The *Mars Lab*: connecting authentic science with the classroom

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THE MARS LAB TEAM AUTHORS

Dr Carol Oliver, lead author, is the Associate Director of the Australian Centre for Astrobiology, University of New South Wales, and Project Manager for the *Mars Lab*.

Dr Jennifer Fergusson is a Research Fellow at the Australian Centre for Astrobiology.

Peter Mahony is the Education and Digital Learning Manager at the Museum of Applied Arts and Sciences.

James Oliver is the Digital Learning Manager at the Museum.

Isabelle Kingsley is a Museum Program Producer.

Craig Browne is a Mars Lab Program Producer with the Australian Centre for Field Robotics, University of Sydney.

ACKNOWLEDGEMENTS: The *Mars Lab* team wishes to thank all the participating teachers who helped to develop the project and to their students for helping us to test the results. In particular we wish to thank our four pilot schools, Armidale PLC and Duval High School in Armidale, NSW, Willunga High School in South Australia and Scottsdale High School in Tasmania.

Introduction

Thirty years ago 94 % of students studied science in Years 11 and 12. By 2010 the percentage had dropped by almost a half to around 51% (Goodrum et.al., 2011, p11). The declines, especially in the enabling sciences and mathematics, continue. The Chief Scientist of Australia, Professor Ian Chubb, says there is an urgent need to act if we are not to be left behind in the science, technology, engineering and mathematics (STEM) enterprise (Chubb, 2013, p6).

This need to act affects the length of the education pipeline, but especially in Years 5 to 10 when it is known students make their decisions about the value of studying science.

Reversing the slide in senior enrolment in science and mathematics is critical for Australia and for the students, if they are to be prepared for their working lives as adults. Shortages are already occurring in STEM-related jobs and the nature of the work that will contribute to the future economic health of Australia is changing too:

Businesses of all sizes are facing a continuing and deepening severe shortage of STEM-qualified graduates, and as a result the potential to create a major impact on their capabilities to do business (Australian Industries Group, 2013).

75% of the fastest growing careers today require at least some STEM skills (Chubb, 2013, p10; Australian Industry Group, 2013).

60% of future careers a decade from now have yet to be invented so it is no longer possible to teach for the majority of careers in which today's students will be employed (Schleicher, 2010; Frey, 2011).

Science is boring!

There are clear indicators that one of the drivers of the decline in students choosing science is a student perception of the nature of science, one in which science is seen as a boring collection of disconnected facts and there is nothing further to learn. In a major study, two thirds of students who elected not to take science in Years 11 and 12 did so because they felt unconnected to science (Lyons and Quinn, 2010). They were unable to imagine what it is like to think like scientists, to feel what it means to push back the limits of our knowledge.

Experiencing real science

The literature supports the view that traditional school science remains in stark contrast to how science is practiced (Wong and Hodson, 2009) and that inquiry-based tasks commonly used in schools are different from the epistemology of authentic science (Chinn and Malhotra, 2002). If this is so then student (and teacher) contact with real research is essential (Oliver, 2008).

The perennial problem is in how to teach thinking like a scientist within the constraints of school science. Some good programs exist to assist teachers such as the Australian Academy of Science's *Primary connections*, and CSIRO's *Scientist in schools* program. Partnerships between universities and museums also have the potential to create a conduit through which the learning environment of schools can easily access university science and engineering research in the familiar informal educational nature of the museum environment.

One such major project has just completed two years of development and testing. A collaboration of the Australian Centre for Astrobiology (ACA) at the University of New South Wales, the Australian Centre for Field Robotics (ACFR) at the University of Sydney and the Museum of Applied Arts and Sciences (MAAS) have created a working Mars laboratory in the public space of the museum to provide schools with access to authentic science and engineering research.

The *Mars Lab* project

Launch of the Mars Lab project in March 2014.With the three rovers *Mawson*, *Mammoth* and *Continuum*. Left to right: US Ambassador to Australia John Berry, head of NASA and four times astronaut Charles Bolden, Research Director Australian Centre for Field Robotics Prof Salah Sukkarieh, Director of the Museum of Applied Arts and Sciences (MAAS) Rose Hiscock, and MAAS Board of Trustees member Jim Longley

The *Mars Lab* education and research project was developed with 18 teachers from four pilot schools in NSW, South Australia and Tasmania, tested over 18 months and deployed without difficulty across nearly 40 schools in NSW, South Australia, Tasmania, Western Australia and Victoria for Years 5 to 10 students via the broadband network. There have been almost 6,000 student and public interactions with the *Mars Lab* in the past 18 months. It is embedded into the Museum's mainstream education offerings.

The *Mars Lab* is a science and engineering-based dynamic and immersive digital and spatial experience that uses a 140 square metre scientifically correct surface of Mars called the Mars Yard, which is located in the Museum. The Mars Yard has three research-grade Experimental Mars rovers that are used by researchers in-situ but are also accessible by students in their classrooms and across multiple browser independent platforms, including desktops, laptops, iPads and other devices.

Mars exploration today includes rovers and orbital spacecraft from the National Aeronautics and Space Administration (NASA), the European Space Agency and India. The United States recently tested its Orion spacecraft as a first step to human exploration of Mars within 15 years. The research is cutting edge and multidisciplinary, making it ideal for a project aimed at inquiry-based learning and science as a human endeavour.

OK to be *Science-y*

One of the drivers of this project is the decline in the numbers of young people choosing science subjects at senior school levels. While education professionals often consider these choices as milestones along a

PLC Melbourne: ***Mars Lab mission video conference***

learning journey, for young people, such decisions may be understood within a broader social context.

In considering attitudes to education from the perspective of social dynamics, Wierenga and Wyn (2013) present three dimensions of concern for young people:

- meaning and identity (*people like me do things like this*)
- control or agency (*include me in discussions about the future*)
- connections and networks (how trust is the driver of ideas, inspirations and possibilities).

A place to engage with young people is through *voice and choice*, which is found in the nature of informal education offerings like the *Mars Lab*.

Education programs

Teachers encountered through the program believe that the curriculum, both NSW and Australian, are crowded, leaving little time for extra-curricular activities. As a result, three distinct NSW and Australian science curriculum linked online education programs were built in collaboration with teachers and supported by the *Mars Lab* team.

For teachers using them, the content in projects like the *Mars Lab* is less important than the inclusion of authentic science inquiry learning skills and the perception of science as a human endeavour. Both of these aspects are embodied in the rover, and eventually human, exploration of Mars. Key future learning competencies such as critical and creative thinking, working together collaboratively and communication skills are implicit and explicit in the *Mars Lab* programs.

The experience to date is that students readily engage with the *Mars Lab* opportunity. There are three programs.

Mars mission five

This is a two-part video conference program, led by the *Mars Lab* team that has Years 5-8 students investigating space, considering the possibility of life on other planets and carrying out a collaborative teleoperated rover mission.

The program begins with a 45-minute video conference to introduce students to the search for life on Mars, gives clues about what features to look for on the Mars Yard and demonstrate the tools they will use to plan and practice their mission.

About a week later students connect again to the

Mars Lab to remotely control a robot rover across the Mars Yard to capture close up images of the sites they believe match their clues. Following the mission, students examine their images and consider what evidence they provide about the possibility of life on Mars. *Mars mission five*, made with the Junior School of the Presbyterian Ladies' College (PLC) in Melbourne, show how the program captures student interest.

Sixty minutes on Mars

This is a five-lesson teacher-led unit of science curriculum-linked activities that provide an introduction to the search for evidence of life on Mars for Years 7–10.

During this program, students investigate some of the geological and astrobiological features of interest on the Martian surface and consider what it means to look for evidence of life on Mars. Students ask questions like:

- what do we look for?
- where do we look?

They then use this knowledge to:

- carefully plan, practice and execute their collaborative 60-minute rover mission
- gather photographic evidence of these features

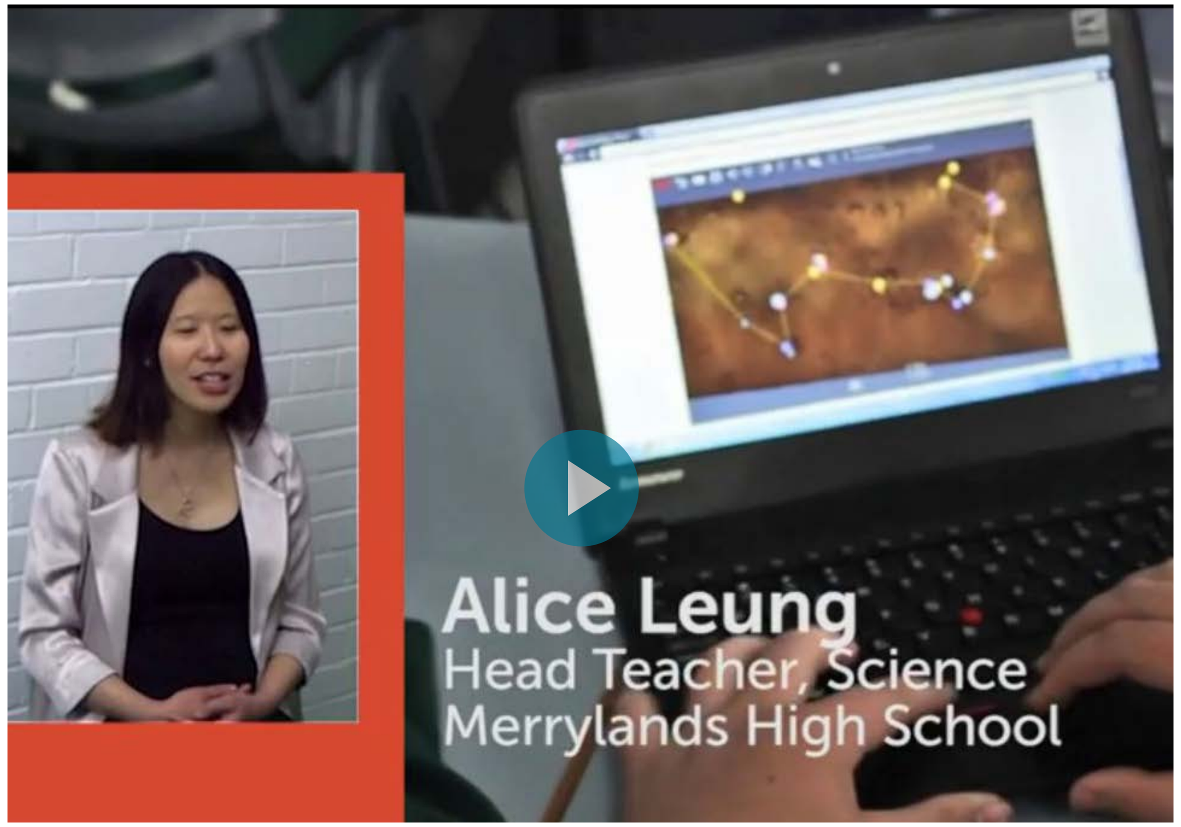
draw evidence-based conclusions.

Project Mars

This is a 5-6 week project-based learning (PBL) unit for Year 9 chemistry and physics but adaptable (and tested) for younger and older students.

The program has a dual purpose:

- it uses PBL to allow students to direct their own learning and have an authentic scientific experience with the *Mars Lab*
- it provides a step-by-step guide for teachers on how to apply PBL in their science classrooms.



Alice Leung talks about Project Mars

Students are provided with a single driving question: *can Mars support life?* In their attempt to investigate this question, students need to work with others and use a variety of science inquiry skills. In this video, Alice Leung, science head teacher at Merrylands High School in Sydney's west, outlines the benefits of this program for her students.

The students identify their own research questions and hypotheses to:

- learn about the structure of the atom
- explore aspects of spectroscopy, light and electromagnetic radiation science
- conduct a scientific investigation using a *Mars Lab* rover and its virtual instruments
- collect and analyse data
- interpret the results, report on findings and make a formal presentation of their findings to *Mars Lab* science advisors.

Assessing learning

Assessment of the PBL program is summative and formative, an assessment methodology employed in Australian schools, which greatly enhances learning outcomes (Boston, 2002; Organisation for Economic Cooperation and Development (OECD), 2005). The teacher assesses student presentations and a written report. The students undertake peer review, self-assessment and group assessment, all of which Finnish students are taught to do from Kindergarten. Finland led the OECD Program for International Student Assessment tests in numeracy, literacy, reading and science literacy in 2000, 2003 and 2006.

TV multi-cast studio

The education programs are also supported by a series of video conferences in which students interact with Mars scientists, engineers and other experts. The *Mars Lab* has its own multi-cast studio to undertake these video conferences and also in which to build multiple video resources that can be accessed by anyone on the *Mars Lab* website.

What makes Mars special as a context for learning science?

NASA has just announced its intention to send humans to mars by the mid-2030s after the highly successful first test of its new Orion spacecraft.

There are seven orbiters currently around Mars run by NASA, the European Space Agency and the Indian Space Agency.

NASA has two operational rovers on the surface; the large shopping trolley sized *Opportunity* that spent more than a decade exploring Meridiani Planum, and the car-sized *Curiosity* that is exploring a five kilometre high mountain in the middle of Gale Crater.

The *Mars Lab's* connection to NASA

The *Mars Lab* is connected to NASA activities through The Australian Centre for Astrobiology (ACA), which is partnered with the NASA Astrobiology Institute. Members of the ACA are also on NASA astrobiology teams at Arizona State University and the Massachusetts Institute of Technology (MIT).

In 2020, NASA will send a forerunner rover mission to Mars to prepare for human exploration. One of the seven instrument packages on the rover is led by Australian and former ACA student, Dr Abby Allwood, who now works for NASA's Jet Propulsion Laboratory in Pasadena, California.

What is known about Mars?

Mars has water locked up in its soil, at least at Gale Crater, and at the poles (particularly the north pole). It also has a dynamic weather system, and the ingredients for past or present microbial activity. The environment at Gale Crater was once habitable and water was present. If humans were on the planet at that time, they probably would have been able to drink the water.

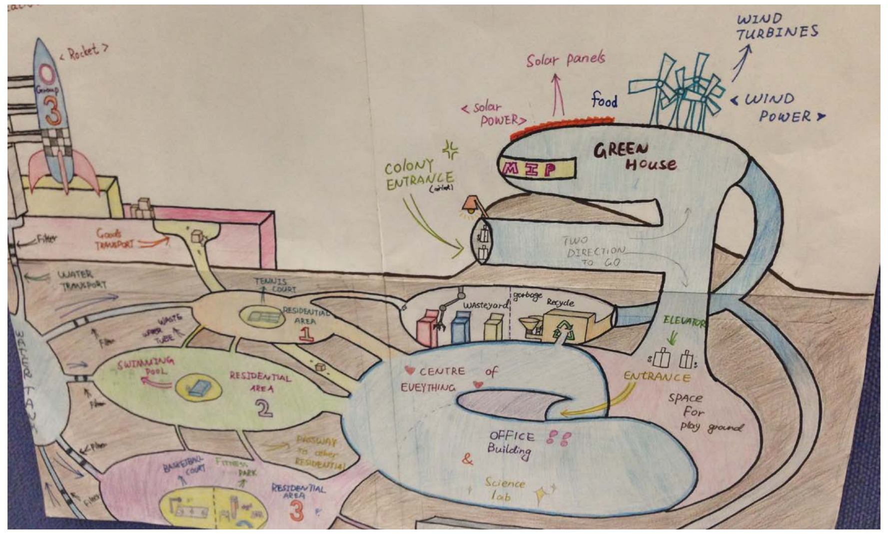
Mars is extremely distant from Earth given our current technology. It takes at least 150 days to reach it. A good way to get a feel for this distance is found at this interactive website.

The *Mars Lab* TV studio is a multi-cast facility enabling full broadcast quality video conference productions in which students are connected with Mars and space-related scientists and other experts

Adaptability

As recently demonstrated by Chatswood High School, the materials are also capable of being adapted to a wider range of curriculum, including design, environmental studies, social studies, and sustainability in considering future colonies on Mars that could well occur when today's students are in their mid to late thirties.

While the *Mars Lab* materials are designed for Australian students, the project has strong interest from overseas with expressions of interest from Hong Kong and the United States. Classes from China have already successfully participated in *Project Mars* with the secondary aim of improving students' English language skills.



An example of an underground Mars colony imagined by a team of Year 8 students at Chatswood High School, Sydney

Digital and virtual tools

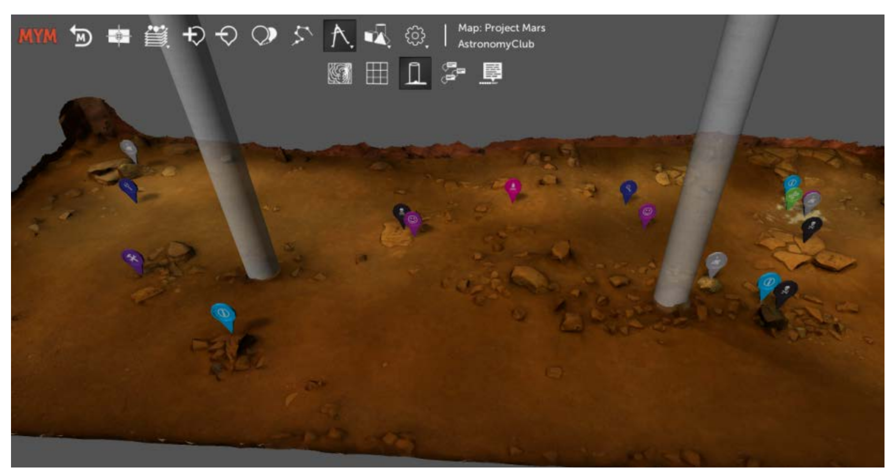
The digital tools have evolved with experience during the testing of the *Mars Lab* programs. For example, observations in the classroom showed students attempting to map their missions in the *Mars Lab* using pencil and paper on less than ideal black and white or colour print outs. From those observations a tool was crafted that allowed them to map their missions using high resolution 3D imagery of the Mars Yard. This has provided greater guidance on what a mission could look like, with the added benefit of allowing students to collaborate online.

Early releases of the tool showed that students needed a way to share their planning without the possibility of it being accidentally edited by other classmates so the mapping tool was made multi-layer. This means a class can be split into teams undertaking different missions or tasks using editable multiple layers. Each team has its own editable layer on the same map and can observe what other students are doing on their layers without being able to change what others are doing.

The full suite of tools is outlined below.

The Mars mapping tool

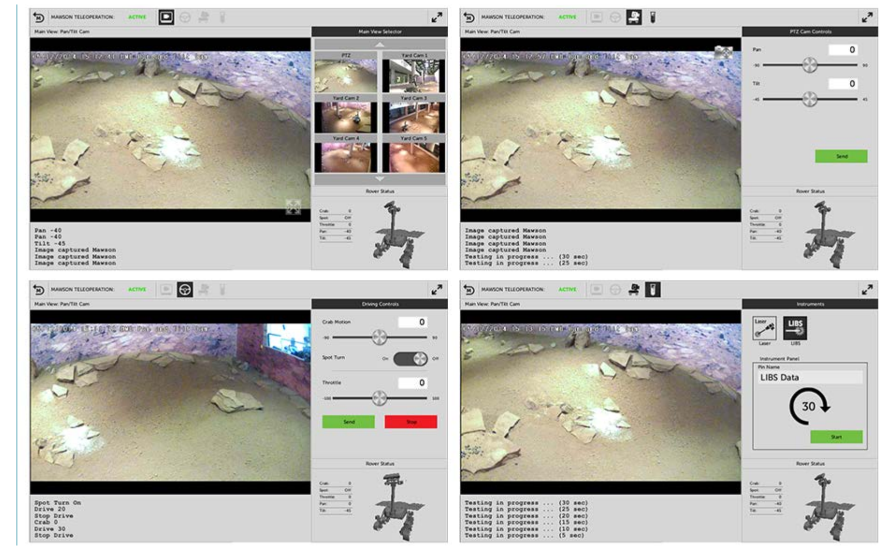
This is a multi-layer editable digital mapping tool that enables web-based collaborative mission planning in teams and ensures every student has a role in each mission.



The digital mapping tool: the *Mars Yard maps* (MYM) app provides *Mars Lab* users with a digital and effective way to plan and record their Mars Yard experiences

A graphical user interface

This provides students with teleoperational control of the rovers and access to cameras on the rovers, a virtual instrument (for *Project Mars)* and cameras situated around the Mars Yard.



The teleoperation (TOP) interface has a different layout to match each mission role. Layouts are selected after login. Clockwise from the top left: main view, rover cameras, instruments, driving

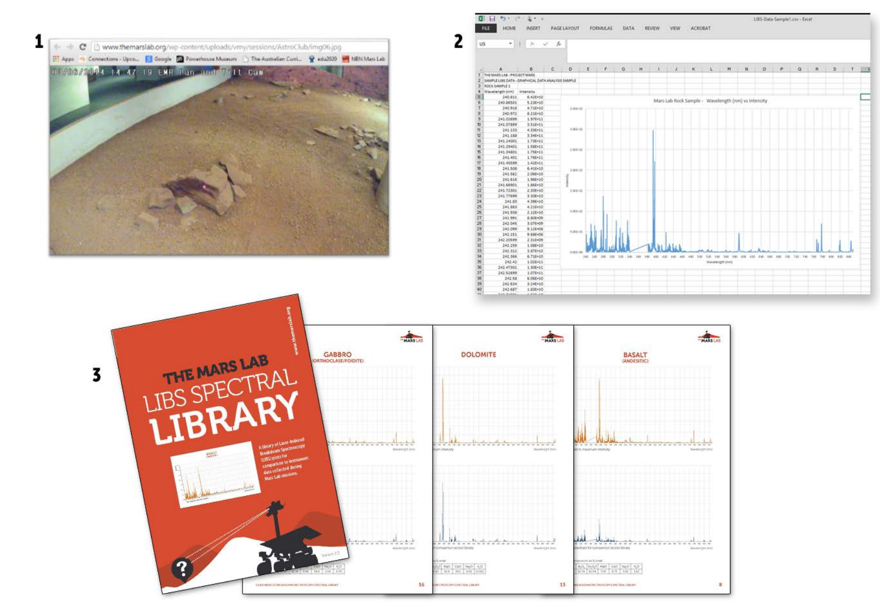
A virtual Mars Yard

This allows users to practice driving the rovers and understand engineering concepts.

The virtual Mars Yard (VMY) is a web-based virtual simulation application that mimics the actual Mars Yard in the Museum. There are engineering tutorials and students have the opportunity to learn to drive the real rovers

A virtual spectrometer

A virtual spectrometer connected to a deep database generated from Mars rover *Curiosity* data, enables students to see inside rocks.



Students can scan any zone on the Mars Yard with the rover's Laser Induced Breakdown Spectroscopy (LIBS) instrument (1). Students then graph the spectral data for their target sit (2) and compare it to a spectral library (3)

More virtual instruments are planned to measure temperature, pressure, and other aspects.

The creation of the Mars Yard

The *Mars Lab* program is based around the Mars Yard, created for a previous project, *Pathways to space*, which was funded by the Government's Australian Space Research Program. For this project students had to physically attend the Powerhouse Museum and the experience was limited to low numbers and just three hours at a time.

The *Mars Lab* was funded by the Government's Broadband Enabled Education and Skills Services program to provide schools with much greater access to the facilities by using the broadband network.

Research

The research results for *Pathways to space* showed that even with a three-hour experience students significantly increased their understanding of the role of creativity and imagination in science (Fergusson et.al., 2012), which is a critical aspect of science that can be difficult to teach in high school. Further research is being undertaken to determine the effects of the *Mars Lab* project on students' attitudes to science and on teachers' approaches to science teaching. A similar pattern of findings is emerging with the *Mars Lab*.

Research design

A mixed methods research approach was employed. A pre- and post-project participation survey design was used, as well as semi-structured interviews. The items for the questionnaire were obtained from the empirically developed *Student understanding of science and scientific inquiry* instrument (Liang et al., 2006), which examined students' views of imagination and creativity in scientific investigations and methodology of scientific investigation. A validated attitude scale (Kind, Jones, & Barmby, 2007) was also used, which included the subscales:

- learning science in school
- self-concept in science
- science outside school
- future participation in science.

Students were also asked about their intentions regarding future science study. Students who participated in the project-based learning unit, *Project Mars*, received additional survey questions about their perceptions of their skills and understandings about the practice of science.

The purpose of the pre- and post-project survey was twofold. One was to establish the level of understanding of the nature of science and attitudes towards science among the participating students. The second was to track any differences between pre and post surveys.

Post-project interviews with teachers were semi-structured and related to affect rather than effect. The objective here was not to compare the interviews with the survey results, but to provide an understanding of how and why the project worked or not, so changes could be made before scaling up the project.Quantitative (survey) and qualitative (interview) methods provide different information, insights from the latter often being deeper than the former (Creswell, 2004, Schram, 2014). Since the focus of this project was on the science inquiry skills and science as a human endeavour strands of the curriculum, the main purpose of the teacher interviews was to gauge how the project met these teaching needs and also to find out whether the teachers had observed any changes in the students' understandings of these curriculum strands after completing the project.

The data was collected and analysed by an education researcher (Fergusson) who did not participate in the project in order to provide an independent insight.

Participants

Four pilot schools in New South Wales, Tasmania and South Australia participated in the project research in 2013 and 2014. A total of 537 students returned pre-project surveys, and 218 returned valid post-project surveys. From those, 168 could be matched pre- to post-project participation. This represents a 31% return in post-project surveys, which is above the expected 20% generally found in education projects (Westwell, 2014).

Survey results

Students returning a pre-project survey were generally positive about learning science, with 84% agreeing that they learned interesting things in science lessons. They were not the top science students, with only 36% agreeing that science was one of their best subjects and 51% agreeing that they got good marks in science. There was 39% agreement that they would like to study science at university and 26% agreement that they would like to have a job working with science. In general, for all three of the education programs as a whole, little change was seen pre to post except in two categories:

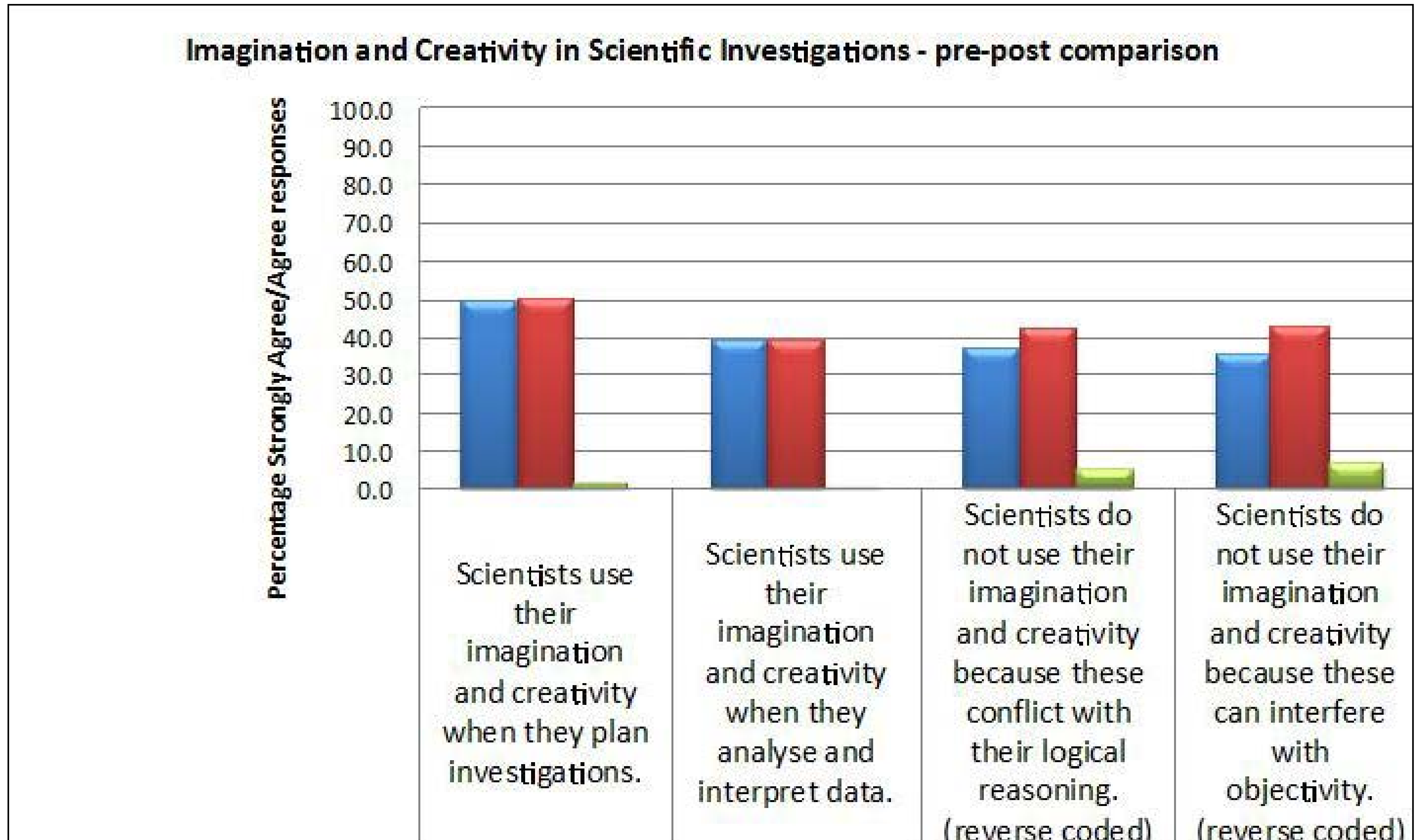
- understanding of creativity and imagination in science
- understanding that the scientific method is not singular or linear.

Imagination and creativity in scientific investigations

Fergusson et al. (2012) reported on the project where students significantly increased their understanding of the role of creativity and imagination in scientific investigations. They also found that the level of understanding of the role of imagination and creativity in science was low with only 30% of students showing understanding in the pre survey. In the current project, 36 of the students completing the pre-project survey showed understanding, that is, they agreed or strongly agreed with statements relating the role of imagination and creativity in science.

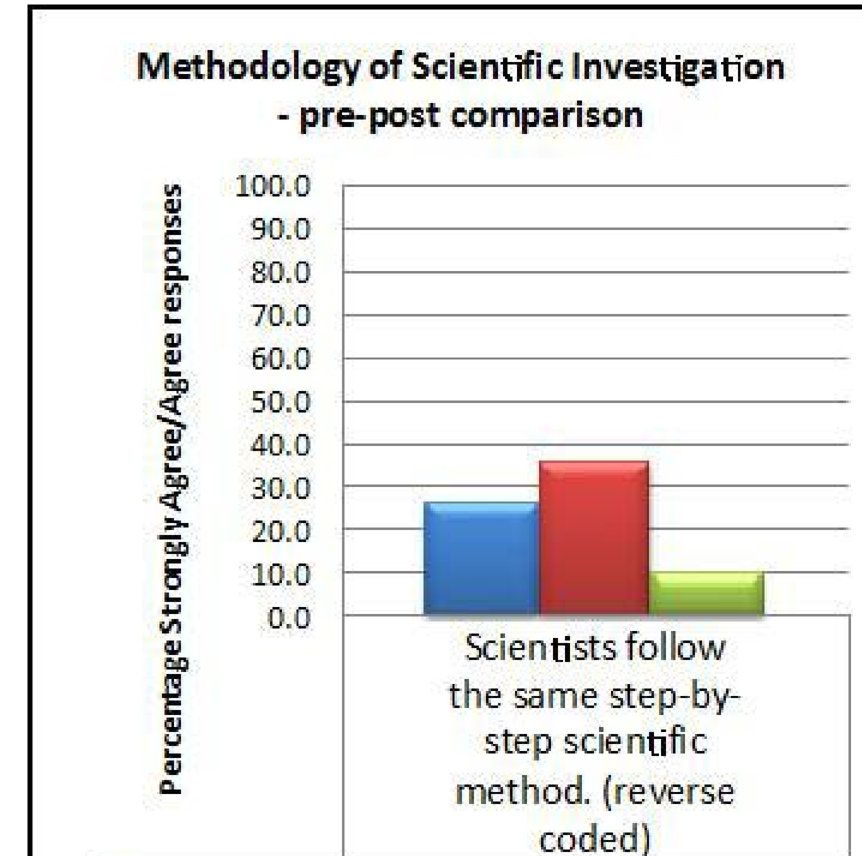
Figure 1 shows the statements relating to the role of imagination and creativity and the difference in the percentage of students who agreed with the statements in the matched pre- and post-project surveys. The level of difference ranged from zero to six and a half per cent. Two of the statements have been reverse coded to facilitate comparison of scale items. Reverse coding a negatively worded item ensures that all of the items are consistent with each other, in terms of what *agree* or *disagree* implies. The difference between these pre and post- project survey scores was not significantly different.

There was an increase in students' understanding that there is no single step-by-step process followed by all scientists, a common misconception among students. This is shown in Figure 2, where there is a nine and a half per cent increase in understanding from the pre to post-project test. Once again this item has been reverse coded to reflect that disagreement with the statement indicates greater understanding, that is, disagreement is similar to agreement that *scientists do not follow the same step-by-step scientific method.* This difference in the pre-and post-project survey results is statistically significant according to a paired samples t-test, which showed a significant increase in mean values from pre-test (M = 2.73) to post-test (M = 2.98) at a significance level of p = 0.01, although the effect size (d = 0.24) was small.



	Scientists use their imagination and creativity when they plan investigations.	Scientists use their imagination and creativity when they analyse and interpret data.	Scientists do not use their imagination and creativity because these conflict with their logical reasoning. (reverse coded)	Scientists do not use their imagination and creativity because these can interfere with objectivity. (reverse coded)
Pre	48.8	38.7	36.9	35.7
Post	50.0	38.7	41.7	42.3
Percentage shift pre to post	1.2	0.0	4.8	6.5

Figure 1: student perception of scientist's use of imagination and creativity: pre and post-project comparison



	Scientists follow the same step-by-step scientific method. (reverse coded)
Pre	26.2
Post	35.7
Percentage shift pre to post	9.5

Figure 2: student perception of scientist's methodology of scientific investigation: pre and post-project comparison

Responses to additional open-ended survey questions

When asked how their understanding of how science is done has changed as a result of the *Mars Lab* project, students' comments include:

Through being a part of this project, I have realised that many scientists come together to help each other and work on a similar investigation. Communication skills are vital for scientific investigations.

I understand now that in order to discover new information and form new theories, it requires rigorous experimenting and observation skills.

I realised that science could be done in a huge variety of ways, and it can be very fun!

I used to think that science was just mixing chemicals.

I believe my most significant realisation was of the fact that creativity is used in so many steps of the scientific process and that imagination is vital to scientific progress.

Results of teacher interviews

Most of the teachers who were involved in the *Mars Lab programs were interviewed.*

In his 2014 report, *Science, technology, engineering and mathematics: Australia's future*, the Chief Scientist recommended that the Australian Government:

- Provide all pre-service and in-service STEM teachers with training and professional development opportunities to deliver contemporary science using contemporary pedagogy, with a focus on creativity and inquiry-based learning, more like science is practiced.
- Develop scientific literacy in schools by: helping schools to teach STEM as it is practiced, in ways that engage students, encourage curiosity and reflection, and link classroom topics to the *real-world* (Office of the Chief Scientist, 2014, p. 23).

The *Mars Lab* project is one way for this to occur. Teachers and students have expressed the opinion that the project made them more aware of the way that science is actually done. Teachers have also commented on the rarity of such opportunities for students to experience doing real science as opposed to learning science. Typical teacher comments include:

The other thing that they told me that they loved, they were like, it was so good that we learned all these different concepts and all this different content and it was to come to a common outcome, it was to achieve something. And their feeling normally about science is that they just sit there and copy stuff from the board and learn all these random concepts.

Teachers also recognised that students had gained a different view of science from doing the *Mars Lab* project. An example they gave was:

I think the students gained the ability to extrapolate from real observation or to know the difference between a scientific fact and a claim that's based on evidence. Because most of the time we present them with a scientific phenomenon or underlying principle and we might show them something that supports that and so we are kind of saying this is true, here watch this, see, it is true. Whereas in Project Mars *they asked a question and then they had to gain some evidence and then interpret that evidence and make a claim based only on that evidence and then possibly look outside and say we think this is true because of what else we've learned in terms of what other scientists are saying or what we know is true.*

Teachers also commented on the engaging and motivating aspect of the Mars Lab project, for example:

They [students] enjoyed it. They were really motivated to get in and have a go so being engaged in science is the key motivator for what we do and I think if you get kids asking questions and looking at science in a really practical way it's really good. So I think, if anything, they understand how scientists work and for me that's huge because you can just look at that on a poster or a video or whatever and say well this is what scientists do but then it's not quite the same as actually Wow! these people do THIS for their job and you think, yeah, they do and these are really interesting people.

Discussion

Although there was little change in the pre-to post-project survey results, the open-response questions in the student post-survey and the teacher interviews are able to shed more light on the effects of this inquiry-based learning project. The project was designed in consultation with teachers, who perceived a need for resources to support the *science* inquiry skills and *science* as a human endeavour curriculum strands. It is not surprising, therefore, that both student and teacher comments indicated that students had demonstrated greater understanding in these areas, which are more difficult for schools to resource and assess.

Teachers have expressed their appreciation for a project that allows them to involve their students in real science and have reported their observations that students have shown a greater awareness of the nature and processes of science after doing the project. Many of the students have also been able to demonstrate, through their comments, that they have a greater insight into the work of scientists.

With so much science assessment focused on students' understanding of the content of science, it would not be surprising if students did not recognise the learning that took place in relation to the other two strands of the curriculum. One teacher summed it up this way:

> *That pure discovery learning based on data is really valuable…it would be hard for them [students], I think, to articulate that.*

Conclusion

The implications for engaging students in scientific endeavour are clear from the project and research. The *Mars Lab* is a world-class fully-tested resource developed in collaboration with science teachers from a wide range of schools. It is now open to all schools in Australia. *Mars mission five* and *Sixty minutes on Mars* will have fees from 2015 (around the cost or less of an education workshop at the Museum). *Project Mars* will be free to schools that are willing to participate in ongoing research on project-based learning.

Further information

More information is available at the *Mars Lab website*.

The lead author of this paper can also be contacted at *carol.oliver@unsw.edu.au*

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