at school* and contained three items from the SSSQ. The third scale consisted of two items concerned with *teacher-directed experiments in science*. The fourth scale was interpreted as *computer use to find information in science* and comprised two items. The fifth scale contained four items that related to *thoughts about what students need to be able to do in science*. The sixth scale consisted of eight items concerned with *the teacher's role in science*. The final scale was interpreted as *outside experiences in science at school* and comprised two items.

To explore the differences between and within groups the data were analysed using an analysis of variance with repeated measures on the occasion of testing. Separate analyses were carried out for each year level. To reduce the likelihood of a Type I error given that 21 separate univariate analyses are conducted, a full Bonferroni correction is employed. That is to say, the generally accepted p-value of 0.05 is substituted by the more rigorous p-value of 0.002 (i.e., 0.05/21). Significant differences presented in the ANOVA tables below are indicated where * represents a p-value less than 0.002 and ** signifies a p-value less than 0.00048 (Danaia, 2006).

Table 1 summarises the overall trends observed in each of the year groups for the seven scales from the pre- to the post-intervention occasion of testing. Inspection of the table reveals that there are significant differences between the groups of students in relation to their perceptions of science at school on both occasions of testing where small through to large effect sizes are evident. Specifically, the Year 7 group of students displayed significant differences in their mean scores on six of the seven scales from the pre- to the post-intervention occasion of testing. For the Year 8 group of students significant differences were evident in their mean scores on five of the seven scales while the Year 9 group of students exhibited significant differences in their mean scores on four of the seven scales from the pre- to the post-intervention occasion of testing.

Table 1 Summary of results for the seven scales

Scale		Year 7	Year 8	Year 9
Relevance		** occasions ↓	* occasions ↓	ns occasions
	η^2	-0.16	-0.16	-0.05
Difficulty		ns occasions	ns occasions	ns occasions
	η^2	0.11	0.04	0.02
Teacher-Directed Experiments		** occasions ↓	** occasions ↓	** occasions ↓
	η^2	-0.40	-0.59	-0.53
Computer Use		** occasions ↑	** occasions ↑	** occasions ↑
	η^2	0.89	0.97	0.94
Thoughts		** occasions ↓	* occasions ↓	* occasions ↓
	η^2	-0.15	-0.20	-0.27
Teacher's Role		** occasions ↓	** occasions ↓	** occasions ↓
	η^2	-0.35	-0.43	-0.55
Outside Experiences		** occasions ↑	ns occasions	ns occasions
	η^2	0.38	-0.03	0.03

** indicates a highly significant difference.

* indicates a significant difference.

ns indicates that the difference is not significant.

↑ indicates an increase from the pre- to the post-intervention occasion of testing.

↓ indicates a decrease from the pre- to the post-intervention occasion of testing.

η^2 indicates effect size- Cohen's D (magnitudes: 0.15 = small effect, 0.45 medium effect, 0.75 large effect).

Inspection of the table reveals that there was a small effect for the Year 7 and 8 students in relation to the *perceived relevance of science* scale that can be attributed to the occasion of testing.

There was little change however, in the Year 9 students' scores for this scale from the pre- to the post-intervention occasion of testing. With respect to the *perceived difficulty in science* scale, there was little change in all year levels' mean scale score from the pre- to the post-intervention occasion of testing. That is to say, there is no significant difference in the perceived difficulty of the science students' experienced from the pre- to the post-intervention occasion of testing.

There was a highly significant reduction from the pre- to the post-intervention occasion in all year level's mean scores for the scale *teacher-directed experiments in science* where a moderate effect is observed for all year levels. That is, all year levels indicated that they experienced fewer teacher-directed experiments in science on the post-intervention occasion compared with the pre-intervention occasion of testing.

The analysis of the *computer use in science* scale revealed that all year levels experienced a highly significant increase in their mean scale scores from the pre- to the post-intervention occasion where a large effect is observed for each year level. All groups of students indicated that they used computers in science on a more regular basis on the post-intervention occasion than they had on the pre-intervention occasion of testing. In relation to the scale *thoughts about what students need to be able to do in science*, all year levels experienced a significant decline in their mean scores. The effect size due to the occasion of testing is small for each of the year groups.

For the scale concerned with the *teacher's role in science* all year levels experienced a highly significant reduction in their mean scale scores from the pre- to the post-intervention occasion. It seems that there was a significant difference in the level of support and guidance students received from teachers on the pre- compared with the post-intervention occasion of testing. A small to moderate effect size is observed for the Year 7 to 9 groups respectively. With respect to the *outside experiences in science* scale, the Year 7 group of students experienced a significant increase in their mean scale score from the pre- to the post-intervention occasion of testing where a small effect size

is evident. For Year 8 and Year 9 there was little variation in the mean scale scores displayed on the pre- and post-intervention occasions of testing.

Astronomy Diagnostic Test Results

Analysis of the pre-intervention ADT results revealed an appalling and depressing picture. Of the 25 items in the instrument, 14 can be considered knowledge outcomes of the curricula taught in primary school science and which is covered again in Year 7 science classes in most educational systems. The mean score for all students was four correct out of 14. Mostly, they knew what caused day and night and many could describe the orbit of the Moon and the Earth about the Sun. Very few knew what caused the phases of the Moon or the Seasons and many (97%) thought that the Sun was overhead every day at noon (none lived within the tropics). One conclusion that could be drawn from these results is that the astronomy students are taught in primary school has had little, if any, impact. On average, the students possessed seven alternative conceptions that related to day and night, the seasons, the Moon phases, and the orbits of the Earth and Moon. The number of alternative conceptions did marginally reduce as students moved through high school but even by Year 9, the mean number of alternative conceptions was 6.6. One has to conclude that even the secondary school astronomy education has little impact on students' alternative conceptions related to such phenomena as the phases of the Moon and the seasons.

The pre/post-intervention ADTs were analysed with respect to five dependent variables that included: knowledge of astronomy; alternative conceptions; non-responses; complexity of written responses; and, the quality of responses. Analysis of variance with repeated measures on the occasion of testing were used to directly compare the results for the five dependent variables from the pre- to the post-intervention occasion and explore the differences between and within groups. Two independent variables sex and occasion are used in the analyses to examine the differences between and within groups. The analysis was carried out separately for Year 7, 8 and 9 on each of the five dependent variables. Table 2 summarises the overall trends observed in each of the year groups for the five dependent variables measured on both occasions of testing.

Table 2 Summary of results for the five dependent variables being measured in the ADT.

		Knowledge of astronomy	Alternative conceptions	Non-responses	Complexity of written explanations	Quality of responses
Year 7		** occasions ↑	ns occasions ↓	** occasions ↓	** occasions ↑	** occasions ↑
	η^2	0.5	0.0	-0.2	0.3	0.4
Year 8		** occasions ↑	** occasions ↓	ns occasions ↓	ns occasions ↑	** occasions ↑
	η^2	0.5	-0.3	0.0	0.1	0.4
Year 9		** occasions ↑	** occasions ↓	** occasions ↑	** occasions ↓	ns occasions ↓
	η^2	0.5	-0.4	0.4	-0.4	-0.1

** indicates a highly significant difference **p < 0.00067.

* indicates a significant difference *p < 0.003.

ns indicates that the difference is not significant.

↑ indicates an increase from the pre- to the post-intervention occasion of testing.

↓ indicates a decrease from the pre- to the post-intervention occasion of testing.

η^2 indicates effect size- Cohen's D (Magnitudes- 0.15 = small effect, 0.45 medium effect, 0.75 large effect).

There were highly significant increases across all year levels with regard to students' knowledge of astronomy. A moderate effect size is observed for each of the year levels that can be attributed to the occasion of the testing. In addition, all year levels exhibited a reduction in the mean number of alternative conceptions evident from the pre- to the post-intervention occasion where small effect

sizes are evident. Some of the differences for the remaining three dependent variables, in relation to each year level, were in directions that were sought after while other changes were less desirable.

The analysis of students' non-responses revealed that the Year 7 group of students experienced a significant reduction in the number of non-responses evident on the post-intervention occasion compared with the pre-intervention occasion. The Year 8 group of students also experienced a reduction, although not significant, in the number of non-responses on the post-intervention occasion compared with the pre-intervention occasion of testing. In contrast, Year 9 students displayed a significant increase in the number of non-responses evident on the post-intervention occasion compared to the pre-intervention occasion. The effect size due to the occasion of testing is small for each of the year groups.

With respect to the level of complexity of students' written explanations, Year 7 as a whole significantly increased the complexity from the pre- to the post-intervention occasion where a small effect size is evident. There was also an increasing trend, though not significant, for Year 8 students from the pre- to the post-intervention occasion. In contrast, Year 9 students exhibited a significantly lower level of complexity in their written responses on the post-intervention occasion compared with the pre-intervention occasion of testing. The quality of students' responses increased significantly from the pre- to the post-intervention occasion of testing for students in Year 7 and Year 8. For the Year 9 group of students there was a decline, although not significant, in the quality of responses offered by students on the post-intervention compared with the pre-intervention occasions of testing.

Overall, the results of these analyses indicate that there are statistically significant differences between the groups of students in terms of their level of astronomical knowledge, their alternative scientific conceptions related to astronomy, the number of non-responses evident, the level of complexity of their written explanations and the quality of their responses. The Year 7 and Year 8 group of students display similar trends from the pre- to the post-intervention occasion of testing in relation to the five dependent variables being measured. Specifically, students' level of astronomical knowledge, the complexity of students' written explanations and the quality of student responses increases from the pre- to the post-intervention occasion while there is a reduction in the number of alternative conceptions and non-responses from the pre- to the post-intervention occasion. Similarly, the Year 9 students exhibit an increase in their mean level of astronomical knowledge and a reduction in the number of alternative conceptions evident from the pre- to the post-intervention occasion. The overall trend for the Year 9 groups of students however, is different. For the three remaining dependent variables, the Year 9 group of students displayed differing trends to those observed for the Year 7 and Year 8 group of students.

Interviews

This section is concerned with the qualitative data collected from interviews conducted with a sample of students drawn from six schools. The data revealed that there were both similarities and differences across the schools in relation to the learning experiences, in particular, the way in which the program was implemented, the planning for and proceedings of observation evenings, the classroom surroundings and access to facilities and equipment.

There were different levels of teacher negotiation with students and variations in how the program was implemented across the schools. Country High School appeared to be at one end of the continuum in relation to the teacher-directed nature of how the program was implemented. It seemed that the teacher at this school governed the teaching and learning experiences where he conducted lessons in a very prescriptive way, captured images of the celestial objects using the remote telescope that students had planned to image and assumed responsibility for constructing the equipment students would need for their investigations in class. The only time that the teacher

seemed to relinquish some control and give students a choice in what they were doing was in deciding the objects that they would like to image using the remote telescope. This teacher-directed approach toward implementing the program left students disappointed and wanting more autonomy during science lessons.

Students from Metro, City and Town High School had different reactions toward their experiences in science. It seemed that they were involved in constructing the devices and carrying out the practical activities themselves with guidance from their teachers at varying levels. This seemed to give them ownership and a sense of control over their learning which was evident in their comments when they referred to themselves as making things and doing the activities. Further evidence of this was apparent when students from Metro and Town High School proudly showed the researcher some of the work that they had been involved in during the program and that included research projects, scale models and some of the devices that they had made.

Some of the students from Beachside High commented on how their experiences in science were “different” during the practical astronomy program compared with what they typically experienced in science. It seemed that students were not required to sit and take notes for the majority of science lessons. Instead, they appeared to be engaged in using computers nearly every lesson and were provided with the opportunity to be involved in more practical experiences. It was evident from the comments made by students that experiencing science in this “different” way resulted in them being interested and excited about what they were doing and science lessons were no longer boring.

There were common problems encountered with accessing computer facilities at each of the schools. The approaches adopted, however, in dealing with such problems varied across schools. It seemed that computer laboratories had to service the entire school, which made problems with timetabling inevitable. In addition, there were obstacles to contend with when classes actually received access to the computer facilities such as slow internet access, problems with the network and limited time in the computer laboratory. Country High School seemed to adopt the most feasible and effective approach in dealing with such problems where the science teacher worked in conjunction with the computing teacher to implement the activities. This approach overcame many of the access problems that appeared to be ongoing for certain schools. Perhaps schools such as Town High School who seemed to experience ongoing computer access problems could do something similar to what happened at Country High School.

Using the Charles Sturt University Remote Telescope to take images of their very own appeared to generate great excitement amongst the majority of students who were interviewed. It was evident that when students were themselves given the opportunity to control the telescope to capture the images it did motivate and enthuse them. Students at Country High School illustrated the reverse situation where they watched their teacher control the telescope to take what was meant to be their photographs. This quashed the excitement that they had had about using the remote telescope and was damaging in the sense that students could see little value in the whole experience.

It seemed that students’ enthusiasm or lack of it in science was a consequence of their experiences during lessons. In settings such as Country High School where they were exposed to more practical work and were copying fewer notes in science lessons, they still conveyed their disappointment as the lessons seemed to revolve around their teacher doing things. Students wanted the opportunity to try things out for themselves. Conversely, when students had the freedom to explore and conduct activities themselves they appeared to thrive on the opportunity.

Overall, the interview data revealed that to a certain extent the situation was different for every class even though they had access to the same set of learning materials, the remote telescope and teachers had been exposed to the same level of professional development. The difference in part

was due to the varying degrees of how the program was implemented and the experiences of students and teachers during the program.

Discussion

The findings presented in this paper indicate that an intervention based on astronomy that involves using a remotely controlled telescope over the Internet and which employs five aspects of the *ideal* picture of science education (Goodrum et al. 2000) can have a significant impact on students' perceptions of science and their knowledge outcomes. In addition, it can influence the pedagogies adopted in implementing science curricula.

Overall, the pre- and post-intervention analysis of students' scale scores revealed that there were significant differences in relation to their perceptions of science at school after their involvement with the Practical Astronomy Program that incorporated five aspects of the *ideal* picture of teaching and learning in science. The most notable difference related to students' perceptions concerning the use of computers in science classes. Specifically, there was a highly significant increase in the incidence of using computers and accessing the Internet compared with their previous experiences for all year levels. This is not surprising given the content of the Practical Astronomy learning materials that required the extensive use of computers. Many of the activities within the Practical Astronomy resources integrate the use of technology. Students were also required to use computers to control the telescope and to process the images they had captured.

The results of the pre-intervention Astronomy Diagnostic Test revealed that student participants displayed extremely low levels of astronomical knowledge on such things as day and night, phases of the Moon, the seasons. That is to say, what they were supposed to have learnt in primary, or in the first year of junior secondary, school did not happen. One could hypothesise that students were not exposed to such content in primary school or in the first year of high school, or that perhaps the way in which the content was covered had failed to engage students. In addition, a number of alternative astronomical scientific conceptions were identified, which suggests that students had not previously been exposed to activities in science that had challenged their personal mental models and resulted in them reconstructing their notions to the scientifically accepted beliefs.

Analysis of the Astronomy Diagnostic Test data revealed that all year levels experienced a highly significant increase in their knowledge of astronomical phenomena from the pre- to the post-intervention occasion. This was probably an outcome of their involvement in the Practical Astronomy Program. Students displayed significantly fewer alternative conceptions on the post-intervention occasion of testing compared with the pre-intervention. This was probably also related to their interaction with the teaching and learning experiences. It also implies that for a large proportion of students their learning experiences during the intervention period were successful at challenging their alternative conceptions.

The interview data suggest that even though all participants had access to the same set of Practical Astronomy learning materials, there still seemed to be unique features happening within classes. It seems that teaching and learning experiences in science during the intervention period, to a certain extent, were different for each of the classes involved. This was most probably a consequence of a combination of factors such as the varying degrees of how the program was implemented and the experiences of students during the program. Perhaps if additional focus had been placed on supporting teachers in employing and maintaining appropriate pedagogies that foster student-centred learning, the impacts on students might have been more substantial when compared with the outcomes of how science is actually being taught.

It seems that the way in which science is implemented is crucial to the success of teaching and learning experiences in science education. It was evident from the interview data that students

sought more practical work and wanted more control over their learning in science at school. The promotion of student-centred approaches appears to be vital if students are to have meaningful and relevant experiences in science lessons. Furthermore, science teachers need additional support to employ pedagogies that foster student-centred approaches toward learning in science lessons. Teachers cannot just change the forms of instruction that they have been accustomed to using and simply move on to implement student-centred approaches in science in effective ways. The Practical Astronomy Program seemed to empower some of the teachers involved to employ pedagogies that fostered student-centred approaches. It is important to recognise, however, that change takes time and to sustain such practice, ongoing support for teachers is necessary. The adoption of curricula that incorporate aspects of the *ideal* picture of science education in conjunction with appropriate teaching practices are necessary if positive dispositions and knowledge outcomes are to be engendered.

Additional research needs to be conducted on the impact of the Practical Astronomy Program on the perceptions and knowledge outcomes of pupils in junior secondary school science where specific attention is devoted to the pedagogies employed by teachers to implement such curricula. Careful consideration needs to be given to how data are collected on the pedagogies that teachers adopt in implementing such curricula and the way in which the instructional approaches are monitored. In addition, teachers will require support in sustaining approaches that foster student-centred models of instruction and which are consistent with the *ideal* picture of teaching and learning in science. This research will allow relationships between the content covered and the methods of instructions employed to be examined to determine how effective certain approaches are in relation to student outcomes.

References

- American Association for the Advancement of Science [AAAS]. (1990). *Science for all Americans: Project 2061*. New York: Oxford University Press.
- Ausubel, D.P. (1968). *Educational Psychology: A cognitive view*. New York: Holt Rinehart and Winston.
- Bordens, K.S., & Abbott, B.B. (2005). *Research and design methods: A process approach* (6th ed.). Boston: McGraw-Hill.
- Cleaves, A. (2005). The formation of science choices in secondary school. *International Journal of Science Education*, 27(4), 471-486.
- Collaboration for Astronomy Education Research (CAER) (1999). *Astronomy Diagnostic Test*. <http://solar.physics.montana.edu/aae/adt/> modified for Southern Hemisphere 2002 by the University of Sydney, further modified 2004 by Charles Sturt University.
- Committee for the Review of Teaching and Teacher Education [CRTTE]. (2003). *Australia's Teachers: Australia's Future Advancing Innovation, Science, Technology and Mathematics Agenda for Action*. Canberra, Australia: Department of Education, Science and Training.
- Cook, T.D., & Campbell, D.T. (1979). *Quasi-experimentation: Design analysis issues for field settings*. Boston: Houghton Mifflin Company.
- Creswell, J.W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, Calif: SAGE Publications.
- Danaia, L.J. (2006). *Students' experiences, perceptions and performance in junior secondary school science: An intervention involving astronomy and a remote telescope*. Unpublished PhD Thesis, Charles Sturt University, Bathurst, New South Wales, Australia.
- Dekkers, J., & De Laeter, J. (2001). Enrolment trends in school science education in Australia. *International Journal of Science Education*, 23(5), 487-500.
- Deming, G. L. (2002). Results from the Astronomy Diagnostic Test National Project. *Astronomy Education Review*, 1(1), 52-57.
- Drury, C., & Allen, A. (2002). Task force on the physical sciences: Report and recommendations. Department of Education and Science, Ireland. Retrieved Sept. 2005 from <http://www.sciencetaskforce.ie/>.
- Dunlop, J. (2000). How children observe the universe. *Publications of the Astronomical Society of Australia* 17, 194-206. http://www.atnf.csiro.au/pasa/17_2/dunlop/
- Goodrum, D., Hackling, M., & Rennie, L. (2000). *The Status and Quality of Teaching and Learning of Science in Australian Schools*. Research Report for the Department of Education, Training and Youth Affairs. http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/status_and_quality_of_science_schools.htm

- Hackling, M., Goodrum, D., & Rennie, L. (2001). The state of science in Australian secondary schools. *Australian Science Teachers' Journal*, 47(4), 12-17.
- Hassan, G., & Treagust, D. (2003). What is the future of science education in Australia? *Australian Science Teachers' Journal*, 49(3), 6-15.
- Hufnagel, B., Slater, T., Deming, G., Adams, J., Lindell Adrian, R., Brick, C., & Zeilik, M. (2000). Pre-course Results from the Astronomy Diagnostic Test. *Publications of the Astronomical Society of Australia*, 17(2), 152.
- International Bureau for Education. (2001). *Science education for contemporary society: Problems, issues and dilemmas*. Geneva: International Bureau for Education, UNESCO.
- Johnson, B., & Christensen, L. (2004). *Educational research: quantitative, qualitative, and mixed approaches* (2nd ed.). Boston: Allyn and Bacon.
- Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education*, 28(6), 591-613.
- McKinnon, D.H. (2005). *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 (DEST), Canberra.
- Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future* (The report of a seminar series funded by the Nuffield Foundation). London: King's College London, School of Education.
- Osborne, J., & Collins, S. (2000). *Pupils' and parents' views of the school science curriculum*. London: King's College London.
- Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton Mifflin.
- Speering, W., & Rennie, L. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education*, 26, 283-298.
- Stead, B.F., & Osborne, R.J. (1980). Exploring students' concepts of light. *Australian Science Teachers' Journal*, 26(3)84-90.
- Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social and behavioural research*. Thousand Oaks, CA: SAGE.