Measuring the Impact of Specialist Science Enrichment Programs at the Gravity Discovery Centre

David Blair, Grady Venville, David Coward and Nancy Longneker
University of Western Australia
Mario Zadnik
Curtin University of Technology
Fred Deshon, Richard Meagher, Geoff Cody, John Delaeter
Gravity Discovery Centre Foundation
Neil Jarvis
Polly Farmer Foundation
Martin Hendry
Glasgow University

Abstract

This paper describes a new research project to evaluate the benefits of science enrichment programs in changing student attitudes to science. The study is focussed on a new innovative science education centre – The Gravity Discovery Centre – where three different approaches to science enrichment will be evaluated. After reviewing the current worldwide problems in science education, we describe the rationale and the planned methodology in the context of three very different approaches which have been designed for students with different needs: a) narrative based learning, b) learning through real astronomical research, and c) more conventional learning based on specialised learning modules.

Aims and Background

Academics interested in promoting and enhancing science education (from the University of Western Australia, Curtin University and the Univ of Glasgow) have joined forces with a charity, The Polly Farmer Foundation and The Gravity Discovery Centre Foundation to undertake an in-depth study of the effectiveness of schools science enrichment programs. The Polly Farmer Foundation specialises in providing education enrichment to indigenous disadvantaged students in remote schools. The GDC and the AIGO Research facility makes it possible to offer three types of science enrichment , one especially designed for indigenous students and those without positive attitude to science. The second provides challenging modules some of which focus specifically on modern concepts of space, time and gravity, including Einstein's theories and the search for gravitational waves. The third enrichment program allows students to take part in real research and offers the possibility of real discoveries, using UWA's large new robotic telescope – The Zadko Telescope.

The motivation of the project is the current science teacher shortage in secondary schools. Many specialist facilities and programs have been set up to provide science enrichment programs. All aim to help reverse the decline of students taking science and at reversing the declining attitudes towards science in schools.

Our proposition is that:

a) specialised enrichment programs stimulate teachers as well as students and can lead to a positive change in student attitudes towards science

b) creating positive attitudes towards science in schools is a critical factor in students' career aspirations
c) students can be engaged and motivated through exposure to real science and scientific endeavour
d) for some students, particularly from disadvantaged and indigenous backgrounds, a narrative approach to science can motive and engage them in science.

The new research program aims to test these propositions.

Science enrichment is often only offered to science motivated talented students. While we want to measure the effectiveness of enrichment for this group, we also want to find out whether programs can turn around the attitudes of students who have a negative view of science, and whether they can excite students who have had minimal exposure to science.
To change the attitudes of students with negative attitudes to science, as well as for remote and deprived schools, we will make use of a brand new specialist facility at the GDC: The Cosmology Gallery that combines traditional creation stories told through art work, text and movies, with the scientific story of the origin of the universe. We want to measure the benefits of learning by narrative using this specialist facility.

The aim of the new project is to measure the effectiveness of science enrichment programs in changing student attitudes to, and interest in science and in student career goals and expectations. We will follow attitudes and opinions of students from different groups who have been exposed to specialised enrichment programs at the GDC, and to those who have had additional enrichment through participating in real astronomical research.

The problems with indigenous education are well known. This project will assess a particular approach that combines multicultural and traditional cosmology with scientific cosmology. Four leading indigenous artists were commissioned to create cosmology related artworks. These works sit alongside the Timeline of the Universe, a 60 meter scientific installation. Meteorites and megafauna fossils provide tangible evidence. We believe that this purpose built facility will excite and motivate indigenous students and students who have negative attitudes to science.A particular focus will be on indigenous students from remote schools from the Pilbara and Kimberley regions. Stakeholders such as mining companies who already support indigenous students in the regions of their operations through the Polly Farmer Foundation will be able to obtain quantitative measures of the benefits of their support. Specifically we will work with

a) disadvantaged and un-engaged students from remote schools and low socio-economic city schools
b) academically talented students including those with negative attitudes towards science.
c) Mainstream students

Comparing three types of enrichment programs.

A) Specialised Enrichment (SE): We will assess the benefits from participation in exciting high quality programs that have already been developed by the GDC Foundation, and which are comparable to many enrichment programs offered by

diverse facilities across Australia. (but including pre-visit and post-visit classroom activities)
B) Motivating through Research (MR): Students will use the Zadko telescope and interact with research students: this research will enable students to discover new astronomical objects and to improve the orbital analysis of known objects. (asteroids, near earth objects and gamma ray bursts).
C) Learning through Narrative (LN): Students will use the new Cosmology Gallery facilities. Here we will focus on the story of the universe and we will compare cultural creation stories with the scientific story. This unique facility is specifically designed for a multi-culural approach to learning.

We will follow students over three years. Where possible we will monitor both students attitudes towards science and student's pre-tertiary subject choices (compared with control groups). *At the end of this research program we will have quantitative data that will allow the education sector to better determine the benefits of specialist science education facilities. Through the programs we will be measuring we will have provided thousands of students with valuable science enrichment.*

The Gravity Discovery Centre
The Gravity Discovery Centre, operated by the GDC Foundation is an independent non-profit facility set up at the instigation of the WA Government to provide education resources to complement the Australian International Gravitational Observatory(AIGO) Research Centre at a location 80km north of Perth CBD. It was set up through a major fundraising process that led to a total investment of more than $10m.
The GDC was designed to be a learning centre that focussed on modern physics, astronomy and biodiversity. It was funded mainly through private sector donations. In parallel with the development of the buildings and exhibitions the Gravity Discovery Centre Foundation worked with a group of talented and dedicated school teachers to develop education programs linked to exhibits. Stage 1 of the GDC was opened in 2003 and Stage II in 2008. It is now a large scale facility containing more than 2000 square meters of exhibits, displays and educational resources. It is located beside the AIGO Research Facility where up to 20 research personnel conduct large scale experiments with high power lasers, all related to the discovery of gravitational waves, a new spectrum of radiation expected to allow humanity to listen to the gravitational "sounds" of black holes and the big bang.
The facilities of the GDC include a large public astronomy centre (Gingin Observatory) , the new state of the art robotic Zadko telescope owned by UWA, a 20m pendulum tower, a 1km scale model of the solar system, the Leaning Tower of Gingin, (a 45m steel tower for students to do free fall experiments), and research laboratories available for student visits. The main GDC buildings include four large scale galleries

a) The Discovery Gallery: discovering gravity, and the other fundamental forces of the universe, the links between space and time, and the links between time and gravity.
b) The Innovation Gallery: examples of local innovations and inventions: displays organised in cooperation with local high technology businesses.
c) The Cosmology Gallery: exhibitions on the origin of the universe including a 60m timeline of the universe from the big bang to life on earth, including exhibits of meteorites, minerals and fossils and also including cultural

cosmology with large scale artworks depicting creation stories from indigenous culture and world religions.

d) The Biodiversity Gallery which focuses on the unique and extraordinary diversity and specialisations of plants and invertebrates on the 50km^2 pristine bushland of the Gravity Centre.

The GDC currently has 20,000 visitors per annum, half of which are school groups from WA and SE Asia, who undertake curriculum related enrichment programs.

Uniqueness of the GDC

The Gravity Discovery Centre is unique and innovative. It combines art with science, real research with learning modules linked to large scale facilities such as the Leaning Tower and the Pendulum Tower, and cosmology linked to astronomy, geology, paleontology and traditional cultural beliefs. The founders of the GDC won the Prime Minister's Eureka Prize for Promoting Science. It was written up in Nature July 10, 2008.

Problems with Student Attitudes to Science: Enrolment Decline

Australian schools and universities are not producing enough scientists and engineers to sustain the scientific and economic development of Australia (DEST, 2006; Royal Australian Chemical Institute, 2005). Despite science and technology being key factors contributing to the economic growth and social prosperity in both advanced and developing nations, there is a worldwide phenomenon of declining student attitudes to science in developed nations (Sjoberg, 2005), including the UK (Office of Science and Technology and the Wellcome Trust, 2001), Europe (European Commission, 2007), the US (National Academies Committee on Science, Engineering, and Public Policy, 2006) as well as Australia (DEST, 2006). Within Australia this phenomenon has been referred to as a crisis (Tytler, 2007) because it has resulted in "a decreasing proportion of students taking post-compulsory science; low levels of participation in tertiary courses in physics and chemistry and higher mathematics; [and] a shortage of graduates and research students in key areas" (Tytler & Symington, 2006, p. 40).

The problem of poor student attitudes towards science and falling enrolments in science subjects at the secondary and tertiary levels of education is of critical importance to the scientific and economic development of Australia. There are a number of indicators of the enormity of the problem. The most recent results from the Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Cooperation and Development (OECD) showed that 15-year old Australian students showed very low interest in learning science. Of the 57 countries that participated in the PISA in 2006, Australia was ranked 54th for students' general interest in learning science (Thompson & De Bortoli, 2008). Moreover, on an index for motivation to learn science, or take up a science career, 15 year-old Australian students' mean was below that of the OECD average (Thompson & De Bortoli, 2008).

The Longitudinal Surveys of Australian Youth (Fullarton et al., 2003) show that between 1993 and 2001 national participation rates for Year 12 students in all science subject areas dropped (with the exception of psychology). In chemistry, for example, the participation rate dropped from 22.6% in 1993 to 17.8% in 2001. A further indication of the declining numbers and the declining quality of students selecting science in further education is that in all four public universities in Western Australia the minimum tertiary entrance rank (TER) for students selected to enter a general science degree dropped considerably in the five years from 2003 and 2007. For example, at Curtin University of Technology the minimum TER dropped from 80.1 in 2003 to 70.3 in 2007 (Tertiary Institutions Service Centre: http://www.tisc.edu.au/).

In addition to poor student attitudes towards science, falling achievement of Australian high school students in science is well documented and is making national headlines (Ferrari, 2008). Year 8 science scores in the Trends in Mathematics and Science Study (TIMSS: conducted by the International Association for the Evaluation of Educational Achievement) have declined significantly since TIMSS 1995 (Thompson et al., 2008). In the 2007 cycle of testing, Australia's average science score at Year 8 showed a statistically significant decrease of 12 score points from that of TIMSS 2003. The results also show that eight per cent of Australian Year 8 students did not reach the minimum international science benchmarks (Thompson et al., 2008). These factors, combined with significant improvements by other countries, have moved Australia down in the rankings.

Research on Science Learning in informal contexts

Compared with formal, school environments, learning in informal (out-of-school) contexts is learner-led and intrinsically motivating (Rennie, 2007). The Gravity Discovery Centre program meets the criteria of an 'informal' program because it is a voluntary program, students are given choices as to the direction of what they do, the program is not formally assessed and can be delivered to students of a range of secondary school ages (Wellington, 1990).

To date, the quantity of research that investigates science learning in informal contexts pales into insignificance compared with that conducted in formal school settings (Osborne & Dillon, 2007). Research within Australia suggests that outreach programs offered by science centres and other providers increased students' interest and skills and benefited students and teachers by demonstrating new approaches, content, techniques and resources (Garnett, 2003). While participants are generally positive about the experience, it is unlikely that the potential of excursions and incursions into schools are fully realised in terms of student learning of science (Rennie, 2007). Research suggests that to maximise the benefit of informal programs they must be complemented by the in-school curriculum, incorporate pre-visit instruction, be flexible and make use of organised, post-visit reflection (Rennie, 2007).

Unfortunately, even though most providers supply information to teachers to enable them to integrate visits within the curriculum, most teachers do not use the activities provided (Rennie, 2007). For many students it is likely that the major benefit of their experience is the memory of enjoyable science activities.

The GDC programs offer us a unique capability of comparing the three types of enrichment discussed above: a) the narrative and multiculturally focussed programs of the Cosmology gallery, b) discovery programs with pre and post visit activity (equivalent to those of the best typical science centres), and c) programs that incorporate real research into the experience.

We discuss the significance and innovation of these programs below. For the narrative based programs we have informal evidence that they are particularly well received by students with indigenous background. The existence of indigenous creation artworks and stories beside the scientific story appears to have a strong resonance with some students. We believe that when reinforced by real astronomy this may lead to significant engagement and changes in attitude. This we will assess.
For programs which incorporate real research, after on site visits and training, the Zadko telescope and two others in the Tarot telescope network can be accessed remotely to collect real scientific data from home or the classroom. The program can thus be integrated into the students' regular science lessons. Students have a significant probability of discovering new asteroids, near earth objects and gamma ray burst afterglows and will be able to analyse and report their findings, working with and acting as real scientists. (To substantiate this statement, three students have discovered 7 new asteroids and 7 gamma ray burst afterglows in less than 3 months of occasional observing in 2009). Students will be able to observe objects from our solar system to distances of more than 10 billion light years. They will be observing events that occurred before the solar system existed. We believe that the motivational effectiveness of such observations (linked to the conceptual framework for understanding them) to be very high but it is essential to assess this assertion.

Research Design

The research design will be a multiple case study (Stake, 2006), each case study being a single school in city (6 cases) or rural and remote regions (6 cases). The "quintain", the whole or entity having cases or examples, (Stake, 2006, p. vi) is the program at the Gravity Discovery Centre. We seek to understand how this program operates in different situations, or multiple cases, including those that are focussed on specialised enrichment (SE), motivating through research (MR) and learning through narrative (LN). Experimental and quasi-experimental designs were deemed inappropriate for this proposed research because students within each school cannot be randomly assigned to the Gravity Discovery Centre experience and a control experience. Moreover, equivalent groups of students in other schools that could be used as a control would be difficult to identify due to the unique cultural and socio-economic contexts of the participating schools, particularly those in the rural and remote regions. The logic of using the multiple case study design is replication (Yin, 2009), which is analogous to multiple experiments. If all 12 cases turn out as predicted, they will provide compelling support for the initial set of propositions (a-d) outlined on the first page of the proposal. Alternatively, if the cases are in some way contradictory, the initial propositions must be revised.

Methods of Data Collection

In order to maximise our understanding of the impact of the Gravity Discovery Centre program has on students' attitudes towards science and their understanding of astronomy and to ensure the research rigour, mixed methods, including both qualitative and quantitative forms of data collection will be utilised (Creswell & Clark, 2007). Comprehensive survey data will be collected for statistical analysis so that broad spectrum understanding of the impact of the program can be developed.. Qualitative data collection, such as interviews and observations, will provide more fine grained and detailed information about the impact of the Gravity Discovery Centre program on students' attitudes towards and understandings of science.

Survey: A pencil and paper survey will be administered face-to-face to students in participating schools before and immediately after as well as six months after the Gravity Discovery Centre experience (n≈720 i.e. approx. 60 participating students in 12 schools). The survey will consist of two parts. Part A will obtain data related to the students' attitudes, intentions (or actual participation) with regard to science subjects and science careers. An established survey previously developed for ascertaining high school students' attitudes towards science and science careers will be used for Part A (Bennett & Hogarth, 2005; see http://www.york.ac.uk/depts/educ/research/ResearchPaperSeries/index.htm). Part B will obtain data about students' conceptual understanding of relevant astronomical science concepts. Part B will be constructed specifically to suit the learning experience the students participate in as part of this research. For example, items from previously validated astronomy concept inventories, such as those developed by the NASA Centre for Astronomy Education. Items from the Astronomy Diagnostic Test 2.0 (ADT 2.0) (http://solar.physics.montana.edu/aae/adt/) and the Star Properties Concept Inventory (SPCI) may be used to ascertain students' understanding of concepts related to motions in the sky, size and scale, temperature, luminosity, mass, formation and fusion. We are aware, however, that learning that occurs in science centres is a personal process, often different for each person, is contextualised in rich, interactive, out-of-school contexts, and it takes time (Rennie, 2007). For these reasons we also will employ a method called personal meaning mapping (Falk, Moussouri, & Coulson, 1998) as a method of capturing the personal meaning that students construct as a result of their unique experiences in three learning programs in this research. Personal meaning mapping uses diagrams and concept maps which represent the 'big picture' regarding a specific concept. It includes a level and breakdown of individual detail that enables information to be organised in meaningful ways.

Interviews: Semi-structured interviews will be conducted in each school before and after the Gravity Discovery Centre experience with two or three key teachers and/or administrators and up to one quarter of the participating students (n≈180 i.e. approx. 15 participating students in 12 schools). Face-to-face interviews will be continued with the same teachers/administrators and students for delayed, post-program data collection six months after the completion of the Gravity Discovery Centre experience in each school. Like the surveys, the interviews will focus on the students' attitudes towards science as well as their understanding of key concepts. The interviews will be used to provide explanations of outcomes from the quantitative data and to enrich and explain the quantitative results in the words of the participants (Creswell & Clark, 2007). All interviews will be audio recorded and fully transcribed.

Observational field data: Observational field data will be collected in schools during the Gravity Discovery Centre experience. Observational field data will be recorded by field notes and a digital voice recorder. All field notes and audiofiles will be transcribed.

Data Analysis

Data analysis will be complex, multi-layered and ongoing from the middle of the first year to the middle of the third year of the project. Quantitative survey data will be scored by two researchers, entered into SPSS software program and analysed using descriptive statistics and analytical tools to determine if there are significant differences between the pre and post and delayed, post-program scores and to determine other patterns in the data relevant to the propositions. Qualitative data will be analysed through processes such as network and discourse analysis (Cohen, Manion & Morrison, 2000). Both the quantitative and qualitative data will be used to search for confirming and disconfirming evidence with regard to the propositions. Quantitative and qualitative data from each school will be analysed on an individual basis so that school case study reports can be constructed. Cross case analyses of each school and comparative case studies will be constructed so that similarities as well as distinctive and significant aspects of the case studies can be highlighted and juxtaposed.

Strategies to enhance the quality of the research have been embedded in the research design so that each of four quality criteria as outlined by Yin (2009) can be shown to have been addressed. The construct validity will be addressed through the use of multiple sources of evidence including the survey, interviews and classroom observations. Moreover, key stakeholders (such as case study school teachers), will be asked to review and give feedback on draft case study reports. The internal validity of the research will be addressed through a search for confirming and disconfirming evidence for the propositions in both the quantitative and qualitative data. Rival explanations will be generated and considered in the data analysis process. External validity is addressed through the replication logic of the multiple-case design where the findings from the multiple cases may or may not converge in support of the propositions. Finally, reliability will be addressed through careful documentation of the research procedures (described below) and the development of a case study data base (Yin, 2009).

Implementation

Bringing classes from target schools to GDC to participate in proposed programs. Administer pre, post and delayed post survey (all participating students) and interviews (one quarter of participating students and two teachers) for each school group.
Bringing classes from Newman and Port Hedland (subject to BHP participation) Karratha and Dampier Peninsula(subject to Woodside participation)
Having students participating in Near Earth Objects Research, Gamma Ray Burst Research and work experience programs at GDC, AIGO and Zadko Telescope.
Office space and work location.

Conclusion

The shortage of science teachers means that some schools no longer offer upper school physics and chemistry. This means that many students are deprived of science opportunities. One solution could be the creation of more specialist science education enrichment facilities. We have described a. This project is designed to provide that data which will determine the benefits of such facilities. This could inform future investment in the education sector.

Many indigenous students will take part in these programs and our research will determine their effectiveness in motivating students from this population. Results of the research will enable the benefits of such programs to be determined to allow future funding options to be assessed.

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