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Space to Grow: LCOGT.net and Improving Science Engagement in Schools

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Abstract

Space to Grow is an Australian Research Council Grant that engages high school students in real science and supports their teachers in implementing inquiry-based approaches using astronomy as the focus. Currently, Grade 9–12 students and their science teachers from three educational jurisdictions in one Australian state are acquiring, and making scientific use of, observational data from the 2-m Faulkes Telescopes owned by Las Cumbres Observatory Global Telescope Network. Data are being collected to investigate the impact of the project on students and teachers. Some investigations have led students to work with astronomers to publish their results in the astronomical literature.

1. INTRODUCTION

In many western countries, secondary school science education continues to suffer from a number of problems. These include a lack of student interest in science ([Barmby, Kind, and Jones 2008](#), [Osborne and Collins 2000](#); [Sjøberg and Schreiner 2010](#)) and a declining proportion of the student cohort pursuing science in the postcompulsory years of schooling, particularly in the physical and Earth sciences ([Ainley, Kos, and Nicholas 2008](#), [Osborne and Dillon 2008](#)). In addition, there is variability in teacher competence where a number of teachers are teaching outside their area of expertise and have limited, if any, effective professional learning opportunities ([Darling-Hammond *et al.* 2009](#), [Harris, Jenz, and Baldwin 2005](#)). More often than not, the transmissive, traditional way in which the science content is covered stands in contrast to the collaborative, inquiry-based practices of real scientists ([OECD 2006](#), [Osborne and Dillon 2008](#)). Moreover, this content is disconnected from real science. There have been many calls from Governments and relevant stakeholders to transform school science to make it more engaging for students ([AAAS 1989](#), [Bybee and Fuchs 2006](#), [Millar and Osborne 1998](#)). Recommendations have focused on making the curriculum more student centered by employing inquiry-based pedagogies and supporting teachers in implementing these approaches through ongoing professional development ([Bybee and DeBoer 1994](#), [European Commission 2007](#), [National Research Council 1996](#), [Osborne and Dillon 2008](#)). It would seem, however, that even though there have been calls for reform over the past two decades, there is little evidence to suggest that any real wide-scale, sustainable change has happened.

The situation in Australia is no different. Science education in Australia has been described as being in “a state of crisis” ([Tytler 2007](#), p. 1). The seminal reports on the Status and Quality of Teaching and Learning of Science

in Australian Schools (Goodrum, Druhan, and Abbs 2011, Goodrum, Hackling, and Rennie 2001) concluded that science teaching in Australia's elementary and secondary schools was far from ideal. In secondary school science, a major concern identified related to the prescriptive way in which science is taught involving information transfer and memorization of facts from textbooks, notes, or the chalkboard. Transmissive, teacher-dominated approaches toward teaching and learning appear to be commonplace in many science classrooms (Stockmayer, Rennie, and Gilbert 2010). Employing open-ended tasks, building teacher confidence and supporting them through professional development have been identified as key elements in reimagining school science (Tytler 2007 and Tytler *et al.* 2008).

What has been lacking in the literature previously associated with telescope use in the classroom is information on what is required to make "scientific use" of these instruments using inquiry approaches for the benefit of students and teachers (Slater, Slater, and Olsen 2009). Often, what happens when teachers and students use or request data from optical telescopes to acquire images is that they obtain the image(s) or "pretty pictures" of the object(s) and little, if anything, is done in their science lessons with the scientific information contained within the image(s) (Rosing 2010). One of the main aims of the Space to Grow project is to explore and identify ways in which students and teachers could make scientific use of the images obtained from research-grade telescopes and to investigate the impact of the approaches adopted on both students and teachers.

The purpose of this paper is to describe briefly the Space to Grow project, the curriculum materials used in the project, professional learning program instigated, and the educational research undertaken that underpins the project. The methodology to investigate the impact of the project on students' perceptions of school science, their knowledge outcomes, and teachers' professional learning will be described. The results section presents some preliminary findings from the project, while the final section outlines its future goals and directions.

2. OVERVIEW OF THE SPACE TO GROW PROJECT

The Space to Grow project is a 3 year funded Australian Research Council Linkage Grant administered by astronomers at Macquarie University and supported by curriculum experts and educational researchers at Charles Sturt University. It also is backed by four partner organizations that each contribute to the project in a variety of ways. Specifically, Las Cumbres Observatory Global Telescope Network (LCOGT.net) provides students and their science teachers with observing time on the two robotically controlled 2.0 m Faulkes telescopes so that they can acquire scientific data, which they use to undertake real scientific investigations in their school science lessons. Three educational partner organizations are responsible for the 37 participating schools within one Australian state: New South Wales. These educational partners also are concerned with the declining numbers of students pursuing science in the postcompulsory years of school. They are interested in developing professional learning approaches for science teachers that focus on supporting them to implement inquiry-based approaches and to move away from the transmissive approaches typically employed to deliver school science. The partners provide access to students in Grades 9–12 and their science/physics teachers, and fund their professional learning sessions.

The largest of the educational jurisdictions contains 22 metropolitan high schools. The other two jurisdictions are classified as regional with ten and five participating high schools located in the western region of the state. The largest and smallest jurisdictions contain a mixture of co-educational and single-sex schools, while the middle-sized one contains entirely co-educational schools. The 37 schools will eventually provide access of up to approximately 9000 students in the four grades and approximately 200 science teachers. We say "up to" because participation in the project is at the discretion of the Principal of each school, the Head Teacher of Science, and the individual science teachers. Thus far, 19 schools have provided teachers who have elected to participate. Many of the remaining schools are planning to implement in 2012.

The project is focused on the science curriculum of Grade 9–12 and more specifically the physics and astronomy content. Toward the end of Grade 10, in Australian schools, students elect to take their subjects for the final two years of high school. The originators of the project hoped to influence students' science subject choice for Grades 11 and 12, in particular Physics, which has significant astronomy components in both grades.

One of the key features of this project is to develop and implement a professional learning program for teachers that builds their confidence and competence in implementing investigative science. The approach requires them to acquire and use real scientific data and to process it with various computer applications and associated

technologies. Teachers are provided with a set of curriculum materials that have been designed to support them in implementing inquiry-based science. The project also comprises an educational research program that will investigate the impact of the approaches on both students and teachers. These project components are described more explicitly in the relevant sections below.

2.1. Components of the Space to Grow Research Project

Key to the Space to Grow project is the curriculum materials and the professional learning program for teachers. A carefully staged approach to both has been adopted by the research team.

2.1.1. Teaching and Learning Materials

The teaching and learning materials have been designed by two of the authors [Michael Fitzgerald (MF) and David McKinnon (DM)] to support teachers in implementing inquiry-based science that makes scientific use of the observational data obtained from the telescopes, and which also meet the various learning outcomes of the State's science and physics curricula. To date, three projects have been developed using an educational design described below and which have been informed by extensive feedback provided by participating teachers.

The educational design that underpins these materials employs backward-faded scaffolding (Slater, Slater, and Lyons 2010), draws on the 5Es learning cycle (Bybee 1997) as a framework within and across projects, and provides opportunities for students to engage in the four types of inquiry-based learning: confirmatory, structured, guided, and open-ended. Thus, teacher direction and support for students are provided initially at depth, but as students develop the necessary analytical and scientific skills and become more autonomous, the teacher's support is faded backwards and their role changes to that of facilitator.

It is important to note that the development of the materials described below is an ongoing iterative process involving two of the project team (DM and MF) writing the materials and trialing them with small groups of teachers. The teachers provide in-depth feedback and insights both before and after they run these materials with their classes. The feedback and suggestions are incorporated into the next iteration before more widely distributing the project materials.

To date, the materials developed comprise three projects that contain a number of learning experiences and include teaching and learning resources such as PowerPoint presentations and student worksheet guides. In addition, a set of movies, involving famous public astronomers such as Professors Fred Watson and David Malin, have been created that are used in conjunction with the materials to introduce and engage students and teachers in the topics under investigation. The materials contain various exit points to cater for the different ability levels and interests of students and teachers within a school setting. That is to say, the projects are designed in such a way that they could span four lessons for a simple introduction to astronomy, 10–12 lessons for a conceptual and mathematical introduction to stellar properties and evolution, or they could involve an entire school semester's worth of work. There is also information for teachers on how they could implement the materials within their class where they are provided with opportunities for students to work both independently and collaboratively.

The first project entitled *Discovering Telescopes and Deep Sky Objects: Introduction to the Faulkes Telescopes and LCOGT.net* provides students and teachers with an overview of the Space to Grow Project and how telescopes work. Students and teachers have the opportunity to obtain some images from the Faulkes telescopes and, in the process, they begin to understand how robotic telescopes work and become familiar with a number of different classes of deep sky objects. They will then use these images in the second project: *Understanding the universe through color: Astronomical imaging with LCOGT.net*. Before they do, students and teachers gain an understanding of how astronomers create color images of celestial objects using a set of black and white images taken through different colored filters. They acquire the skills of creating color images from a library supplied with the project using two software packages, MAKALI'I and GIMP. Students and teachers are thus prepared for the arrival of "their" images. This is designed to be a motivating activity as they understand that they actually *own* the images. Figure 1 displays three images that were created by students undertaking these projects.

The third project, *Uncovering the Nature and Lives of Stars: Star Cluster Photometry with LCOGT.net*, spans a series of classes that involve students and teachers analysing a set of images of an open cluster of stars. They first understand the correlation between color and the shape of a cluster's color-magnitude diagram before they



Figure 1. Example of images that students selected to image in Project 1 and created color versions of in Project 2. (From left: M20, M3, part of the Veil Nebula).

generate their own color-magnitude diagram of one of two well known clusters: a minimally reddened cluster NGC2420 and, a heavily reddened cluster, NGC654 (confirmatory inquiry). They calculate the distance and age of the chosen cluster, and, in the process, they need to understand various concepts such as the inverse square law and stellar parallax (structured inquiry). If NGC654 is the cluster of choice, students also will have to conceptually learn about, and understand how to correct for, reddening and extinction (guided inquiry). More advanced components of this project involve the use of isochrones to determine more accurately the age and distance, and an aperture photometry method to calculate the size, of the cluster. Figure 2 shows a color image of the cluster NGC654 (left) and displays an example of a color magnitude diagram (center) that was created by a group of students who measured a representative sample of 60 stars. These data illustrate the fundamental components of this project. The color-magnitude diagram included at far right compares the student data with the latest published data for this cluster. Students' estimates for distance, reddening, and age are within the estimated error of the published values.

The backward-faded scaffolding coupled with the 5Es learning cycles embedded within the design of the materials equips students and teachers with the necessary knowledge and skills to pursue real open-ended inquiry. They can then proceed to acquire images of unstudied or poorly studied clusters, and if they are interested, have the opportunity to work with professional astronomers on existing projects or to initiate their own research proposal and submit requests to obtain data from the Faulkes telescopes. To date, four groups of students have chosen to proceed to this level of open-ended inquiry.

Within the projects, two supplementary documents guide students and teachers through how to request images from the telescopes. In collaboration with astronomers, a list of potential targets is provided from which classes and/or students choose objects to investigate. In working through these documents, they develop the necessary skills and knowledge needed to submit an image proposal request. This involves them doing research on the objects, determining whether their object(s) will be visible during the night and from which hemisphere, and lastly identifying the essential information needed in order to request scientific images (i.e., types of filters to be used, exposure times, number of images needed, and time intervals between images). They then complete an image proposal request that presents both their argument for why their object(s) should be photographed and the

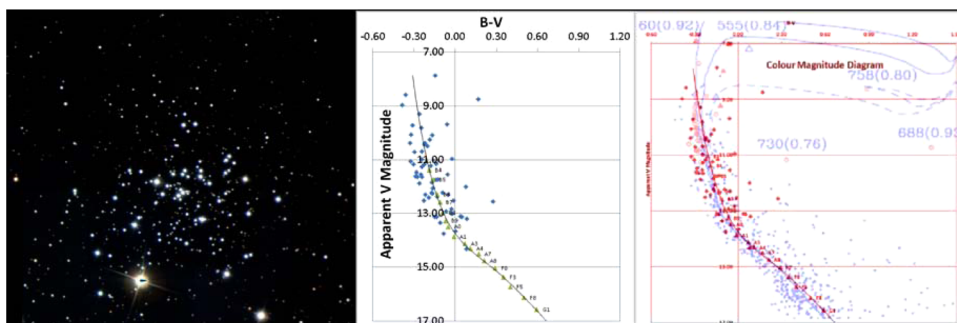


Figure 2. (Left) Image of NGC654 constructed from project data, (middle) Dereddened data and ZAMS visual fit from a sample of 60 Stars from the cluster measured by students, and (right) Student data overlaid (RED) on data from latest NGC654 photometric CMD study from [Pandey et al. \(2005\)](#).

essential information. This image proposal is emailed to Space to Grow personnel who check the information and enter it into the LCOGT.net web interface. Observations are then automatically scheduled and robotically taken. Some preprocessing takes place automatically at the observatory (e.g., flat field, dark, and bias frame correction) before being sent to Space to Grow personnel. The images are then preprocessed and made available to students and teachers to allow them to commence their data analyses. Typically, from the time that the observations are taken, the preprocessing takes only 1 day. Weather at the observatory, however, is the major determinant of turnaround time.

2.1.2. Professional Learning for Teachers

Teacher professional learning is central to the Space to Grow project. A unique aspect of our research into professional learning is that a number of approaches are being concurrently trialed. These are totally dependent on the needs and requirements of both the teachers and the educational partners involved. In all cases, however, they are being examined in terms of their scalability and effectiveness to inform future models of teacher professional learning.

The first approach to teacher professional learning is covered within the materials used in the project and which were outlined briefly above. The materials are constructed in such a way that everything a teacher *needs to know* in order to implement the activities using the inquiry-based approaches is contained within the documentation and supported by resources. For example, the materials provide teachers with a “running commentary” on how to implement the inquiry-based activities, e.g., suggestions for grouping and using cooperative learning strategies are explicitly unpacked. The background information needed in order to teach the scientific content is provided together with curriculum links and instructions on how to use the software needed for various activities. Short movies on how to manipulate and understand the software and spreadsheets as well as interpret the output are provided to help the teachers and students in the context of what they are doing at the time. The activities are structured in such a way that they lead the teachers through the four levels of inquiry-based learning identified above.

A second approach to teacher professional learning involves groups of teachers from the same jurisdiction meeting with the Space to Grow team in a small number of intensive face-to-face day-long sessions. To date, we have employed three- to five-day-long sessions, but it is important to note that this number is flexible and is based on the needs of the teachers involved. This intensive, face-to-face approach allows them to “trial” the materials and to become confident and competent at using the technologies involved. In the process, they become familiar with the scientific content and how to use inquiry-based approaches to cover the content. The sessions are designed to model how teachers should implement the activities within their science classes. One of the key features of this model is that it requires teachers to assume two roles: that of teacher and that of student. That is to say, teachers are not only learning how to “implement” or “teach” the materials in their classrooms, they also are acquiring the scientific content knowledge and engaging with the materials from the perspective of a student. Teachers are released from their regular classes to undertake this form of professional learning. Figure 3 displays two photographs. The first was taken during one of the intensive teacher professional learning sessions and the second is at a school location where students are working through project two that involves them creating color images. The students are deeply engaged in what they are doing.



Figure 3. (Left) A group of teachers collaboratively working together during one of the intensive professional learning days, (right) groups/pairs of students working through Project 2.

During the initial sessions, teachers are immersed in the materials and technologies and exposed to the inquiry-based teaching strategies required to implement each of the activities. In between face-to-face sessions, “homework” is set for the teachers that requires them to complete activities from the materials. This involves them working collaboratively and remotely, using communications technology, and employing cooperative learning strategies such as Jigsaw, Jigsaw II, and role cards (Aronson *et al.* 1978, Prince George’s County Public Schools 2012, Slavin 1986). These initial sessions and the homework feed into the next face-to-face session where teachers work in pairs to teach the first three projects to students whom they do not know. This experience gives teachers the opportunity to “trial” the materials in a “supportive” way before trying them out in their own school with their own science classes. A final face-to-face session is conducted after all teachers have implemented the materials within their school science classes. It is designed to allow them to reflect on the process and provide feedback that will inform future implementation. These teachers then become facilitators for the other teachers within their science departments who intend to implement the projects. A variant of this latter approach involves teachers in remote schools interacting with project personnel and each other using various communications technologies and video conferencing.

2.1.3. Educational Research

The educational research component is designed to investigate the impact of the project on students and teachers. In particular, students’ perceptions of science, their knowledge outcomes, and their intentions to pursue science beyond the postcompulsory years of school are examined both before and after their involvement in the project. In addition, teachers’ perceptions of the science they teach at school and the pedagogies they employ are explored both before and during their involvement with the Space to Grow project. Where possible, pre/postdata are collected from students and teachers who are located within participating schools but who have not been exposed to the materials used in Space to Grow in their science lessons. These classes cover the required astronomy content in the “normal” way, i.e., the way it has been taught in the previous years.

A subset of the research, involving teacher participants, is part of a PhD study that is concerned with teacher professional learning and the impact of the project and approaches adopted on teachers’ pedagogical practice. This study involves collecting additional data from teachers and is complemented by in-depth interviews to elicit the impact of the approaches in relation to their science teaching self-efficacy and practice. Results from this subset of the research will be reported in subsequent papers.

A multiple-baseline, multiple-probe, concurrent nested mixed-method approach employing a nonequivalent dependent variables design is employed to investigate the impact of the materials and pedagogical approaches on students and teachers. The data collection procedures for this research involve the collection of questionnaire, interview, observational, and work sample data. The data are collected on multiple occasions from different cohorts, groups and classes of students, and their teachers of Science and Physics.

A modified version of the Secondary School Science Questionnaire (SSSQ) (Goodrum *et al.* 2001), is employed to gather information on students’ perceptions of school science. The preoccasion instrument asks them to reflect on their prior experiences in science, while the postoccasion questionnaire asks them to reflect on their experiences during their involvement in the project. Additional questions have been added to both that ask students to indicate their intentions post-Grade 12 in relation to areas of future study and potential career paths. A teacher version of the SSSQ that corresponds with the student version is used to collect data on teachers’ perceptions of the science they teach at school both before and during their involvement in the project.

An Astronomy Knowledge Questionnaire (AKQ) is also administered to students to collect information on their knowledge of certain astronomical phenomena. It contains 19 multiple-choice items that are mapped to various astronomical concepts, which are meant to be covered in the Science/Physics curriculum in the latter years of elementary school through to Grade 12. The multiple-choice distractors are common alternative conceptions related to each of the concepts. The items in the AKQ comprise two reliable subscales one of which is designed *not be affected* by the intervention (nonequivalent variable; Cronbach’s $\alpha = 0.784$). The second scale is *designed* to be influenced by the intervention (equivalent variable; Cronbach’s $\alpha = 0.854$). The items in the AKQ have been drawn from the Astronomy Diagnostic Test [Collaboration for Astronomy Education Research (CAER) 1999] and the Star Properties Concept Inventory (Bailey 2007).

Teachers and students complete the questionnaires either online or using paper and pencil. This latter option is provided for those schools that have problems in accessing computers connected to the Internet. We have found

that there are often issues associated with the speed of school networks and the stability of their Internet connections.

Interviews are conducted with a sample of participants to explore further their perceptions of science and to elicit student and teacher accounts of what happened in their science class during their involvement in the Space to Grow Project. Data are collected by observing a sample of teachers implementing various components of the materials within their science class. In addition, student work-samples, which may include students' color images, color-magnitude diagrams, and individual/collaborative research projects pursued, are also collected from classes.

3. PRELIMINARY FINDINGS

For the purpose of this paper, only some of the preliminary results of this project are reported to give the reader a flavor of the richness of the data. Subsection 3.1 presents analyses of a subset of the AKQ preoccasion data that focuses on content that can be directly mapped to the curriculum outcomes of the New South Wales elementary science curriculum (Grades 3–6) and which are again covered in the first two years of high school (Grades 7 and 8). Subsection 3.2 reports the pre/post-AKQ analyses for the first wave of participants involved in the Space to Grow project. Subsection 3.3 describes student scientific outputs as a consequence of their involvement of the Space to Grow project. Subsection 3.3.1 of results reports teacher feedback in relation to the professional learning approaches and project materials.

3.1. Preoccasion AKQ Results

For illustrative purposes, this section presents the results of the first four of the nonequivalent dependent variables that are designed *not to be influenced* by project materials. They are chosen because they can be directly mapped to the elementary and junior high school science curricula. That is to say, students *should know* the answers to these questions. The remaining four items of this scale are not included in this analysis because they relate to aspects of Physics not dealt with in the earlier years of high school and not covered by this project. The scale has an internal reliability of 0.854.

The participants in this sample comprise all of the students who have supplied preoccasion questionnaires since the project began collecting data. The bulk of participants come from Grade 10, while many fewer come from Grades 11 and 12 due to the external-examination-driven-nature of the curriculum in this state. The following data should, therefore, be treated with some caution for these senior years of high school.

Table 1 displays a breakdown of students' preoccasion responses in Grades 9–12 to four of the eight items that comprise the nonequivalent dependent variable scale. The items used in these analyses cover the causes of day and night, the phases of the Moon, the seasons, and the apparent movement of the Sun across the sky.

The first item relates to the causes of day and night. Of the 1374 students who provided responses, 51.3% and 50.5% of Grade 9 and 10 students, respectively, offered a correct response. For Grades 11 and 12, the figures were 74.4% and 73.3%, respectively. For Grades 9–12, respectively, 45.7%, 43.7%, 24.8%, and 26.7% of students possessed an alternative conception where the most common one encountered for day and night was that it is the Earth's movement about the Sun that causes day and night.

The second item relates to the phases of the Moon. Of the 1369 students who provided responses, 38.5% and 34.8% of Grades 9 and 10 students, respectively, chose the correct response. For Grades 11 and 12, the figures were 63.6% and 63.3%, respectively. For Grades 9 and 10, the bulk of the responses for this item (55.1% and 61.7%) were classified as alternative conceptions where the most common alternative conception identified was that the shadow of the Earth falling on different parts of the Moon causes the phases of the Moon. Students in the more senior years of high school (Grades 11 and 12) were more likely to offer a correct response for this item, but a significant number still possess alternative conceptions (32.2% and 26.7%).

Less than one third of students in Grades 9–11 (N = 1345) were able to offer a correct explanation for the third item on the causes of the seasons (30.6%, 30.4%, and 34.7%), while half of the students from Grade 12 (N = 30)

Table 1. Students' responses to four items from the pre-AKQ that can be mapped to junior secondary science content.

Item	Grade	Total N	Correct responses		Alternative conceptions		I do not know	
			N	%	N	%	N	%
Causes of day and night	9	265	136	51.3	121	45.7	8	3.0
	10	958	484	50.5	430	43.7	44	4.6
	11	121	90	74.4	30	24.8	1	0.8
	12	30	22	73.3	8	26.7	0	0
Phases of Moon	9	264	102	38.5	146	55.1	16	6.0
	10	959	334	34.8	592	61.7	33	3.4
	11	118	77	63.6	39	32.2	2	2.0
	12	28	19	63.3	8	26.7	1	1.0
Causes of Seasons	9	265	81	30.6	167	63.0	17	6.4
	10	959	292	30.4	565	58.9	102	10.6
	11	121	42	34.7	74	61.2	5	4.1
	12	30	15	50.0	14	46.7	1	3.3
Movement of Sun across sky	9	262	49	18.7	177	67.6	36	13.7
	10	915	133	14.5	605	66.1	177	19.3
	11	118	14	11.9	93	78.8	11	9.3
	12	30	4	13.3	21	70.0	5	16.7

provided a correct response (50.0%). The most common alternative conception identified was that the Earth's varying distance from the Sun causes the seasons.

Even fewer students selected the correct option for the fourth item on the apparent movement of the Sun across the sky (18.7%, 14.5%, 11.9%, and 13.3% Grades 9–12, respectively). It is interesting to note that more than 65% of the responses from all grade levels could be categorized as alternative conceptions, viz., that the Sun always rises directly in the East and sets directly in the West.

The majority of students opted to select an answer to these items and very few chose the "I do not know the answer to this question" option. One might conclude that they "think" they "know" the correct answer and have previously covered these concepts in science. The low proportion of students who chose the "I do not know" option may also be able to be attributed to the exam-driven nature of the education system where teachers encourage students to attempt to provide an answer even although they "do not know."

The fact that there are a high number of student responses that contain alternative conceptions, however, might suggest that previous science lessons covering this astronomy content have not resulted in students successfully learning or understanding the concepts. Rather, students appear to retain their alternative conceptions or possess hybrid conceptions about these fundamental phenomena. These data are consistent with data published by [Danaia and McKinnon \(2007\)](#).

3.2. Student Pre/Post AKQ

The sample of students that these results relate to is comprised of the first wave of participants all of whom have been involved in the Space to Grow learning experiences described above. Thus, there is no "control group." Instead, a pretest/post-test longitudinal design is employed to analyze students' responses. There is a major limitation of the current data set related to the time of year when the materials were implemented by teachers. That is to say, teachers decided to leave implementation until after final examinations had been completed and students were anticipating the onset of their summer vacation. In part, this decision may be attributed to some teachers not feeling completely comfortable with the scientific content, while others used the materials to "entertain" students (i.e., keep them occupied) until the end of the school year at a time when there was no threat to student performance. Thus, while a relatively large sample of students supplied preoccasion data (N = 612), a much smaller group provided postoccasion data (N = 235), and of these only 161 provided both preoccasion and

postoccasion data on components of the materials. Of these 161, 70 students in five classes covered the same project materials and therefore their results are directly comparable. Thus, the data can be considered, at best, indicative of the approaches employed.

Consequently, we have chosen to present a series of analyses that reflect the Ns above. First, a between-groups analysis of the equivalent and nonequivalent scale scores is presented. It should be noted that the nonequivalent dependent variables design is employed to improve the attribution of causality to the intervention. That is to say, if students' content knowledge as measured by the nonequivalent dependent variables scale is *not* affected, while the equivalent dependent variables scale is, we are in a much stronger position to be able to claim that the interventions have caused the change. Here, the means and 95% confidence limits of three random samples drawn from the preoccasion data supplied by respondents who did not supply any post-test data (N = 451) are presented graphically in Figure 4. The size of the preoccasion random sample is determined by those who supplied post-test data (N = 235). One-way analysis of variances were computed with the occasion of testing as the independent variable. These results are presented graphically in Figure 4.

Figure 4 shows that there appears to be no impact on the nonequivalent dependent variables here coded in blue from the preoccasion to the postoccasion. There is significant change, however, in the equivalent dependent variables coded in red. The effect sizes of this difference ranged from 0.25 to 0.47.

Table 2 presents the means and standard deviations for students who supplied complete sets of data on both preoccasions and postoccasions *and* who completed the same project content. Here, a multivariate analysis of variance with repeated measures on the occasion of testing was computed. For the nonequivalent dependent variables, there was no main effect due to the occasion of testing, while for the equivalent dependent variables there was highly significant main effect [$F(1,68) = 33.423, p < 0.0001$] and a moderate to strong effect size (ES = 0.66).

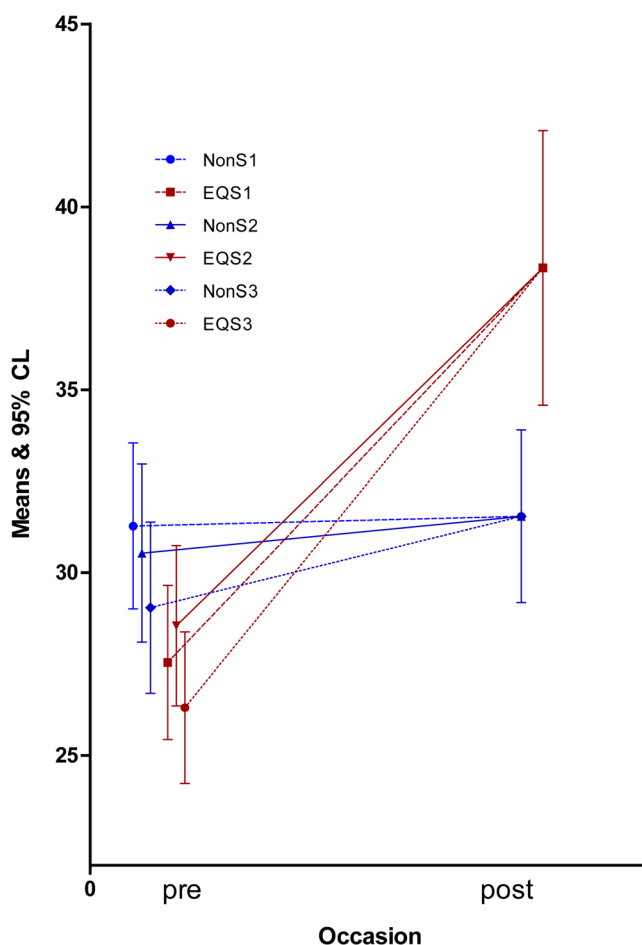


Figure 4. Graph of the equivalent and nonequivalent mean scale scores with 95% confidence levels.

Table 2. Means and standard deviations for equivalent and nonequivalent dependent variables.

Scale	Pre			Post			F	p	Cohen's d ES
	n	M	SD	n	M	SD			
Nonequivalent	70	36.79	12.57	70	37.86	17.42	0.185	0.668	0.07
Equivalent	70	39.55	17.17	70	51.90	20.18	33.423	< 0.0001	0.660

The authors acknowledge that improvements still can be made to students' knowledge outcomes. As teachers acquire familiarity with the new pedagogical approaches embodied within the materials used in the Space to Grow Project, and as students undertake additional projects, it could be argued that the knowledge outcomes are likely to increase.

Of additional interest, students report changes to the practices commonly found in their science classrooms. A total of 643 students provided data on the preoccasion and 177 on the postoccasion. Similar analytic approaches were employed as reported above for the astronomy content knowledge. For the sake of brevity, there is a highly significant reduction in the amount of time students reported that they copied notes prepared by the teacher, a massive increase in the use of computers and a significant reduction in frequency of teacher demonstration of experiments. It is also interesting to note that while they reported they found the science more challenging, they also reported that the content of the projects was not too hard. A fuller analysis of the changes to the conduct of science classes will be the subject of a future paper.

Things may well change as 2012 unfolds when subsequent waves of participants become involved thereby increasing the number of teachers and students who supply complete sets of data. Nonetheless, these preliminary findings indicate the approaches adopted seem to have had a moderate impact on improving students' knowledge outcomes on curriculum topics that are addressed by the project.

3.3. Scientific Outputs

It is also interesting to note the scientific outputs that have been obtained by groups of students who have engaged in the Space to Grow project. To date, there are three groups of students from three different schools who have pursued group projects that have led or are leading to publications in the professional literature.

In the early stages of Space to Grow, prior to the development of the curriculum materials described above, a group of ten female students at a metropolitan high school undertook aspects of a study of a little known planetary nebula (PN), K1-6, where they worked in collaboration with their teacher and project astronomers to analyze and publish their results in the astronomical literature (Frew *et al.* 2011). Students were responsible for generating the color image of the PN, using the Virtual Observatory (VO) tools to retrieve various archival data, and generating the light curve of the PN central star.

A second publication (Fitzgerald *et al.* 2012) has resulted from the work of two male Grade 11 students from a second metropolitan high school who undertook an independent research project on a previously little studied Globular Cluster, NGC6101. Students received guidance from their teacher and worked closely with one of the authors (MF). Students assumed responsibility for measuring, identifying, reclassifying, and updating the periods of the RR Lyrae population contained within it (Fitzgerald *et al.* 2012). Students also made an independent estimate of the reddening toward this cluster and found one, as yet unclassified, new variable star. Figure 5 shows a photograph of the two students together with MF presenting their work at their school's Science Fair.

A third publication is underway that involves high school students in a regional high school collaborating with students from a Canadian metropolitan high school. This has resulted from an initial trial of the current materials with a teacher in Canada who received no training. (He could not attend any teacher professional learning sessions.) Two groups of students chose to undertake further open inquiry studies on clusters of their own choice. Students were presented with details of potential clusters to examine. One pair of students from the Canadian class chose to investigate an open cluster that previously only had been examined with photographic methods in the late 1950s: NGC2215. During the same period, a Year 10 class in Australia also had chosen to look at the open cluster. It was suggested by project personnel that there would be the potential for these students to collaborate. As a result, a pair of students from the Canadian class collaborated with one of the Australian



Figure 5. Two students (Josh Criss and Tom Lukaszewicz) together with project team member Michael Fitzgerald displaying their work on the RR Lyraes in NGC6101 at a school Science Fair.

students who assumed the role of lead investigator. They used email extensively to communicate and to jigsaw the task. The students have added significantly to our understanding of the main physical parameters of this open cluster: the distance, age, metallicity and reddening. They explored whether an apparently more distant stellar population was a true stellar cluster or just a photometric coincidence. The results have been submitted for publication to an astronomical journal.

3.3.1. Teacher Feedback on Materials and Professional learning

As indicated above, data are also collected from teachers to obtain feedback on both the teaching and learning materials used and the professional learning approaches employed. The development of the materials in light of feedback supplied by teachers is of special interest.

It appears that their interpretation and implementation of the professional learning materials has had a major impact on their attitudes toward what the project team was trying to achieve. For example, when a head of a science department who had provided feedback on an earlier version saw the latest materials and the changes that had been made, she made the comment “Oh! So you *actually* do listen to what we tell you.” The increase in “street credibility” that this generated led to a number of new teachers wishing to become involved.

Preliminary, anecdotal feedback from teachers, on both the materials used and the suggested pedagogies for implementation, reveals that the approaches adopted are “different” (in a positive way) to what they “normally” do in secondary science. That is to say, the inquiry-based nature of the materials and the fact that they are implementing “real” science is different from how they would normally cover this content (such as using a prescribed textbook). Some of the teachers who have experienced the face-to-face professional learning sessions also have indicated that being able to work in collaboration with teachers from other schools, and the trialing of materials with a group of students before implementing them within their own science classes, are invaluable features of the project’s new professional learning approach. It will be interesting to track what happens with the first wave of teachers as they develop greater levels of expertise not only with the project materials but also with inquiry science approaches that involve backward-faded scaffolding.

4. CONCLUSIONS

Through being involved with the Space to Grow project and using astronomy and the images and data acquired from the LCOGT.net, the authors hope to engage students more in the exciting world of science. Teachers are a key element and need to be supported in implementing inquiry-based science that makes scientific use of the images and data acquired from these robotic telescopes. Consequently, the different teacher professional learning approaches that are being trialed and implemented are fundamental to the success of this project. It will be interesting to assess the impact of these different professional learning approaches and document the modifications made to them based on the needs of participating teachers. It is anticipated that the data collected from teachers will help identify the worthwhile features of the different models to inform future teacher professional learning not only in science but perhaps more generally.

The preliminary AKQ findings highlight that a number of the students who have tendered prequestionnaires appear to have low levels of knowledge or hold alternative conceptions about fundamental astronomy concepts that are supposed to be covered in elementary and the first three years of the high school science curriculum in the educational jurisdictions from which the participants have been drawn. The high number of students who are not able to offer a correct response, or who provided alternative or hybrid conceptions, raise questions about the way in which these concepts were taught in the junior years, if indeed, they were covered at all. Students' difficulty in retaining these concepts also suggests that perhaps we need to visit how these concepts are taught and redress the pedagogical deficits of the transmissive model that, perhaps, have given rise to them.

The pre/post AKQ results presented indicate a moderately sized learning effect for the equivalent dependent variable scale, while there was no change for the nonequivalent dependent variable scale. These knowledge gains appear to be accompanied by positive changes in students' perceptions of what is happening in their science classrooms. As the project gains momentum, and additional schools and classes become involved, it will be interesting to see what happens in relation to students' knowledge outcomes and also their perceptions of the science they experience at school during their involvement in the project.

To date, various student investigations have led to two scientific papers being published (Fitzgerald *et al.* 2012, Frew *et al.* 2010) and a third that has been submitted with students as co-authors. This suggests that students and teachers can make scientific use of the data obtained from telescopes provided that they have access to appropriate resources and professional learning to help facilitate their analyses. It also indicates that some of the students have become highly engaged by these learning experiences to reach and undertake open inquiry at this level.

In July 2012, the Space to Grow project will expand into the junior years of high school to also include Grades 7 and 8. The research team hope that by broadening the project to span all grades of high school, students' interest in science will be captured much earlier and, in addition, retain them in the study of scientific subjects during the postcompulsory years of secondary school (Grades 11 and 12).

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