STEM EDUCATION BRAINSTORMING WORKSHOP SUMMARIES

28th July 2015 Brisbane

Hosted by The Royal Society of Queensland

The following summaries were submitted by participants prior to the workshop to inform discussion. For consistency, some changes have been made to formatting. They are listed in alphabetical order of the contributor. Titles are as indicated by the authors.

STEM EDUCATION IN QUEENSLAND STATE SCHOOLS

By Betty Baram

The Queensland Government is committed to strengthen the state's knowledge-based economy through the creation of new products, services, jobs and industries, and to improve the teaching of science, technology, engineering and mathematics (STEM).

Education is the key to preparing young people to succeed in a global economy and this success is underpinned by STEM capabilities.

The Department of Education and Training (DET) recognises the important role of school education in meeting Queensland's need for specialist STEM practitioners – to address the future workforce needs of industry, to strengthen the knowledge-based economy and to support continuing prosperity.

To address the Government's STEM commitments, DET is reviewing existing practices in the teaching of STEM subjects, including a survey of all state schools and an extensive literature review capturing world-wide best practice in STEM education.

DET has formed a dedicated STEM team with a focus on ensuring every student is succeeding in STEM. The work of the team will build on a continuing collaboration with the Office of the Queensland Chief Scientist and other key stakeholders in STEM.

DET aims to:

- build teacher capability in STEM subjects
- lift student achievement in STEM subjects
- increase student participation in STEM in Years 11- 12 and beyond.

To support each school's decision-making about the best strategies to improve STEM in their school, DET will:

- identify and showcase successful teaching practices and school approaches to improving STEM learning
- promote and support the broad range of opportunities to optimise student success available through partnerships with STEM practitioners in industry, government and higher education.

The DET STEM activities are underpinned by *Every student succeeding*—the State School Strategy for 2014 to 2018. It promotes a model of collaborative empowerment to scale up improved performance across the system.

In the *Every student succeeding* model, school communities are seen as being best placed to make decisions about the most effective ways to meet STEM challenges in their context and to improve student achievement and participation in STEM subjects.

Schools are supported to drive their own STEM improvement agenda tailored to the local context and designed so that student achievement continues to be enhanced over time and innovative practices are ongoing. In this way, sustainability is a key consideration in schools' decision-making process.

To maximise the outcomes for students, the approaches selected need to be evidence-based, use high-yield teaching strategies, and meet diverse needs in a targeted way. Schools leaders and teachers are encouraged to work together within and across school communities and with external partners.

Principals are recognised as the key drivers of change in schools and are encouraged to lead a whole-school approach to STEM and promote the value of STEM education to their school community.

The recently awarded *STEM in Action* grants support schools to:

- implement their own research-based innovations focussed on improving STEM teaching and learning
- collaborate with other schools and community partners and share effective practice.

Systematic curriculum delivery is a proven part of improving student achievement and it is important that STEM education maintains the integrity of individual learning areas as described in the Australian Curriculum as well as supporting interdisciplinary approaches to real-world contexts.

DET supports school implementation of the Australian Curriculum with comprehensive resources for curriculum planning and delivery. The relevant Australian Curriculum learning areas are Science, Mathematics and Technologies. Digital technologies (including computer programming) and Design and technologies are subjects within the Technologies learning area.

DET will continue to improve access to targeted professional development in STEM through a number of initiatives. One example is the *How to teach mathematics* and *How to teach science* professional learning online coaching modules that provides Queensland teachers and pre-service teachers with research-validated information and advice to build knowledge, skills and understanding of how to teach Mathematics and Science from Prep to Year 10.

A key activity of the STEM work is in establishing and strengthening partnerships. Partners have a role in increasing teacher confidence and competence to teach the STEM subjects and ensuring rigorous and effective approaches used to improve student engagement and achievement.

Through the STEM cross-sectoral reference group and ongoing collaboration, DET is strengthening partnerships between the Office of the Queensland Chief Scientist and the wider STEM community to optimise outcomes for students.

The current range of partners and collaborators includes:

- SPARQ-ed and Wonder of Science collaborations with the University of Queensland Diamantina Institute that bring together quality researchers with science students and their teachers
- *Scientists in Schools* program designed to increase the number of students studying science subjects at university
- National Science Week
- CSIRO centres and professional development for pre-service teachers
- CSIRO's *Lighting pathways for Indigenous students* partnership with the BHP Billiton Foundation
- The Queensland Museum
- professional associations.

DET will work to provide clear and coordinated information to schools and to ensure the activity and services of partners aligns with DET's goals of building teacher expertise; inspiring students to take STEM pathways and fostering improved student achievement.

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QUT SCIENCE AND ENGINEERING FACULTY (SEF): WIDENING PARTICIPATION (WP) PROGRAM

By Maria Barrett

A HEPPP-funded initiative to build awareness and aspiration for tertiary studies and careers in STEM for students from disadvantaged backgrounds.

Aims:

- Demystify the uni experience
- Generate interest for tertiary studies in STEM
- Create awareness of careers in STEM
- Improve demand for STEM-enabling school subjects

Summary of 2014 activities (taken from: 2014 End of Year Report to QUT Equity Services)

Workshops and other activities were presented by undergraduate and postgraduate QUT STEM students to a total of 22,250 students from years P-12. These activities are offered free to schools in the Moreton Bay Regional Council area.

Breakdown of activities for 2014:

- Extreme Science and Engineering Van – 320 workshops presented to 8,564 individual students
- High School Excellence/Transition days – 74 workshops presented to 870 individual students
- Explore Uni – 172 workshops to 5,135 individual students
- STEM Futures – 21 sessions to 541 individual students
- STEM High School Engagement on-campus workshops – 4 visits – 86 students
- Specialised STEM Events – National Science and Numeracy Week performances, S&E Challenge, Imagine IT, Go 4 IT gURL, Power of Engineering, The Science Experience, Murrumba Maths Tournament, RNA Rural Discovery Day, Excellence/Feeder Days – 4,304
- General community STEM events – Ekka National Science Week booth, Stand Up maths comedy, Robotics @ QUT – 1,320 participants.

SEF WP's *STEM Excellence Program* partnership with Tullawong State High School received the 2014 Peter Doherty Science Education Partnership Award. This Queensland Government award is recognition for outstanding and innovative contributions to science education in Queensland.

In addition to this, SEF WP staff presented at the following local, national and international conferences in 2014:

- Australian Science Communicators Conference, Brisbane – 5 February – Conference Paper: Maria Barrett - *STEM Futures: an innovative approach to guiding career choices for high school students*
- STAQ Science is Primary Conference, Brisbane – 15 March – Workshop: Maria Barrett and Dr Christina Chalmers – *Robotics, STEM and Fair Testing*
- STEM in Education, Vancouver, Canada - 14 July - Conference paper: Maria Barrett- *University STEM School Engagement- Supporting Graduate Capabilities*

Insights:

- Evaluation – ensuring consistency; reach; response – target teachers, students, university ambassadors
- Tracking success – how do we know the program is achieving aims in engaging students, teachers and community in STEM and promoting study and careers?
- Addressing the needs of an ever-changing future and promoting the value of STEM
- Sustainability – how do we ensure continuation of outreach to these areas post-grant funding?
- Training of university ambassadors – need to ensure quality in delivery and consistent messaging.

Maria Barrett, 16 July 2015
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CQ JUNIOR ROBOTICS COMPETITION

By Jason Bell

From robot vacuum cleaners, self-parking cars and automatic irrigation systems to security systems and industrial manufacturing, increasing levels of technology are becoming a critical part of our everyday lives. The skills required to develop and understand these systems require knowledge in the disciplines of science, technology, engineering and mathematics (or 'STEM' education).

Make learning fun

To foster an interest in STEM at the grass-roots level, the CQ Junior Robotics Competition brings students together for a community-based educational initiative. CQUniversity has hosted this annual event since 2003, attracting from 70 to 200 students per year. The event is based on the state and national RoboCup Junior Competition. Consisting of different categories including rescue, soccer and dance, the event is open to primary and secondary students. The competition is hotly contested and many participants have progressed to competitions at the state and national championship level. See www.cqjrc.cqu.edu.au for further information.

Educational robotics has a multidisciplinary focus across technologies such as computing, mathematics, software programming, electrical and mechanical engineering, artificial intelligence, communication, sensor technology, educational technology, image processing and game theory. It requires participants to demonstrate teamwork and knowledge across the different discipline areas, whilst overcoming challenging real world situations.

That sounds like pretty advanced education, right? But to kids, it's just good fun. It's promoting STEM at the level that's needed to support society's future needs whilst engaging participants in a way that appeals to their current interests.

Identify and address potential barriers to learning

Within Central Queensland, schools and students are very keen to get involved with robotics however feedback indicates a number of potential barriers to uptake. Some of these include:

- Teachers often lack the specific robotics skills and knowledge required to mentor students
- Teachers and students often don't have access to the required equipment and resources within their school and
- Many schools struggle to find the time and space within the curriculum to support programs of this nature (and therefore rely on the personal time and interest of specific teachers to engage students in extra-curricular activities).

Support key influencers to overcome the challenges

To overcome some of these potential challenges, the CQ Junior Robotics Competition trialled a discovery program called 'discover the world of robotics'.

To support local schools to get involved in the competition, the program offered 10 schools the opportunity to participate in a fully funded professional development activity. Over 30 nominations were received from local schools. The program included:

- a hands on full day learning workshop with world renowned robotics educator Dr Damien Kee (with one teacher from each of the 10 participating schools)
- a student focussed robotics excursion (with up to 3 students per school) and
- a heavily subsidised robotics kit for the school.

Overall, the pilot program proved to be a huge success. Teachers returned to their schools with practical skills and knowledge they could use to teach their students. Whilst students discovered new confidence and experience they could use to inspire others as school based mentors. The program was made possible by funding from CQUniversity and a grant from the Department of Education and Training (CQ Gifted and Talented). Their generous support enabled 10 schools to enter the competition for the very first time. As a result of the program, the 2015 competition is likely to achieve record participation levels, more than doubling the number of students from the previous year.

There is considerable demand for initiatives of this kind, however future programs are heavily dependent on available funding.

Where to from here
The students of today are the scientists, technologists, engineers and mathematicians of the future… they are our innovators and problem solvers.

The CQ Junior Robotics Competition has succeeded by engaging these very kids (and their schools) in a fun, supportive and community based environment. And in doing so, has provided a clear pathway into further STEM education. This has been evidenced by many of the past participants progressing to tertiary studies. So how can we encourage more of this sort of involvement?

To sustain and grow interest in STEM, our experience indicates that further support is required at the grass-roots level. Some key questions that need to be considered and addressed include the following:

- Are there opportunities to ensure further school-based technology programs to be recognised and supported within the wider educational curriculum?
- Is it possible to provide teachers with greater access to the professional development required to support higher-level STEM initiatives?
- How can we ensure schools are appropriately funded and equipped to support specific learning in advanced STEM areas? and
- What else can be done to get kids excited and actively engaged in interactive, real-world, learning opportunities?

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WONDER OF SCIENCE: BUILDING KNOWLEDGE, SKILLS AND PASSION FOR SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM)

By Robyn Bull

The Wonder of Science program builds knowledge, skills and passion for science, technology, engineering and mathematics (STEM) in Queensland's young people.

It is creating aspiration for STEM education – thus generating capacity for technical innovation in Queensland and indeed, Australia.

Wonder of Science is demonstrating to Queensland students that science is fun, exciting and rewarding. It is opening their eyes and minds to the wonder of science and the diverse opportunities for further education and STEM related careers.

The Wonder of Science program:

- is aimed at students in the middle years of schooling (Years 5 – 9)
- challenges students to respond to real life scenarios with projects that spark their natural curiosity and are fully aligned to the Australian Curriculum: Science
- mobilises young enthusiastic postgraduate students as Young Science Ambassadors for school visits, mentoring and assisting at student conferences
- utilises university facilities and resources to host student conferences
- focuses on students in regional, rural and Indigenous communities.
- is supported by a website http://wonderofscience.com.au/

Wonder of Science works because:

- it capitalises on the natural curiosity of students in investigating and understanding real world scenarios in response to challenge tasks fully aligned with the Australian Curriculum: Science
- the challenge tasks encourage an open inquiry approach to teaching and learning that builds higher order thinking skills and scientific understanding
- inspirational Young Science Ambassadors recruited from postgraduate research students at Queensland universities visit schools and support students and their teachers with the challenge tasks.

The 2014 Annual Report which includes evaluation findings on the program; and further information and materials are available to download from the website.

Evaluation of the 2014 Wonder of Science program showed:

- it is positively engaging students in regional and rural Queensland in STEM education
- it is positively influencing student attitudes towards STEM studies in Years 11 and 12
- students learn more and are developing higher-order cognitive skills through engagement with the challenge tasks and subsequent presentation of their research findings
- students develop deeper understanding of potential STEM career pathways through access to young enthusiastic and passionate scientists – the Young Science Ambassadors
- the opportunity for Young Science Ambassadors to work with students and communities is valuable for all – it is improving access to scientists for regional and rural Queenslanders and has a positive effect on career development for the Ambassadors.

Wonder of Science was initiated by the Queensland Division of the Academy of Technological Sciences and Engineering, in recognition of the need for students from all areas of Queensland to be exposed to the potential of STEM studies and career pathways. The program now sits within The University of Queensland Diamantina Institute. Findings from the evaluation completed by James Cook University on the pilot of Wonder of Science in 2012 indicate the 'transformative potential' of the program. This report is also available on the program website: www.wonderofscience.com.au/about.

Wonder of Science brings together education, government and industry through its support from the Queensland Department of Education and Training, as well as companies and organisations across Queensland who give generously to the communities they work in. The investment of these organisations in Wonder of Science is a tangible contribution to the future of Queensland and its communities.

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SCIENTISTS IN SCHOOLS - INSIGHTS FROM PARTICIPATING IN THIS PROGRAM

By Satish Choy

Introduction

As a scientist in CSIRO's "Scientists in Schools" program (SiS), I spent several years with primary and secondary schools in the Brisbane area and found it to be very rewarding. I wanted to make a difference. Given my own background of not having any career councillors in school and, no idea about what 'real scientists' did, I stumbled my way through school and university until I somewhat accidently fell into place of making a science career out of one of my hobbies.

As a child growing up in Fiji, I was very fortunate to live on a small island and next to a pristine tropical rainforest stream and a fringing coral reef. I loved exploring the stream as well as the numerous reef tidal pools each time the tide went out. At that time and, until university, I did not know one could become an ecologist and do this for a living! Like many parents, mine wanted me to be a doctor but I wanted to be a pilot. I applied for both and got the scholarship for pilot training first and so started training for my pilot's licence. However, after about a month into this training I also got a scholarship to do medicine overseas. My parents were ecstatic and asked me to leave the pilot training, which I did. However, due to the then Government's 'affirmative indigenous policy' my overseas place was passed on to an indigenous student and I was told to do the local Diploma in Medicine program, which I refused. The Ministry of Education then offered me a BSc degree program at the local university, which I very reluctantly took. It was not until my third and final year into the BSc program, when I did the Marine Biology course that I knew I had found my vocation! Even after I got an academic position and obtained my PhD in Marine Biology my mother still could not understand that, while I was a 'doctor', I could not treat patients! Yet she acknowledged the fact that I was getting paid for what I loved doing and she loved the fact that I had not really grown up – 'still pottering around in the streams and sea' she used to say. I also used to bring home very fresh dinner!

Since my time in school, I know that many improvements have been made in schools to motivate students to take science: career counselling and advisors, subject streams and options, multiple pathways, etc. The SiS program seemed an interesting innovation to me, hence my interest and participation in it.

SiS Program

CSIRO's Scientists and Mathematicians in Schools is a national program that creates and supports long-term partnerships between primary or secondary students, school teachers and scientists or mathematicians. Partnerships are flexible to allow for a style and level of involvement that suits each participant. The Scientists in Schools (SiS) program is open to research scientists and engineers, postgraduate science and engineering students, and professionals working in applied sciences, such as doctors, vets and park rangers. The Mathematicians in Schools (MiS) program is open to anyone with a maths component to their university degree, and who uses maths as part of their working life. This includes economists, accountants, surveyors and mathematical scientists, among others. For more information, please see: http://www.scientistsinschools.edu.au/.

Since the program began in July 2007, a total of 4619 partnerships have been established in 2368 schools across Australia. Currently, 1799 partnerships are active in 1263 schools as at 30 June 2015. The proportions are 61% in Primary Schools and 39% in Secondary Schools of which 18% are in Catholic Schools, 18% in Independent Schools and 64% in Government Schools. Regional proportions are: ACT: 4.4%, NSW: 29.9%, TAS: 6.6%, VIC: 23.4%, SA: 8.3%, NT: 1.8%, WA: 9.9% and QLD: 15.7%.

Aims of the SiS Program

Through the establishment of sustained and ongoing partnerships between scientists and school communities, the project aims to:

1. bring the practice of real world science to students and teachers
2. inspire and motivate teachers and students in the teaching and learning of science
3. provide teachers with the opportunity to strengthen their knowledge of current scientific practices
4. enable scientists to act as mentors or role models for students

5. broaden awareness of the types and variety of careers available in the sciences

6. enable teachers and scientists to share ideas and practices with other teachers and scientists

7. increase scientists' engagement with the broader community, thus raising public awareness of their work and its social and economic importance.

The scientists can provide a host of services such as: links to 'real science', arrange a class visit to their workplace or another science site, give a presentation to students, help run a school science fair, mentor students who are working on science projects, field trips and excursions, answer students' questions by email, help a teacher run science activities with students, and provide support and information to teachers.

Benefits of the SiS Program

Based on the SiS newsletters, scientists who have worked with schools have found it very rewarding. Their own enthusiasm for science is often increased through contact with students' curiosity and engagement. Many scientists also feel a sense of achievement in nurturing and inspiring students' interest in science as a career option and as part of their everyday lives.

'I loved your story and your passion. I now know that I want to become a scientist.' Student, QLD.
'Our scientist delivered a wonderful presentation to my Year 8 class and they couldn't believe what a career in science could offer them' Teacher, QLD.
'Student and teacher enthusiasm were great. Lots of questions!' Scientist, QLD.

My own experience has been similar and I believe that the students, teachers and I have all benefited. Students were very keen to know what I did and how I got there professionally, what were the pros and cons of being an aquatic ecologist and what options did they have if they could not 'make the grade'. None knew that you can initially enter a lower entry-level university program and then later change to a program that was of interest to you, provided you did well. Some said that *"there are too many subject options without proper guidance and advice on what to take for what"*. There is also a top-down approach and many teachers and students feel that they have not been adequately consulted on what worked for them. How about asking successful students what worked and what didn't? I am not aware of any surveys done on this matter. Inter-generational differences and new technologies also need to be taken into account to enhance motivation and passion for science among students, not only for a profession but also for science literacy.

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QUT YUMI DEADLY CENTRE

By Prof. Tom Cooper

I am Director of the YuMi Deadly Centre, a research centre in the Faculty of Education at QUT that works with schools to improve mathematics teaching to enhance student mathematics outcomes. Thus, my involvement in STEM is through mathematics teaching and learning. I am a member of QUT's STEM Education Network and I was also a member of a working committee for the National Indigenous Engineering Summit coordinated by the Melbourne School of Engineering, University of Melbourne, which I attended on 18–19 June 2015. In the past, I have worked in VET projects with Indigenous adults training for trade certification. I have experienced cases of strong success in both schools and VET.

My position with regard to STEM is that: (a) student participation in STEM is highly influenced by performance in mathematics; (b) increasing the pool of eligible students by improving teaching and learning of mathematics F–12 has to be one of the major ways to increase student participation in STEM; and (c) an important component of this position is to increase the pool of eligible students in Indigenous and low SES schools.

YuMi Deadly Centre (YDC) Mathematics activities

YDC was funded by government grants in 2009 to produce a mathematics teaching and learning pedagogy to improve the capacity of Indigenous and low SES schools to effectively teach mathematics in Years F-9. This pedagogy is called YuMi Deadly Maths (YDM). It is the basis for three programs:

1. YDM Teacher Development Training (TDT): This is a two-year program to train teachers in the YDM approach. The program involves forming schools into clusters and providing 12 days of in-service teacher training supported by resource books and a Blackboard online learning site.

2. YDM Accelerated Inclusive Mathematics (AIM): This is an application of YDM to students in Years 7-9 who have Year 3 knowledge at best. It provides a three-year program to accelerate the learning of these students to where they complete Year 9 able to access mainstream Year 10. It consists of three years of in-service teacher training, a total of 18 days.

3. YDM Mathematicians in Training Initiative (MITI): This is an extension of YDM to deep learning of powerful maths ideas to enable students to have the motivation and capability to complete Mathematics B and C. It develops pedagogical skills and provides rich tasks for Years 7-9 and supports effective and motivating teaching for Years 10-12. It consists of 12 days PD.

The YDM pedagogy is based on developing teacher quality, not textbook materials. It sees mathematics as a structure, connected together in big ideas and sequenced in a manner that logically builds that structure. Teaching is based on ensuring that first ideas and later ideas all integrate together in vertical sequences of learning from strong foundations. The pedagogy also uses an active learning approach which cycles through motivating contexts, body-hand-mind abstraction, consolidation and connections, to reflection and extension. It emphasises working with community and being two-way strong in using resources from the community in teaching. It encourages flexibility by schools to ensure the program meets the particular needs of the school. It has been shown to be effective in special schools and mainstream schools as well as Indigenous and low SES schools.

Recent projects

In the last five years, YDM TDT has been and is being provided to 175 primary and secondary schools, AIM to 28 secondary schools and MITI to 13 schools. Projects were initially funded by Government grants but they are presently being funded by the schools themselves. Analysis of data collected has found that Indigenous and low SES students react positively to the YDM pedagogy. State Government analysis found that Indigenous students performed better in mathematics when taught by an YDM-trained teacher. Teacher responses show that YDM improves attendance, engagement, classroom talk and performance. A Queensland Government Auditor report on out-of-field teaching acknowledged YDM as effective in training out-of-field maths teachers.

As a teacher-quality oriented program, YDM uses a train-the-trainer approach which relies on in-school follow-up to PD sessions, particularly school and administrator support for in-school training and trialling with respect to YDM ideas. Data shows that the YDM approach can strongly and positively change mathematics outcomes where there is: school emphasis on mathematics renewal as a priority, an administrator led school plan for implementing YDM, and teachers willing to lead the change.

Insights

My insights are with respect to experiencing success in schools and TAFEs, with and without YDM, that were attempting to renew and improve their mathematics in order to give their students more opportunities in tertiary study and employment. They are as follows.

1. There is an immediate need for support projects working with schools to improve maths outcomes for students from Foundation to Year 12 so that the pool of students able to undertake tertiary STEM is increased. Attempting to maintain STEM participation by trying to change the interest of existing Years 11–12 students is only a short-term and partial solution.
2. This could allow the shortfall in STEM participants to be filled from existing Australian low participation groups through education not by advertising overseas. In particular, this includes Indigenous and low SES students so that a long term process can be put in place.
3. With appropriate renewal programs, school and TAFE education can be very successful in improving teaching and learning, in general and in mathematics, for Indigenous and low income schools. Such programs, if maintained over time, can significantly increase student performance in mathematics to a level at which STEM careers are achievable. It takes the second year before many YDM teachers and schools start to see what the program can do.
4. Appropriate renewal programs should be based around school processes similar to Chris Sarra’s stronger-smarter program and mathematics pedagogies similar to those used in YDM. These programs should focus on teacher quality and need support over time (more than 3 years) and stability with administrators and teachers, and with the mathematics program.
5. STEM participation mathematics needs a focus on mathematical understanding, not rote learning; even elite schools have problems here. It needs to focus on context, investigation, relationships and schema and not context-less “little bits” of knowledge. In many schools it also needs a focus on family and community.
6. A variety of alternative pathways need to exist to enable a wider group of students to reach STEM employment. In particular, appropriate VET courses can be a stepping stone for University. Further, special entry and supported undergraduate courses such as that being set up by the University of Melbourne would be an advantage.
7. Partnerships between industry and schooling should be encouraged so that schools in areas where STEM people are required can be given extra support. This can be positive for employment in that the STEM people are used to living where the work is and may stay longer.

<u>Special note</u>: YDC was also involved in a pilot project funded by Rio Tinto Alcan Community Fund involving a Year 4 class of an Indigenous/low SES primary school. Students participated in a specialised, construction trades-based learning program with all literacy, science and mathematics learning related to construction learning experiences. This had a very powerful positive effect on students, with the school nominated as a state finalist in the 2011 Education Queensland Showcase Awards for Excellence in the Middle Phase of Learning, and the project winning a Group Training Australia Partnership Award in 2012. This is a project of which I would like to see more.

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ENGAGING A STUDENT HANDS ON

By Simone Cross

Science engagement is crucial to reversing the decline in the uptake of Science (STEM) subjects, choosing Science as a career and understanding the importance of Science (and STEM). This is even more critical in Queensland, where we ask students to make career-defining decisions with very little exposure to real science. By 2050 it is predicted that the world will need around 30% more scientists to drive the innovation needed in a rapidly changing world.

In a 'Day in the life of a Scientist' program, senior science students and teachers visit a dedicated education laboratory in a medical research institute. Participants conduct a curriculum-aligned experiment, make direct contact with young scientists and assess state-of-the-art biotech equipment.

The Scientist for a Day program is:

- Finding a cure from the rainforest (in the lab)
- Talking to a young scientist
- Seeing lasers, micro-lenses and DNA chips in use
- Career speed-dating

There are measurable changes in student and teacher attitudes to considering a career in a STEM (research) related career before and after real life exposure to working science.

Findings: After a hands on experience of working science, there is up to a 70% increase in students' willingness to consider a science career. There is up to a 30% increase in a teachers' willingness to translate that experiment to their classroom. Interaction of scientists with regional indigenous students has increased their willingness to engage with medical health researchers.

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STUDENTS PERFORMING ADVANCED RESEARCH QUEENSLAND (SPARQ-ED)

By Dr Peter Darben

Students Performing Advanced Research Queensland (SPARQ-ed) is a unique educational outreach partnership of the University of Queensland Diamantina Institute (UQDI) and Queensland's Department of Education and Training (DET). It aims to engage school students in the scientific process by connecting school communities with UQDI's medical researchers. The model on which SPARQ-ed operates is one where students of all ages from schools across Queensland can contribute to the work done by UQDI's world ranked researchers. SPARQ-ed is based in a purpose-built facility located on the ground floor of the Translational Research Institute (TRI), consisting of a PC2 rated teaching laboratory and online learning hub.

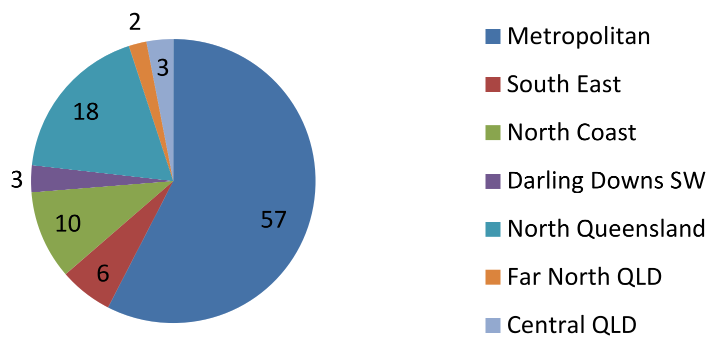
In its six and a half years of operation, SPARQ-ed has provided 315 workshops for 7642 students and 141 teachers from 195 schools across Queensland. The programs offered include:

- *Research Immersion Programs* are unique, five day workshops based around a project designed in conjunction with one of UQDI's research groups, with the aim of the results of each project making some contribution to the work done by that group. These programs are offered to senior secondary science students and their teachers on an individual basis. In addition to the experimental part of the program, participants have the opportunity to attend research seminars by visiting scientists, take part in tutorials in library research and science communication and, at the end of the week, deliver the results of their research to students and staff at UQDI. Students completing an additional component are eligible to receive a point under the University of Queensland's bonus Rank Scheme. Unlike offerings at other science outreach centres, the research immersion programs provide an opportunity for students from outside metropolitan Brisbane to take part, with travel and accommodation scholarship available to students from regional and remote Queensland, supported by funds from a generous donation by the Lions Medical research Foundation. Since 2009, 442 students and 25 teachers from 79 schools have taken part in 42 research immersion programs based on 32 different projects.
- *Cell and Molecular Biology Experiences* are shorter workshops for senior secondary science students based around single techniques routinely performed in modern laboratories, but which are impractical to carry out in traditional school settings. These are conducted for whole classes of up to 25 students. Since 2010, 2157 students, 50 teachers and 19 school scientific officers from 30 schools have taken part in 97 cell and molecular biology experiences.
- *Upper Primary / Junior Secondary Workshops* are context-based activities centred around engaging topics for younger students (eg. microscopes, DNA, forensics, microbiology, cell biology, basic physics, basic chemistry and light). Since 2010, 175 workshops have been run for 5043 students from 57 schools.
- *Outreach* – as a major point of connection between the education and research communities, SPARQ-ed provides a number of outreach services, including the provision of online learning materials, school staff professional development, supplying research staff as guest speakers and judges for school science fairs, community science events and tours of the scientific facilities at the TRI.

SPARQ-ed is jointly supported by UQDI, which provides vital infrastructure support and access to research staff, Queensland's Department of Education and Training (DET) via the Queensland Academy for Science Mathematics and Technology, which employs the teaching staff, and the Translational Research Institute, which provides laboratory space and additional infrastructure support. In addition to this, SPARQ-ed receives a generous donation of $20,000 p.a. from the Lions medical Research Foundation in recognition of its role in fostering the next generation of medical researchers. SPARQ-ed also draws upon the scientific and research staff of the TRI's other research partners, QUT's Institute for Health and Biomedical Innovation (IHBI), Mater Research and Princess Alexandra Hospital Research, for development of programs and workshops.

SPARQ-ed has seen a steady increase in numbers of students engaging with its programs and workshops, particularly in the Cell and Molecular Biology Experiences and Upper Primary / Junior Secondary workshops. Due to the extended nature of the research immersion programs and the support provided by the LMRF Scholarships, a substantial proportion of these students come from outside Brisbane Metropolitan Region (see Figure 1).

Figure 1 - Distribution of Student Participants in Research Immersion Programs by Region (%) 2009-2015



SPARQ-ed is staffed by two registered science teachers employed by DET. Dr Peter Darben is the SPARQ-ed Coordinator, while David Pearce is the SPARQ-ed Teacher. Their roles are to translate the work done by TRI researchers into experiences which are understandable and relevant to Queensland students. David in particular has been responsible for the development of new and engaging workshops for upper primary and junior secondary students, and also runs online science engagement courses through QASMT's innovative Young Scholars program.

In addition to the service provided to senior secondary students through the research immersion programs, SPARQ-ed is endeavouring to expand its reach into regional Queensland for all of its offerings. Since all of the Upper Primary / Junior Secondary Workshops and some of the Cell and Molecular Biology Experiences can be conducted in the SPARQ-ed Laboratory or in-school, such programs are uniquely placed to form the basis of "incursions" into schools in regional areas. The recent acquisition of a FLoid Imaging Station (a portable fluorescence microscope) has greatly expanded the options available to presenting cutting edge science outside the laboratory. In addition, the use of QASMT's well-established online learning infrastructure will make possible the delivery of student and staff professional development workshops to the remotest parts of Queensland.

For more information about SPARQ-ed and the workshops on offer:

- Main Website : http://www.di.uq.edu.au/sparq-ed
- Research Immersion Programs (including list of projects): http://www.di.uq.edu.au/sparqed-rip
- Cell and Molecular Biology Experiences (including list of workshops): http://www.di.uq.edu.au/sparqsingle
- Upper Primary / Junior Secondary Workshops (including list of workshops): http://www.di.uq.edu.au/sparqmiddle

Dr Peter Darben, 6 July 2015
SPARQ-ed Coordinator
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ENGINEERING EDUCATION IN THE PRIMARY SCHOOL

By Prof. Lyn English and Dr Donna King

Introduction

Advancing STEM education (science, technology, engineering, mathematics) across the school years is a key goal of many nations, with the realisation that building the STEM capacities required by societies takes extended time and needs to begin with the earliest grades (National Research Council, 2014; Office of the Chief Scientist, 2014). Despite numerous calls from national and international bodies, as well as from industry and business leaders, for increasing STEM education in schools (e.g., Commonwealth of Australia, June, 2015; Honey, Pearson, & Schweingruber, 2014), the inclusion of engineering-based experiences within primary school programs appears limited in many countries including Australia. Furthermore, the nature of such learning experiences and how these might be integrated within the curriculum remain open to debate.

For the past three years we have been conducting a three-year longitudinal study that introduced engineering education into the primary curriculum (Year levels 4-6) across a number of schools, including state and non-state. This study, as well as a prior three-year study in the middle/early secondary years, was supported by Linkage grants from the Australian Research Council (Les Dawes and Peter Hudson as co-researchers). Strong support has also been received from the Queensland Department of Transport and Main Roads. Key features of the current primary program are described, together with samples of students' learning in solving one of the problems of the first year of the study.

Overview of the Study

The broad aims of the study included introducing students to the diverse world of engineering including exploring its different fields and ways in which engineers work towards improving society. Students' appreciation and independent application of engineering design processes underpinned each of the problem activities implemented throughout the study. Drawing on their learning in mathematics, science, and technology, students were encouraged to apply their own ideas and approaches to designing and creating solutions to all the problem activities implemented. One of our goals was for the students to appreciate how their learning in these disciplines applies to solving problems in the outside world.

We planned the learning experiences in consultation with the teachers, building on their existing programs from the *Australian Curriculum* in *Mathematics, Science*, and *Design and Technologies*. The teachers implemented each of the problem activities and participated in regular briefing and debriefing meetings before and after each implementation. During the meetings we reviewed the students' progress and discussed the planning of subsequent activities taking into account the teachers' feedback. We also involved practising engineers from different fields for as many of the activities as they could attend. The engineers were from the Transport and Main Roads, as well as current and former QUT engineering students.

Eight comprehensive problem activities were implemented across the primary years study, the final being implemented from May through end July, 2015. The problems included:

Fourth grade: What is engineering? Tumbling Towers (civil engineering), the Aerospace Challenge (aeronautical engineering), and Medical Mission (materials engineering)

Fifth grade: Biomimicry (environmental engineering) and Light and Optical engineering

Sixth grade: Earthquake engineering and Bridge Building (civil engineering)

The problems engaged students in designing and constructing 3-D models that they tested, re-designed, and further tested in generating final products that met given criteria and constraints of the problem. This summary paper describes the *Aerospace Challenge* problem implemented towards the end of the fourth grade and provides examples of how the students responded.

The Aerospace Challenge

The problem commenced with a scenario about Qantas seeking the students' assistance in developing educational material for its Longreach museum. The students' challenge was to design and build a paper plane that would stay in the air for as long as possible. Students had been introduced to engineering design processes in a previous problem activity, these processes being illustrated in the engineering story book, *Engibear's Dream* (King & Johnston, 2013), which is the first of a series of very popular children's engineering books written by Brisbane engineer, Andrew King, and beautifully illustrated by architect, Benjamin Johnston. The book series continues to enrich our program. The problem comprised a number of components including an introduction to the forces of flight following students' initial paper plane construction and prior to their redesigns.

Students were presented with the following problem in accompanying workbooks, together with safety information: (a) You will be working in groups of 3 or 4; (b) You will all get to make and fly your own plane; (c) Your plane is to be made from a single A4 sheet of paper; (d) Your plane is to be hand-launched; (e) Your plane is to be designed to stay in the air for as long as possible. Distance and speed are not as important as length of flight; (f) You will time your flight using a stopwatch; and (g) You will have the chance to redesign your plane and try again to see if you can increase the time it stays in the air. The students were to record their responses including sketching and labelling the measurements of their design, their plane's time in the air, a description of how it had been launched, and their observations about its flight path and landing. They were to explain and justify their responses.

Selected Findings

The results from analysis of the responses of 63 students showed that through this aerospace engineering problem the students could complete initial designs and redesigns of their model planes at varying levels of sophistication. Three levels of increasing sophistication in students' sketches were identified in their designs and redesigns. The second level was the most prevalent involving drawings or templates of planes together with an indication of how to fold the materials as well as measurements linked to the plane's construction. The third level incorporated written instructions and calculations.

Students displayed core design processes in working the problem including *problem scoping* (understanding the boundaries of the problem), *idea generation*, *design and construction*, *design evaluation*, and *redesign*. They engaged with these processes throughput their initial designs and redesigns. Students' recommendations for improving their launching techniques revealed an ability to apply their mathematics knowledge in conjunction with their science learning on the forces of flight.

To assist them in understanding the problem boundaries many students' added their own context such as their knowledge of regular aircraft. Interestingly, students' application of mathematics and science knowledge occurred more frequently in the *design evaluation* and *redesign* processes, highlighting the need for students to reach these final processes to enable the important science and mathematics ideas to emerge.

Concluding Points

Our study continues to illustrate young learners' potential for early engineering. These students can engage in design and redesign processes, applying their STEM disciplinary knowledge in doing so. We consider an appropriate balance is needed between teacher input of new concepts and students' application of this learning in ways they choose. For example, initial scaffolding by the teacher about how to improve designs for increased detail could enhance students' application of STEM disciplinary knowledge in the redesign process.

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THE REAL PROBLEM IN ENGINEERING EDUCATION

By Dr David Finch

Australia has more engineering graduates per capita than the United States, Canada, the UK, and even Germany.

Engineering is one of the most popular courses chosen by top performing students at Australian universities.

More top students choose engineering than law.

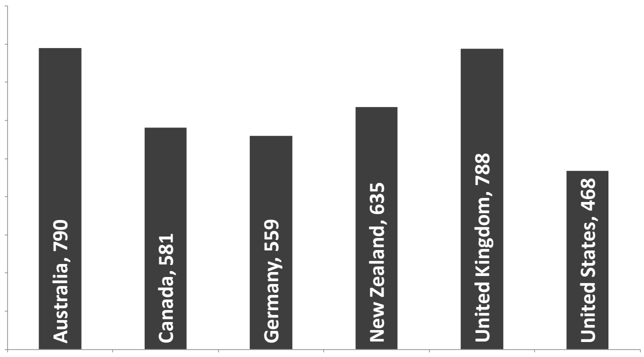
In our schools, classical science subjects have held their popularity while participation in the classical humanities has declined.

Not what you are used to hearing?

For too long the high demand for engineers in Australia has been falsely attributed to a shortage of engineering graduates and a lack of interest in the sciences on the part of high school students. These incorrect conclusions have led to bad policy in the field of engineering education and the promotion of science in schools.

So how did so many people get it so wrong?

It is true that Australia ranks low in OECD stats showing percentage of all university graduates who studied engineering, but is this a relevant measure when we have a more diverse range of available courses than most OECD countries? What really matters is how many engineering graduates we have as a proportion of population, and on this measure OECD data shows that Australia excels.



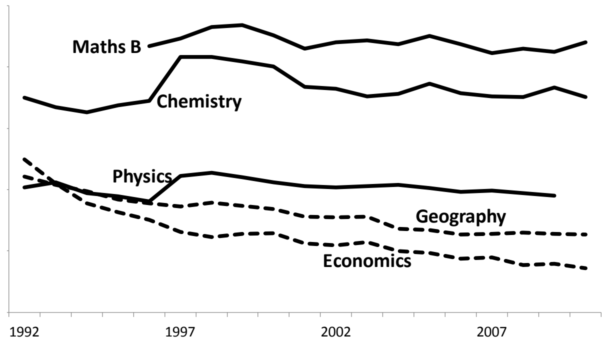
Engineering, Manufacturing and Construction Graduates per Million population (OECD 2008)

It is often also said that engineering is not attracting our brightest students. QTAC entry statistics dispel this myth. If we consider students who achieve an Overall Position (OP) in the range OP1 to OP5 (the top 12% or so of their age cohort), QTAC stats show that in 2011, 18.7% of these choose engineering. That is nearly one in five, despite the wide range of faculties and courses available. An amazing 35% of the males choose engineering, and this proportion is consistent from OP1, to OP5. Even at OP10 it is still 20%.

Unfortunately, the female enrolments show quite a different profile, with only 6% of these top female school-leavers choosing engineering. In contrast to the consistent profile among males, female enrolments start at 10% of OP1 and drop quickly to 5% by OP5.

We are very successful in attracting male school-leavers, but are attracting only the very brightest of females, and not enough of them.

We hear in the media that the problem is a decline in school student participation in advanced maths and sciences at senior (Gr11-12) level. Once again, the proportion of senior students studying science may be declining, as more and more of our youth go on to finish grade 12 compared to earlier years. However, the important measure is whether there has been a reduction in the proportion of all youth who study the sciences. After all, compared to 30 years ago, twice as many young people go on to Gr12 and they have three times as many subjects available to them.



Satisfactory Results in Senior Subjects
as % of Queensland 17yo population

The plot above shows clearly that the cohort passing in the sciences has been steady since 1992, while classical humanities subjects have suffered from the increase in available subjects.

Given the small numbers of females choosing engineering, is there a trend in their subject choices at school?

The answer is yes. Maths B and Chemistry are 46% and 51% female respectively. Physics, which is probably the key enabling science for engineering, is an alarmingly low 27%.

Feedback from recent graduates indicates that the way science is taught in middle school is turning most girls off physics, and the way physics is taught in senior school is turning most girls off engineering.

So what can we do about it?

To start with, we need to help teachers to teach science in a context that will engage all students in the class. Engineers do so much in the community, but science, and especially physics, is still taught within a context of machines, cars, rockets, satellites and the like. Let's teach science in the context of what it means to the community. Let's use solar energy, water security, sustainability and other issues facing the community as the context around which to teach and inspire the next generation.

EA Queensland Division Education subcommittee is working with teacher associations, education authorities and other stakeholders to advance this initiative.

If we can change the face of science in our schools we just might change the face of the engineering profession while we are at it.

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CLUSTER CONNECTIONS: SCIENCE- AN OVERVIEW

By Randall Hall

An innovative model for ongoing, sustainable science support within the South East Region

Since 2003, the Department of Education and Training (DET) has had three state-wide science initiatives;

- 2003-2006 Science Strategy- Spotlight on Science
- 2006-2009 Science Strategy- Science Centres of Innovation and Professional Practice (SCIPPs)
- 2009-2012 Science Strategy- Science Sparks

Upon the conclusion of the Science Spark initiative in July 2012, there was no strategy put in place to support the teaching of science in Qld Schools. This project aims to build sustainable support for primary schools through the formation of working relationships and Professional Learning partnerships between secondary schools and their local feeder partner schools.

This initiative has built capacity in the teaching of science, in the South East Region, by forming new, and building on existing relationships between secondary schools and their local primary schools. Cluster Connections creates common language and common understandings between schools within a cluster and raises the standard of science inquiry skills of students entering Year 7 through student engagement, teacher professional development opportunities and support provided by teachers from the secondary sector (Scientific Operations Officers, Heads of Departments and science teachers).

Through collaborative planning and the building of Professional Learning partnerships, this initiative develops primary school teachers' confidence and capabilities in the teaching of science as well as providing resources, expertise and knowledge from science departments at their local partner secondary schools.

Cluster Connections: Science- Delivery

An initial planning meeting between the secondary schools and primary schools is followed by pre-testing using PAT-Science at Cluster Connection schools. Two 'blind' schools, who received no support from cluster secondary schools, were also tested. This established baseline data to enable student learning outcome 'movement' to be tracked at the Cluster schools and compared with data from the 'blind' schools who received no support.

Teachers from the primary schools attend professional learning workshops facilitated by the secondary schools with a focus on specific Science Inquiry Skills and the Science Understandings from the Australian Curriculum: Science which will be assessed in upcoming units. Teachers also participate in a planning session where they collaboratively look at alternative assessment options, resourcing options and opportunities for secondary teachers to visit cluster schools and co-teach specific, identified focus lessons.

Following the unit, teachers meet again to moderate assessment items from the unit and to reflect on the program. On completion of the program schools are tested again using PAT-Science. This data is analysed, compared to pre-test data and reported back to the school.

Cluster Connections: Science- Pilot Program Student Data Summary

Evaluation Tool

PAT- Science Test booklet
#4 Pre-test

PAT- Science Test booklet
#5 Post-test

- Year 6 students working in programs were evaluated using PAT-Science
- Year 6 from two non-participating schools were evaluated over the same timeframe, using the PAT-Science tool, to provide baseline data

Test Data	Ave Score	Ave Scale Score	Ave %ile rank	Ave Stanine 1-9
Cluster Schools				
Cluster Schools N(168) Pre-test PAT-S #4	13.36/22	123.09	49.93	4.99
Cluster Schools N(157) Post-test PAT-S #5	14.24/24	125.69	61.11	5.71
Difference		**+2.6 ↑ 2.11%**	**+11.18 ↑11.18%**	**+0.72 ↑14.42%**
Blind Schools				
Blind Schools N(92) Pre-test PAT-S #4	12.03/22	119.75	40.33	4.38
Blind Schools N(91) Post-test PAT-s #5	10.25/24	118.13	34.05	4.08
Difference		**-1.62 ↓1.35%**	**-6.28 ↓6.28%**	**-0.3 ↓7.01%**

Cluster Connections: Science 2014 Teacher Satisfaction

	After participating in the Professional Learning Experience	**SD 1**	**D 2**	**U 3**	**A 4**	**SA 5**	**Ave**
		Number of responses					
A.	I have a greater knowledge of the underlying scientific principles explored in the workshop				10	33	**4.8**
B.	I am more confident in my ability to teach the science context of this workshop				13	30	**4.7**
C.	I enjoyed the experience of being immersed in the inquiry process as a learner				4	39	**4.9**
D.	I enjoyed participating in hands-on investigations using the inquiry approach				6	37	**4.9**
E.	My intention is to implement learnings from this workshop in my classroom				6	37	**4.9**
F.	I have gained some useful knowledge and examples of practical science activities that I could use in my classroom				8	35	**4.8**

Overall, how satisfied were you with the workshop?

40	Very satisfied	**3**	Satisfied	0	Neutral	0	Dissatisfied	0	Very Dissatisfied

Cluster Connections: Science- Testimonial

'The staff at Helensvale left feeling very inspired and supported by the model of PD and planning offered today. Amy and Jess are to be congratulated on their organisation and support for our staff. Their enthusiasm, passion and knowledge around the topic created an engaging and very helpful presentation. We managed to modify the assessment task and guide to making judgements as a whole group to suit our needs as well. I believe everyone left the day feeling excited about the topic and prepared with the knowledge and resources to teach the unit effectively. We discussed ongoing support throughout the term and task moderation between schools following the assessment task.'
Deputy Principal, Helensvale State School.

Randall Hall, 26 June 2015

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THE QUEENSLAND MUSEUM SCIENCE, TECHNOLOGY, ENGINEERING, MATHS AND THE ARTS PROGRAM

By Tania Hall

The Queensland Museum provides a platform of lifelong learning where the creative process of discovery and exploration intersects in Science, Technology, Engineering, and Maths (STEM) and the Arts. The STEM education project and supporting programs which are embedded in the Queensland Museum calendar provide opportunity for students, teachers and the community to engage with science through inquiry and adopt a deeper understanding of the value of science through discovery and learning. Such programs continue to be developed in response to the current decline in STEM, and focus on providing layers of support to all learners to encourage the continual journey of engagement and uptake of STEM.

The following STEM projects are underway at the Queensland Museum:

STEM Education Partnership

The Queensland Museum and QGC, two scientifically-focused organisations, are committed to helping change attitudes and deepen appreciation of the value of science in order to create a STEM literate community. The partners are committed to building a highly capable workforce to inspire innovation and to ultimately leave a legacy of future knowledge in Queensland. This partnership will unite industry, education and research in the pursuit of enhancing the performance and awareness of STEM among students, teachers and the wider community. This unique program aims to create a whole-of-life approach to STEM education and is underpinned by leading research and a rigorous evaluation program.

The project which aims to increase the interest, engagement and uptake of STEM through the following components:

- **Direct Intervention:** developing programs in schools which link curriculum with museum objects and resources, and connect students with industry professionals
- **Teacher Professional Development:** upskilling teachers through demonstrating new ways of teaching STEM using arts related techniques and strategies, inquiry new technology
- **Public Engagement:** identifying and supporting events and exhibitions accessible to the families of students and the general public which engage them in science and grow their understanding of the value of science
- **Research:** leading research and rigorous evaluation underpins the activity to provide new information associated with STEM education.

Creative Lab

Queensland Museum is supporting a growing momentum in education circles to integrate creative thinking into STEM education, encouraging a well-considered approach to teaching and learning. Creative Lab is an immersive professional development activity for educators; designed to put them in the role of the problem-solving learner, and encourage a cross-pollinated style of engagement with content.

School and Public Programs

Australian scientists have made discoveries that have changed the world - now it's time to inspire our next generation!

Over the past year, the Queensland Museum has delivered over 70 science and engineering-based programs with themes such as ‘Brick-kids Engineering’, ‘Energy for Life’, and continues to engage with thousands of students and families through programs such as ‘The Science of Bees’, ‘Biodiversity and Classification’ and ‘Megafauna to Minibeasts’. In addition, the Queensland Museum offers ‘It’s Atomic’, hands-on workshops, which enable children as young as six learn to interpret the Periodic Table and explore the invisible microscopic world of astonishingly small atoms, to discover that atoms are made of even smaller particles called protons, electrons and neutrons and some of these particles carry an electric charge. This innovative program proves that everyone can learn Atomic Theory.

Children participating in Queensland Museum programs have fun while developing an understanding of the world around them and getting a head start in their science education.

World Science Festival Brisbane

Brisbane will come alive in March each year as the Queensland Museum has secured the World Science Festival for Brisbane, aligning Australia with one of the world's most prestigious scientific and cultural festivals.

Featuring local scientists and performers from around Australia, New Zealand and South-East Asia, the festival will host the brightest and the best minds in science from around the world. The festival explores the nexus between science and the arts through gripping debates, original theatrical works, interactive experiments and explorations, musical performances, small bespoke events and major outdoor experiences.

The World Science Festival Brisbane is presented by the Queensland Museum and supported by some of the Asia-Pacific region's leading universities and research institutions. World Science Festival Brisbane's 2016 program is currently under development and will be announced in late 2015, with a program and ticket sales launch.

Tania Hall, 21 July 2015

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TEACHERS AS RESEARCHERS PROJECT

By Kathy Harris

The Teachers as Researchers Project is a successful initiative, offered annually since 2010, to encourage, facilitate and support teachers to enhance professional teaching practice, support teachers in their professional learning and improve student learning outcomes. In the project, teachers have a high degree of autonomy and use authentic action research for their active and participatory learning. The project supports the principles of differentiation and encourages the development of 21st century skills for both teachers and students. Independent Schools Queensland (ISQ) has provided an opportunity for schools to identify an aspect of STEM education within their context that required investigation in order to develop or extend their current teaching practices. This investigation is framed as a research question. Nine secondary schools participated in 2014 and twelve primary and secondary schools in 2015. Each school has a team of three or more staff from at least two STEM related disciples and one team member who has a leadership role at the school. The teams receive a grant of up to $10000 (from Commonwealth Government Students First Support Funding) predominately to pay for teacher release and professional development of which up to 40% can be used for specialist resources.

Outcomes of the project are:

- collaborative approaches to teaching
- improved capacity of the school to employ action research as an approach to professional learning
- opportunities for practitioners to engage in practices at the highly accomplished and lead teachers career stages
- publication of journal articles by each team
- enhanced engagement in STEM by students
- improved student learning outcomes and possible student STEM subject choices in senior secondary

Some examples of research schools are conducting are:

a) How does participation in community-based scientific inquiry impact teacher pedagogy and student engagement in the middle years?

b) How does reciprocal mentoring between STEM and non-STEM based subjects impact teacher practice and students perception of STEM?

c) How can we influence girls (12-15yrs) to select STEM-related subjects at our school?

Teaching programs

ISQ has facilitated the first part of the year-long Science by Doing professional Learning Program in 2015. Primary Connections workshops for teachers are occurring in August in Brisbane, the south coast and regional Toowoomba. The Primary Connections workshops will be followed by a Master Class for teachers experienced with the program and online courses in 2016 through an online learning management system called Connect & Learn.

Competitions

Competitions are popular among independent schools. Here are examples of three that our schools participate in:

1. **Engineering - The Australian Space Design Competition**
   This competition draws on students' knowledge of science, technology, engineering and mathematics, as well as their skills in teamwork, marketing and human relations.
2. **Engineering – Thiess bridge building**
   The Thiess Spaghetti Bridge Competition is held annually to promote engineering as a career.
3. **Robotics - Lego Tournaments**
   In this competition students think like engineers and scientists to develop teamwork and technical skills.

Schools

Independent schools offer some great initiatives beyond their own school community. For example, two schools host conferences to encourage girls into STEM fields (http://www.aspiringscience.com.au/ and http://www.sthildas.qld.edu.au/global-learning/st-hildas-stem-institute/ or http://files.sthildas.qld.edu.au/wp-content/uploads/2015/03/STEM.tif

An independent school in Rockhampton has a marine monitoring club that gathers data for the Great Barrier Reef Marine Park Authority (GBRMPA). Future goals for the project are for the school to act as a hub for Marine Conservation Education in the local area as well as a training centre for teachers and students wishing to be involved in marine conservation projects such as Coral Monitoring.
http://www.gbrmpa.gov.au/our-partners/the-reef-community/rockhampton-grammar-school

Other examples of schools engaging in outreach programs are student engagement days where an independent school invites teachers and students from local primary schools to a day of STEM activities.

Considerations for the future

1. One suggestion is for funding to go directly to school sectors. Schools know what they need and they all need something different. Schools are diverse, as can be seen in the images of two Brisbane independent schools below and approaches to STEM education need to differ accordingly.

Brisbane Grammar School, Spring Hill

Arethusa College, Spring Hill

2. Teachers continually need upskilling for long term results. Primary and secondary teachers need pedagogical content knowledge which includes understanding big concepts and how to teach them.
3. Developing teacher resource materials for teachers has not addressed the big issues in the past unless they are embedded with a quality professional learning project, such as Primary Connections and Science by Doing (both Australian Academy of Science education programs).
4. Teachers should be paid more so they are on par with industry professionals and they should be required to have time away from their students on a daily basis to work together to improve teaching and learning.
5. ARC linkage grants should not have a requirement for schools to contribute $5000 or more to partner with a researcher. It should be in-kind support from schools.

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SEEKING EXCELLENCE IN SCIENCE EDUCATION 2015

By Dr Ross Hynes

1. **Ideally, what is the profile of a science student of excellence in the early 21st century, when there have been so many changes in science?**

The nature of science has changed substantially since the 1960s. The basics, in terms of principles and core knowledge, have remained fairly stable but have shrunk in real size as scientific knowledge has expanded exponentially and continues to change. We cannot know it all. Further, our concepts of scientific certainty and uncertainty have changed dramatically e.g. note the ongoing refinement in our understanding and interpretation of Quantum Physics and our ever expanding understanding in the field of Cosmology (Hynes 2011d).

The science student in a school of excellence in 2015 should:

- ***Be computer literate.***
- ***Ideally, have higher levels of numeracy and literacy than those considered as global standards in the 1960s.***
- ***Have developed higher positive discriminatory capabilities and skills in terms of distinguishing what is crucial in solving a scientific problem*.**
- ***Understand Popperian science philosophy*.** In many, our professional stance will have been influenced by Karl Popper's scientific paradigm P1-> H1->Expt. 1 and if not explained then to P2->H2 and ->Expt. 2 etc. in terms of testing *Null hypotheses*. This has led to incremental advances towards a stronger understanding of facts and the explanation of natural and physical phenomenon and processes. Occasionally, within the existing status of scientific knowledge and understanding, too many internal contradictions accumulate and the existing paradigm is overturned i.e. what Kuhn calls scientific revolutions (Hynes 1979c). Some of us present may not agree with this position. For many of us however, the overall experience has given us a level of realistic optimism that we apply to our everyday lives. This became particularly important to me when I was pursuing my PhD at University College London (UCL) in systems and conservation ecology.
- ***Have a strong understanding of the current explanations of the fundamental principles of modern science.***
- Have a stronger understanding of the role of **mathematical modelling in modern science** than previous cohorts.
- Be beginning to develop an understanding that most human problems we face in the 21st century are **whole systems problems**. *These cannot be solved simply by reductionist science*. These require wide window, cross-scale approaches to science that address whole systems. This however is difficult to achieve. Ironically the student in a school of excellence in the 1950s had stronger Mathematics and English communication competencies. They had fewer distractions and invested more time developing a practical focussed understanding of their disciplinary core. **Now we need to do both - but without losing rigour.** So the challenge has increased significantly.
- ***Have developed powerful skills in asking the right questions*.** More than ever we need not only good data, accurate and valid information, and theoretically sound knowledge but a level of **scientific wisdom to help us separate the relevant from the irrelevant**. The quantity of scientific knowledge is expanding exponentially; again we cannot know it all. We need to develop powerful skills, as modern learners, in searching for the right information and developing the right level of knowledge or we usually waste a lot of time. Also, in this environment we must develop high level skills in accurate speed reading.

If schools of excellence do not produce this type of student then it will be very challenging for them to excel at the university level and in turn assist the understanding of science by citizens in the wider community.

2. **The nature and scope of Scientific Research is changing**

Table1. Changes in the approaches to science and knowledge in the 1990s and beyond (adapted from Gibbon et al 1994: in Hynes 1998).

Ongoing traditional approach	Strengthening of new and future approaches
• Traditional disciplinary and cognitive science	• Multidisciplinary and participatory within a social, economic and application context
• Homogeneity of focus	• Heterogeneity of focus
• Hierarchical	• Heterarchical and transient structures
• Quality control by peers	• Quality control through social, economic and political accountability, reflexive and multi-dimensional collaboration -supply and demand of knowledge variable -production of knowledge rather than science
• Economy of scale of operations within disciplines	• Economy of scope across disciplines -solutions beyond any single discipline
• Communication through institutional channels - technology transfer	• Communication through involvement of others – technology interchange and linkages of skills and instructional sites together
• Research staff on permanent employment	• Research staff are transient, regrouping for particular issues
• Management by control	• Management by facilitation
• Individual agencies have defined roles and objectives	• Agencies have fuzzy boundaries and move into and out of alliances
• State-wide and centralized decision making	• Regional and catchment based decision making

Notwithstanding this, science cannot give answers to every problem.

3. **So how do we get there? What do the universities need? What do the citizens of today and tomorrow need?**
   - We need: students who have a balance of skills and a strong knowledge of basic science and strong numeracy, literacy and computer competencies.
   - Students who can measure the dimensions of objects and of time etc., and who have developed an inquiring approach to achieving an understanding of causality.
   - Students who know the difference between accuracy and precision. Students who understand how to calculate levels of error.
   - Students who are not confused by fundamental understandings; but can approach a scientific problem using first principles to seek an explanation. The scientific world is running away from the wider Australian community. We will need to leap frog the information and knowledge log jam to catch up. This will take all our best educational brain power working cooperatively together.

4. **The BIGHAPS, the Big Hairy Audacious Problems of the 21st century e.g. Climate Change need a whole systems science approach.** This level of science is not usually taught effectively in primary or secondary schools or if it is, it tends to be somewhat limited.

- These problems are essentially systems problems**.**
- They are fundamentally non-linear in causation *(Hollings 1993).*
- They are increasingly caused by slow changes reflecting accumulations of human influences on landscapes and seascapes.
- Spatial connections are intensifying so that problems are now fundamentally cross-scale in space and time.

We have only usually been able to achieve satisfactorily linkages between two levels of scale up to the present. We must greatly improve on this performance.

- The economical and sociological components, as well as the natural science components, of these problems have an evolutionary character *(Hollings 1993, Hynes 1994).*

Climate change threatens the whole human family (*Ban Ki-moon, UNDP Development Report 2007/2008*). Material growth using finite resources as if they have no limits, further threatens the future of our sustainability. Global breakdowns in the good governance of the world's financial systems aggressively erode our integrity and expose societies to extreme socio-economic risk.

Yet these crucial issues also provide opportunities to come together to forge a collective response to these global problems. *New Wave* business and economic systems and astute sustainable, natural and human systems management can play pivotal roles in these initiatives. These need to be coupled with enlightened attitudes and responsible resource management practices (Hynes 2009 and 2011c).

5. So, our science of the 21st century needs to operate at many levels of scale

Clearly science needs to rapidly evolve to be able to provide understanding and insights concerning solutions for these challenges.

So will the quality and strategies we employ in primary and secondary science teaching need to rapidly evolve- if we are to achieve scientific literacy in our society.

We need to effectively use computer visualisation as well as hands-on science experience to maximise learning opportunities. Graded, motivating computer learning games covering the key core science and mathematical understandings and skills need urgent development and incorporation in science and mathematics courses from primary onwards throughout secondary levels.

6. What were my 'learnings' regarding excellence in science teaching over the last fifty years?

- Students learn best when the language used fits their level of academic maturity.
- They learn best by doing, by experiencing science and action learning but some rote learning is needed.
- They need to develop skills in basic physical measurement **-** parallel to their leaning experiences in science.
- Further, students need to develop strong competencies in mathematics and language expression to complement their scientific capacity.
- The university concept of science today is largely (although clearly not exclusively) a western cultural construct, which may attempt to impose western patterns of thought on people growing up in other cultures.
- Imposed concepts need to be connected to relevant starting points for those who aim to achieve excellence in teaching science in this setting. This relates particularly to concepts of time, volume and causality (Refer Prince 2010).
- In transitional societies, for example Aboriginal and Torres Strait Islander communities, the conceptual development of students at any given level can vary widely, geographically from area to area, and from individual to individual in mixed groups. This situation would be similar among many migrant families and across a range of disadvantaged groups in our society.
- Before entry into schools seeking excellence in science education, fair but rigorous screening will be crucial to identify the knowledge and skills starting base.
- To achieve excellence in science in this learning environment, students will need unrelenting perseverance and commitment.

Here we must all persevere to achieve a sustainable outcome. It is more than working hard. It is a willingness to tie oneself intellectually, physically, emotionally, spiritually and socio-economically to this fundamental task until it is both complete and sustainable (Hynes 2010a). To make Schools of Excellence in Science Education for the 21st Century a reality we need this level of commitment. In meeting this challenge we need to invest in and optimise best practice computer-based and internet-based leaning strategies.

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WHAT IS HOLDING STEM EDUCATION BACK AND HOW TO IMPROVE IT?

By Dmitrii Khovanskii

1. Introduction

Since 2007 I have been developing a few different projects for education including school management systems, electronic workbooks, testing and accreditation systems, mobile applications for education and educational social networks (‘Znai Vse’, ‘edu-nv’, ‘Arctic teachers’, ‘prof 58’, ‘prof-edu’, ‘MLearn’, etc.). Each of these projects has a list of tools for teachers, students, parents and governmental organisations managing education. The role of my company was development and implementation of these projects in schools for different regions in Russia. Each project has a few distinct stages, such as development, pre-release, adaptation, release and implementation. Each of these stages has its own challenges; however the stage of implementation always contained more challenges than any other.

During the implementation stage I tried a variety of different techniques to increase the teacher's involvement in projects including seminars, video courses, webinars, centralised enforcement from regional governments, competitions for teachers with prizes, etc. However, I found that educators were reluctant to accept the new technology. They claimed that they felt overloaded with new systems, features and reports from different companies and different levels of educational government. Very often in their explanation they claimed that they barely have time to prepare lessons and teaching itself. This position has raised a few questions:

1. Is new technology really important for use in schools?
2. How to reduce the load of teachers by new technologies?
3. What is really important for effective education today?

Each of these questions requires separate consideration.

2. Important aspects for effective education today

The current system of public education has been established due to demands for basic needs for literacy and numeracy of employees. Demands have been increasing and the curriculum has been adapted by adding more new subjects and topics. In about three centuries the information load of students has increased dramatically. One can argue that is reasonable to do so, because tools and technologies become more sophisticated. In addition to the rapid advancement of technology, the average IQ has also increased in last few years. Consequently we can assume that it is possible to further increase the information load. As a result of the increased accessibility of information due to advancement in information technologies in general and particularly the internet, the priority of requirements has shifted from memorisation to problem-solving and creativity.

This change in priorities raises a list of questions:

- How can we develop problem-solving skills
- What is creativity
- Which types of creativity exist
- How can we develop creativity for each type

There is a list of answers for each of these questions. However, old approaches compete with new demands and technologies and for time. All knowledge is considered equally as important because the majority is used as the basis for understanding. Owing to this situation certain ‘trade offs’ are required.

Creativity has a wide range of definitions and requirements. Technical creativity normally requires understanding the process and principles necessary for a new piece of hardware or software. This understanding in most cases requires practical experience, understanding how certain changes of the machine or algorithm can affect the processes and the final result. From one perspective it is too expensive and time consuming to perform experiments for each topic of the school program. However, it is possible to combine them in tasks and ask children to perform them.

3. How to reduce the teacher’s load with new technologies

At present teachers are asked to teach certain topics to students, evaluate their performance and develop reports. I believe most of these tasks can be automated. I believe teachers need to facilitate learning, find the best ways to inspire and encourage children to learn and outsource the rest of the tasks to automated systems. In fact, introduction of a centralised system of support evaluation and testing for students across the state and maybe across the world can bring significant improvements for both teachers and students.

The first reason I believe that this is important is that it would free teachers' time and give them the ability to concentrate on the motivational aspects of learning.

Secondly, if the system is implemented in an attractive child-friendly way it will encourage children to engage in learning without additional support.

To reduce the time constraint on teachers due to both these loads, I propose integrating an intelligent system of support to facilitate the control of education and to navigate the learning process such that all involved are on track.

4. What I am doing to address the problems

At the moment I am involved in two types of activity related to this project. I am a PhD candidate in the University of Queensland. I also started a company to facilitate software development of this project, where the outcome of my PhD will provide basis for practical coding. This project is aimed at easing teachers' work-load by providing a set of tools for independent learning for high school students. One of the primary goals is to achieve maximum engagement of students in learning.

The final version of the platform which is being developed will be represented as an educational game. The main element is 3D action game where children would be required to construct machines, buildings and perform certain tasks. The main scenario will be based on the historical development of science and technologies from the Stone Age until present.

In the game children will be required to interact between each other and communicate with peers including international collaboration.

Some parts of the game could be replaced with practical experiences in the real world. For these cases teachers would be required to facilitate these activities, prepare some prerequisites and ensure the safety of pupils.

The game itself will not be an unchangeable piece of technology; rather it will be adaptable by educators and experts. It will provide high degree of flexibility and adaptation for local resources and policies.

5. Acceleration of the outcome of the development

At the moment I have a small team of software developers. It is enough to develop the game, but a few additional programmers could significantly accelerate the development.

On the next stage there also would be demand for experts and educators to create the game content. The game will provide an easy interface to implement objects and environment in the game. Due to the vast amount of knowledge in the current school curriculum, a variety of specialists with various backgrounds would be required to implement this into the game.

I believe that decrease of load of teachers and increase of engagement of students into education can have positive effect on the outcome of education.

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QUEENSLAND STEM EDUCATION NETWORK

By Kay Lembo

The **Queensland STEM Education Network (QSEN)** is a new tertiary consortium which aims to improve and advance Science, Technology, Engineering and Mathematics (STEM) capacity in Queensland.

Griffith University is the lead institution in a consortium of tertiary partners including the Queensland University of Technology, University of Queensland, James Cook University and the University of the Sunshine Coast and is funded by a $2.85 million grant over three years from the Federal Government's Australian Maths and Science Partnership Program (AMSPP).

AMSPP was formed in response to a 2012 report by Australia's Chief Scientist, Professor Ian Chubb AC, which identified troubling trends in maths and science. AMSPP is seeking to redress that situation through innovative partnerships between universities, schools and other relevant organisations and stakeholders.

The major goals of the Queensland STEM Education Network are:

1. To raise awareness, interest and achievement in science and mathematics among Queensland junior secondary students leading to increased STEM enrolments at senior secondary and tertiary levels

2. To engage students, parents, teachers, guidance officers and the broader community to demystify and raise awareness of the importance of STEM education and STEM related careers

Collaborative networks

QSEN's role will include providing engaging, informal, out-of-class STEM experiences that capitalise on the expertise, resources and infrastructure available at each of the partner universities. It will also aims to raise STEM career interest and awareness through active engagement with those in position to influence or advise young people, including parents/carers, teachers, careers advisors, work experience co-ordinators.

QSEN will achieve these goals in collaboration with key stakeholders across Queensland including the Office of the Queensland Chief Scientist, the Department of Education Training and Employment, the Science Teachers Association of Queensland, the Queensland Association of Mathematics Teachers, Queensland Society for Information Technology in Education and community, local education and parent groups.

Phase 1

The initial networks establishment phase has involved identifying current status of university STEM engagement, sharing of best practice, and challenges, encountered with effective implementation of STEM education collaborations. While an extensive suite of STEM experiences offered from university partners has been identified, external university awareness or involvement was limited. However discussions of current engagement practice identified similar and generally unified range of successes and challenges (Table 1). These will provide the foundation for future collaborations and integration of operational 'best practice'.

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Table 1: Identified successful practice and institutional engagement challenges

	Successes	Challenges
Students	Utilise local, relevant contexts	Venue/laboratory capacity
	Use of 'hands-on' activities	Engaging all students in cohort (not just STEM students)
	Provide unique, 'cutting-edge' experience	Student forced attendance - Behaviour management
	Presentation by 'young' people (students/researchers)	Maintain engagement /momentum of activity
	Ensure relevant to year level and study area	Time frame and timing for activity
		Aligning presentation/presenter to student ability
Teachers, Schools	Provide teacher release costs to schools	Timing - school calendar
	Provide catering	Time - 'Crowded' curriculum, - competing priorities/events
	Engagement with 'lead' teacher with schools or clusters	Awareness of opportunities
	Establish collaborative relationships	Recognition and reward
	Ensure relevance – curriculum, PD & interest	Identifying 'key' teacher contact
	Direct connection with researchers/facilities	Gaining other internal support ie technicians, GO's
	Flexibility - respond to defined needs/requests	Geographic location constraints
	Recognition & reward	Financial support for teacher ie TRS
Parents, community	Ensure feeling of worth/value	Overcoming stigmas -previous 'bad' education experiences -lack of experience /confidence with STEM - low value on education
	Active engagement during events	Accessing/connecting with parent groups
	Establish strong collaborative relationships	Time – competing obligations and priorities
	Engaging with volunteer organisations	Awareness of opportunities
	Recognition – awards (formal and informal)	Setting realistic expectations and outcomes
	Tailoring to level of community involvement	Geographic location constraints
University	Promotion of institutional STEM expertise	Recruitment vs outreach: Communication/collaboration with marketing
	Engaging Indigenous outreach	Poor internal awareness and/or co-ordination between faculties
	Provide catering	Lack of formal recognition - academics involvement - value of engagement activities
	Acknowledgement/involvement of University executives/academics	Staff availability: Academic support vs academic burn-out
	Contextual links -support with industry/science organisations	Defining STEM - integrated or separate?
	Provision of access to 'high-tech' equipment and professionals	Duplication between institutions – lack collaboration between institutions
		Internal partnerships/sharing - Coveting teacher contact lists
		Sufficient internal funding / support
		Universities competitive nature (student numbers, contacts, program details)

PRIMARY INDUSTRY CENTRE FOR SCIENCE EDUCATION (PICSE)

By Kay Lembo

PICSE has involved collaborations between universities, regional primary industries, national research and development (R & D) corporations, national and regional agribusinesses, regional research institutes, government authorities, schools and the federal government. Each PICSE Activity Centre is managed by a Science Education Officer (SEO) who undertakes a range of annual, integrated engagement activities.

Engagement occurs through:

Industry Placement Scholarships (IPS):
a) Science-based class presentations to Years 10, 11 & 12. Students are exposed to cutting edge scientific research and the exciting opportunities for science graduates in their region, with examples of the application of science in local primary industries.
b) A five-day industry science induction camp for selected Year 10, 11 &12 students in their vacation period, involving in-depth consideration of career and research opportunities for science graduates. Postgraduate students from local research institutions and scientists working in local primary industries provide assistance and input at these camps.
c) A five day student industry placement for Year 11 & 12 scholarship students in their vacation period with a team of scientists in specific local industries or research organisations. At the end of the placement, students provide a written and verbal report to other scholarship students, the industry mentors, key university personnel and parents.

Science and Engineering Investigation Awards (SEIA): Science-based class assistance with primary, middle and secondary students engaged in undertaking scientific investigations and developing knowledge of scientific methodologies culminating in a regional Science and Engineering Investigation Award event. Here students present their science investigations and undertake additional science activities. The judging of this event is based on poster displays and on students' project presentations. This is supported by the on-line **Science for Growth Awards** which focus on engaging rural, remote and urban students.

Teacher professional development: Secondary science teachers and laboratory assistants are provided with two different opportunities:
a) a *two-day professional development forum* to illustrate the contextualisation of the Australian science curriculum and the science used locally in primary industries, agribusinesses and R & D organisations and/or
b) *one week industry internships scholarship* (in vacation periods) with scientists in specific local industries or research organisations. At conclusion of the placement, they produce a written report or teaching resource to demonstrate its value and relevance.

Undergraduate Industry Internships: a one-week Internship for Undergraduate 'STEM' or pre-service students (in vacation periods) with scientists in local industries or research organisations that relate to their field of study. At conclusion of the placement, they produce a written report to demonstrate its value and relevance.

Program insights and evaluation

Annual evaluation of the operational aspects of the engagement activities as well as student and teacher impact has been undertaken as part of the program. The full 66 page 2013/2014 Impact report can be provided on request, however highlights from the 2013/2014 Impact Report include:

- Teachers are very positive about the usefulness of professional development in helping them to teach science (2013/2014 average rating 8.7 out of 10). The PD continued to impact strongly on participant teachers' understanding of primary industries (86% noting that their understanding had changed) and career pathways (98% indicating an impact). Teachers appreciated the practical and relevant knowledge gained providing *lots of ideas for classroom use*. They continued to feel that the PD was generally relevant to their curriculum. Almost all respondents (90%) thought that they were provided with activities/resources which can be used in the classroom/laboratory/field. Teachers indicated a greater improvement in their thinking and motivation in teaching science as a subject (84% and 66% respectively). There is a sustained belief that PICSE resources positively contribute to the science curriculum with activities/resources which could be used in the classroom/laboratory/field.

- Students participating in the IPS camps continued to find that their experience impacted on their attitude towards the importance of studying science at university (77%). The majority felt that the camp gave them a broader understanding of primary industries (88%) Students commented that the whole IPS experience broadened their understanding of science and its capacity to open doors to diverse careers.

- From the Reporting Back Session feedback almost all respondents (98%) agreed that IPS had impacted on their broader understanding of primary industry. Most students (85%) noted that their placement influenced their study and career pathways. Guests at the session (parents, industry partners, university-based staff) believed that the industry placement had very positive impacts on the students (average rating 9.1 out of 10) and significantly increased their enthusiasm for and commitment towards a career in science and/or primary industries.

- Primary school students continued to enjoy being a part of the Science and Engineering Investigation awards (average rating 8.1 out of 10) and again indicated that as a result they had improved their understanding of the relevance/importance of science (81% agreed). Primary school students tended to like science before being involved in the SEIAs (79%), however almost all respondents (98%) indicated that they liked science more after their investigation/experiment, building on evidence that SEIA involvement has a significant impact on primary school children's attitude towards science. Most secondary school students again said that as a result of the SEIAs they improved their understanding of the importance/relevance of science (81%).

Undertaking these evaluations, along with frequent staff forums and teleconferences, has allowed for program innovation and refinement of engagement strategies. The program has also been supported by the development and provision of Science Education Officer training, activity protocols and scheduling to enhance quality assurance and program outcomes.

The highlights of the program are the 'celebration' of engagement initiatives through the production and dissemination of student and teacher reports and promotion through wider media opportunities.

Qualitative feedback:
…I had never even considered plant pathology but I chose plant pathology as my first preference even though I had no knowledge of microbiology or pathology, it sounded interesting. I was correct. I found my short visit into the world of plant pathology fascinating! As a result I am now rearranging my enrolment pattern so I can study USQ's Microbiology courses as part of my biology major.'

'I have just received a packet of Teacher Resources … and I would like to thank you for them. They are a fantastic set of resources which will really help my department with the Science as a Human Endeavour component of the ACARA curriculum. The citrus industry and organic chemistry discs are fantastic.'

Valuable aspects of Industry Placement Scholarships:
'Knowledge of the massive range and the relevancy of the many fields of science'; 'A greater knowledge to previous unknown areas of agriculture'; 'Met new people / made connections'; 'What I would like to study at university'; 'My time spent at Withcott seedlings has helped my decision in becoming an agronomist and possibly majoring in horticulture'; 'Environmental management was an area that I had looked at before wanting to become a veterinarian, although I never fully understood what their job required'; 'My Industry Placement has influenced me by showing me a part of the Agricultural Industry that I didn't know existed'; 'I didn't know much about sheep, especially wool sheep. This is what I want to do for a living and I think that the range of jobs exhibited on the camp was immense and diverse, all with good prospects'; 'After the internship, I realised how much career potential there is within the industry, and as an aspiring Agricultural Engineer, this excites me a great deal.'

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AN INVESTIGATION INTO POTENTIAL MODELS FOR PARENT SCIENCE COMMITTEES IN QUEENSLAND AND THEIR ROLES IN EDUCATION

By Jackie Mergard and Sue Stevens

The purpose of the project was to examine how science might be supported by parent involvement within Queensland schools. The introduction of the *Spotlight on Science* initiative by Education Queensland in 2003 placed a greater emphasis on science in the school curriculum. This resulted in the development of a number of initiatives and strategies designed to increase student engagement with the key learning area of science.

The *Partners in Science* objective of the *Spotlight on Science* initiative, outlined the then Queensland Government's vision for science education. It recognised that new approaches were needed to bring together educators and members of other important community, industry and government sectors to create more productive science partnerships between the stakeholders involved with the learning experiences of our students. Through a combination of increased investment in science education, increased public awareness and community engagement with science education, students and teachers across all phases of schooling would benefit.

Parents as a distinct body were not expressly nominated as one of the stakeholders in the *Spotlight on Science* strategy, but clearly they are an untapped resource that should be used to facilitate any science education program. To overlook the valuable contribution that committed and experienced parents can make to the school environment, is to rob the any science initiative of its full effectiveness.

In this 2004 study, it was hypothesised that in seeking to assist schools to introduce scientific literacy, parents and carers would have the capacity to provide:

- a range of scientific expertise and experience that can be brought into the classroom to complement existing education strategies
- linkages into science based industry and/or research organisations
- contacts to suppliers of scientific equipment, specimens and/or teaching materials
- ongoing capacity to fundraise in order to provide out-of-classroom teaching experiences and resources
- opportunities to link with the local community in order to promote the science activities being undertaken within the school
- locally identifiable science career role models
- informal professional development for teachers

Additional outcomes of including parents in the planning and learning process could be:

- increased scientific literacy of students and the general parent body
- the creation of mechanisms for engaging new parents into the P&C Association
- the active engagement of parents and extended families in the classroom environment and with the teaching staff
- the creation of a sense of 'community' with parents working together on a common project for the school.

A survey of all schools in Queensland was conducted to determine if any Parent Science Committees existed. Information was requested on how these committees operated and how successful they were. It was anticipated that networks of parents, schools and community groups supporting science would be identified. It was also anticipated that information would be received describing the ways in which these committees might increase the scientific literacy in schools and support the implementation of *Spotlight on Science*.

The survey provided the opportunity to identify potential 'best practice' models of parent committees from both Australia and overseas, which could work in both primary and secondary Queensland schools on a sustainable basis. It was expected that we would identify the types of resources that might support the establishment of such committees in schools. Finally, the survey aimed to highlight the trends and issues, which might affect scientific literacy in the future.

The results from the survey and interviews indicated that there were few, if any, Parent Science Committees active in Queensland schools. This is despite there being other recognised parent committees for activities such as sport or music in existence in the school. Interestingly, fewer than 30 percent of respondent schools at that time indicated an engagement with *Spotlight on Science* initiatives.

There are a number of identified factors, which can contribute to the lack of existence of Parent Science Committees and parental involvement in schools generally.

These include the prevailing culture in schools which discourages parental involvement; the expectations of the teaching staff about the type and levels of parental involvement; and the level of support given by the school principal and administration for parental involvement.

The outcome for the project from the limited responses received was to identify the characteristics of any existing successful models of parent-school engagement and to extrapolate these to a science context. While the expected outcomes of the project were not met, valuable data on parental involvement strategies has been amassed and is presented in a ‘parent engagement manual’ for schools. Areas for further investigation by educational authorities and schools on parental involvement within the school environment were also identified.

While this report is now ten years old, the opportunity for the involvement of parents and the community in science education has not reached its full potential. The current climate of political and community support for STEM education would seem to be conducive to revisiting this opportunity and establishing how the mechanisms for increased parental involvement in science education in schools could be effectively and sustainably implemented.

The initiative also presents the opportunity to address the level of scientific literacy within the community – an issue which has been of concern to successive Federal and State governments who have introduced and continue to support programs such as *Inspiring Australia.*

The active involvement of parents in their child’s science education can potentially increase their own understanding and interaction with scientific concepts and principles as they explore these in a positive and supportive environment with their children, whatever their previous exposure to education or science. This is an untapped opportunity to bring about attitudinal change within the community while supporting the role and efficacy of teachers and schools in the teaching of science.

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TOWARDS A SUSTAINABLE FUNDING MODEL FOR STEM EDUCATION PROGRAMS IN QUEENSLAND SCHOOLS

By Jackie Mergard and Mary Rowland

Aristotle — 'The whole is greater than the sum of its parts.'

The importance of STEM education to the future growth and security of Australia has been well-documented. The challenges involved in raising the quality of STEM teaching and learning in Australian schools has also been well-documented. How do we move forward to deliver the STEM education that Queensland needs during the 21st century?

For maths and science teachers in Queensland primary and secondary schools, the implementation of effective STEM education programs has always been problematic, particularly in regard to sustainable funding, delivery mechanisms, access, monitoring and evaluation.

To effect long term change, students must be exposed to numerous science touchpoints along the P-12 continuum. They need to be excited and engaged by science concepts during each year of their schooling rather than exposed sporadically or infrequently to engagement with programs or one-off events that inspire interest for a time but are not reinforced in subsequent years.

Shortcomings of funding and implementation of STEM education programs

Some of the shortcomings of previous and existing funding and implementation models include:

Funding

- A lack of focus for current grant schemes:
    - The parameters and expected outcomes are not clear before people apply.
    - Application processes are onerous with ad hoc processes that can vary from funder to funder.
    - A lack of integration of funded projects: Projects have individual agendas, audiences, delivery mechanisms and focus.
- The short term (usually three year) funding cycle is inadequate to promote any real attitudinal or generational change in a state as large and diverse as Queensland.
- A lack of a long term strategic framework for planning informed by a rigorous gap analysis and environmental scan.
- Insufficient or sustainable funding to engage students in rural and remote areas.

Implementation

- A lack of effective monitoring and evaluation frameworks: all have different evaluation methodologies and key performance indicators which limit the sharing of learning from existing programs, the design of new programs or the adaptive management of existing programs.
- A lack of regular networking opportunities to allow project officers to share ideas and resources.
- A lack of active collaboration between programs: all have individual agendas, audiences, delivery mechanisms, time frames and focus.

Funding and implementation options for the future

Options available to address the shortcomings listed above include:

- an evaluation of the current Queensland STEM education strategic plan. Does the existing plan provide a long term strategic framework? Is it informed by a rigorous gap analysis and environmental scan?
- a revised funding model to:
  - support five or six effective programs targeted to groups across the spectrum (P-12)
  - allow statewide delivery and participation
  - ensure that programs are fully funded for five to ten years to allow for generational and attitudinal change.
- implementation of tender arrangements for grant schemes that establish clear parameters for delivery and the expected outcomes
- a revised implementation model that allows the integration of funded projects to ensure collaboration between programs and reduce duplication of effort.
- the use of a consistent monitoring and evaluation framework across programs to improve efficiency and effectiveness and allow valid long term comparisons and measurement.
- the provision of funding for researchers and organisations to test and evaluate new ideas and to encourage innovation as well as for the evaluation of 'tried and tested' initiatives.
- the establishment of a private, independent, not-for-profit foundation that would encourage Queensland–wide consortium bids. It would ensure that diverse groups with common STEM education goals (industry, philanthropists, government and community) can work together to deliver effective, cost-efficient programs supported by agreed evaluation strategies, for sustainable time periods, and relieve the pressure of continually sourcing ongoing grant support.

Expected benefits of an integrated plan and one source funding model

- A shared vision for STEM education in Queensland among stakeholders.
- Development of an informed, realistic and achievable long term strategy
- Development of STEM ecosystems encompassing schools, community or industry settings and informal learning experiences to constitute a rich array of STEM learning opportunities for P-12 students
- Sustainable co-ordination of resources and funding to deliver the shared vision
- Development of a consistent and reliable evaluation methodology to monitor and track progress of the strategy
- Long term generational and attitudinal change to STEM that permeates the community and leads to general greater scientific literacy
- Greater uptake of STEM subjects in school by students
- Increased perceptions of and desire for STEM careers by students
- Increased engagement of teachers with STEM concepts and resources leading to greater confidence in the classroom.

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COMMUNICATING COAST: EDUCATORS, COASTAL ENGINEERS AND LOCAL GOVERNMENTS COLLABORATING TO CREATE SUCCESSFUL EDUCATION PROGRAMS

By Maggie Muurmans

The Gold Coast beaches are amongst the most managed in Australia. With significant engineering projects ranging from sand bypassing systems to artificial reefs and beach nourishment, a wide range of Australia's coastal management techniques is evident on the Gold Coast.

Part of the Australian curriculum for primary and secondary schools has a focus on coastal process. CoastEd, the collaborative environmental education program based at the Griffith Centre for Coastal Management, focusses on illustrating, highlighting and explaining the complex engineering, ecological and social aspects as well as its politics that are all part of managing and protecting the shoreline. Sessions cover topics such as climate change, coastal processes, mangroves, rocky shores, dunes, coastal tourism and development, beach health, surf science, coastal geology and many more.

The collaboration between the city council, coastal engineers from the Griffith Centre for Coastal Management and its award winning environmental educators has ensured that the education program has high quality factual and up-to-date information which is delivered in an interactive and fun learning experience. Through CoastEd and their educators, The City of Gold Coast is able to communicate important (future) coastal management plans and the coastal engineers are able to share their recent projects, research and projections with the general public.

CoastEd was established in 2001 and has since delivered interactive educational programs to at least 6,000 future decision makers and stakeholders each year from schools, community groups, local residents and kindergartens. The program received an Australian Coastal Award in 2015 in the Community Engagement category. The number of affordable, high quality coastal education programs for schools on the Gold Coast are limited and being able to provide the opportunity to access these services from a source that combines knowledge, policy and teaching expertise, as well as offering these programs free of charge, has culminated into the success of CoastEd. The continuity of the program over the past 15 years has ensured respect and trustworthiness from the community to the stage where CoastEd is viewed as an integral part of coastal education for schools on the Gold Coast, Brisbane and beyond.

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A COLLABORATIVE MULTIMODAL INQUIRY MODELFOR TEACHER PROFESSIONAL DEVELOPMENT RESPONDING TO THE AUSTRALIAN SCIENCE CURRICULUM

By Dr Kim Nichols and Prof. Robyn Gillies

The decline in students studying STEM subjects in senior high school is a trend in the developed world and is particularly steep in Queensland. There are a number of reasons, not the least being primary, junior and middle secondary school teachers' confidence in being able to teach science with fewer than 5% of primary teachers indicating that they have taken coursework beyond the introductory level in a given science discipline. With low content knowledge comes a lack of understanding of anticipating what students might find difficult in science subjects or how to effectively monitor understanding in the classroom. Further, few primary teachers feel very well prepared to engage or support effective learning of students from low SES backgrounds and racial or ethnic minorities in science.

Engagement with learning in STEM subjects is critical given Australian students low performance in reading literacy in science on the Program for International Student Assessment. This outcome is more marked in students with low SES backgrounds. Despite this, there is a greater demand for STEM skills than ever before due to the rapid growth in contemporary science and technologies. Research in the science classroom that has focussed on the making of meaning using multiple modes (i.e. text, visual, gesture, spoken language) indicates that literacy education has been narrowly restrictive and that to support literacy development and inquiry learning, students now need multiple modalities for the representation of scientific knowledge such as photo images, video clips, sound effects, voice or audio, music, animation or more specialised representations (simulations, 3D molecular software images etc.).The extent to which teachers' representational (i.e. meaning making) practices (Figure 1) need to be developed to accommodate teaching of the Australian Science Curriculum has never been more important given this emphasis on multimodal communication, social/collaborative processes, and inquiry skills.

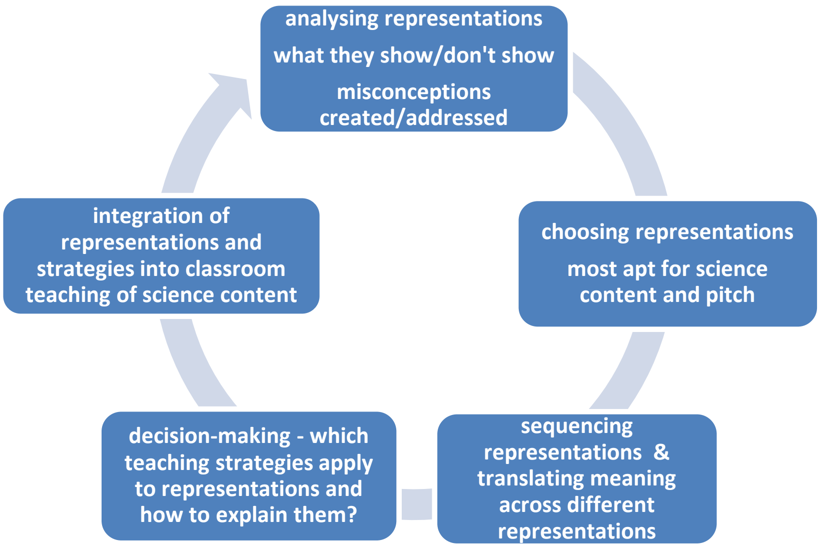

Fig. 1. Core teacher representational competencies (Nichols et al., 2015)

This pilot study trialled a sustainable professional learning model to:

- improve primary teachers' classroom strategies and competencies for choosing, using and explaining scientific representations
- improve primary teachers' content knowledge around the new Australian Science Curriculum enhance primary teachers' confidence in using ICTs to support science teaching and learning
- foster primary teachers' capacities to support student explanations of science phenomena using representations
- promote primary teachers' skills in planning for and implementing cooperative inquiry curriculum in science in order to raise students' capacities for cooperative inquiry learning
- raise primary teachers' confidence to teach science.

The teacher professional development employed in this study was designed to build confidence and core teacher representational competencies which include evaluating representations, choosing representations, sequencing, explaining and translating meaning across different representations, as well as integration of representations and strategies into classroom teaching of science content. Teachers in this study achieved varying levels of conceptual understanding of these core competencies, and across the study period, the median level achieved was significantly improved. Teachers were focused on developing their own representational competencies and cultivating competencies in their students. Video recorded lessons reflected the improved representational competencies. Teachers' surveyed revealed that their confidence to teach science also significantly increased.

Training teachers to foster the development of representational competencies was associated with a positive perception around the use of representational practices following the professional development. Importantly, while the study focused on teachers' representational competencies in relation to the professional development, it also explored the relationship between teachers and students in the classroom setting and the extent to which teachers' competencies with representations was associated with student learning outcomes. The findings indicated that teachers receiving training in representational practices and competencies were able to successfully foster representational competencies in their students in the four month period following the professional development. Consistent with these findings, teachers indicated that their students' engagement and use of scientific language improved as well as their ability to explain science concepts using multiple representations.

Our findings from the study revealed:

1. A significant improvement in teacher representational competencies and self-efficacy to:
    - Evaluate representations,
    - Choose apt representations,
    - Sequence representations,
    - Explain representations.
2. Evidence of teachers reasoning around representational use and benefits in the primary classroom.
3. Significant increases in primary student representational competencies including;
    - Conceptual understanding,
    - Interpreting representations,
    - Explaining representations,
    - Creating representations.
4. All classes in the study, regardless of starting point, moved to a more similar level of performance on all measures (as revealed by multilevel modelling analysis).

Professional learning that focuses on teaching with representations as well as implementation of a cooperative inquiry unit in science can significantly improve teachers' and students' representational competencies and understanding of science content as well as build confidence to teach and learn science. As learning with representations is critically important to the development of scientific literacy, this professional learning can contribute to the declining student performance measures as well as foster engagement and interest in science.

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QUEENSLAND MINERALS & ENERGY ACADEMY

By Dan Rea and Katrina-Lee Jones

The Queensland Minerals & Energy Academy (QMEA) is Australia's largest and most successful industry/education partnership. It is a partnership of the Queensland resources sector, represented by the Queensland Resources Council and the Queensland state government.

Through its school/industry partnership the QMEA offers a range of programs and experiences for students in years 7 to 12 as well as teachers which broaden their knowledge of the sector and provide pathways for young people into resource sector related careers.

The aims of our experiences for students are to:

- recognise the value of STEM related education
- deliver hands on activities and real life challenges that expose students to what is expected in industry careers
- promote the merits of safety and teamwork in working environments.

The aims of our experiences for teachers are to:

- provide professional development that encourage the teaching of STEM subjects
- increase knowledge of industry related innovation and current practice
- provide a wide range of STEM related resources through our innovative website www.oresomeresources.com.au which is linked to the national curriculum.

We also aim to encourage strong partnerships between industry and schools within the companies' operational communities and more widely across Queensland.

Outcomes

The QMEA is proud of its achievements. Analysis of 'Next step' survey data and other information collected from our schools has shown a legitimate impact from QMEA programs. It was found that 13.8% of students from QMEA schools entered a Bachelor degree in Engineering and related fields of study compared with 9.6% of non-QMEA students. Equally impressive is the percentage of students gaining an apprenticeship in Engineering and related fields. In non-QMEA schools 46% of students successfully entered an apprenticeship compared to 56.4% from QMEA schools.

Below is a short summary of some of the major STEM offerings through the QMEA.

Energy for the Future

High achieving Year 8 students interested in pursuing a career within the STEM fields may be invited to participate in Energy for the Future. The daylong event investigates the range of energy options that exist to meet growing energy demand. Students work with industry experts and University representatives throughout the day to determine a countries best energy mix for today and 50 years into the future.

Expand Your Mind

Year 9 students from QMEA and other invited schools will participate in QMEA's Expand Your Mind program. The full day activity provides students with an opportunity to learn more about industry applications of simple science concepts as they complete a number of hands on challenges ranging from robotics, chemical processing, engineering and design and environmental practices.

STEM 4 School Kids

This one day event is offered to Year 10 students who are looking to pursue an academic pathway of study in Year 11 and 12. The day will consist of a series of hands-on activities including experimental and problem-based challenges and be an opportunity for students to interact with industry representatives and to start their professional networks.

MINE (Make It Now Engineering) Challenge targets those students considering a professional pathway into engineering or geology. Students have the opportunity to engage with industry mentors to solve genuine problems encountered on site. The M.I.N.E. challenges are a unique experience for students to experience the full scope of what a career in the resources industry can entail. Living away from home for a week, the students come together in groups to solve their problem while at all times adhering to the strict safety, environmental and human resources policies of the companies they are working with. Culminating in a professional presentation to management the students come away with an amazing experience and a good understanding of what their future pathway may entail. In 2015, MINE Challenges will be held in Mackay, Mount Isa and Moranbah.

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GRIFFITH SCIENCE EDUCATION ALLIANCE: A MODEL FOR SCIENCE EDUCATION ACROSS QUEENSLAND'S EDUCATION REGIONS

By Jackie Rudd

The Griffith Science Education Alliance (GSEA) is a collaborative initiative between Griffith University, Education Queensland, the Department of Education and Training (DET) and the Gold Coast City Council (GCCC). It provides a coordinated, region-wide approach to science education in the South East Region. Griffith plays an active role at all levels by providing a range of teacher professional development programs, enhanced student learning opportunities and curriculum development initiatives. The GSEA employs Griffith University's science outreach program, Science on the GO!, to take resources, infrastructure and expertise from Griffith University directly to Gold Coast classrooms to assist teachers and students in all aspects of science education.

The major goals of the Griffith Science Education Alliance are three-fold:

1. to raise general awareness and interest in science and science studies leading to increased enrolments at senior secondary and tertiary levels
2. to assist individual teachers (who are sometimes out of their depth) and school cluster groups to develop common programs, with a prescribed quality, that could be used at a number (if not all) schools across the Griffith corridor
3. to provide a coordinated region-wide approach to science education with visible Griffith involvement in the development and delivery of these programs, thus establishing a clear link (and pathway!) between school science studies and tertiary science studies.

Science on the GO!

Science on the GO! aims to bring dynamic and engaging science demonstrations and teaching resources to the classroom, providing primary and secondary school staff and students access to innovative facilities, resources and expertise.

The program offers a diverse array of science activities to choose from. In addition to delivery of specialised technical demonstrations and practical laboratory classes, Science on the GO! also offers field trips, events and science shows as well as professional development and teaching resources.

Griffith Sciences Partnership Program

The program aims to promote science and improve science education in Queensland secondary schools. The Griffith Sciences Partnership Program focuses on engaging students from local, regional and remote Queensland through the STEM Ambassador Program and the Griffith Sciences High School Pathway Programs.

STEM Ambassador Program

The STEM Ambassador program aims to promote Science, Technology, Engineering and Mathematics (STEM) in Queensland Primary and Secondary Schools. A school appointed Program Coordinator will liaise with Griffith Sciences and to lead a team of selected student STEM Ambassadors. Griffith Sciences works closely with the Program Coordinator and STEM Ambassadors to develop a strategic plan to engage students and peers in Science, Technology, Engineering and Mathematics.

Griffith Sciences Partnership Program Coordinator: a school appointed program coordinator

Roles and Responsibilities:

- Griffith Sciences STEM Ambassador Program point of contact
- support STEM Ambassadors to promote STEM in the school community.

STEM Ambassadors: a group of aspiring leaders selected to engage peers in science and to improve science education in their school.

Roles and Responsibilities:

- work with Griffith University to promote STEM in the school community
- work with Griffith University to engage the school community in STEM events and activities
- represent/support peers at Griffith Sciences Annual events (Science and Engineering Challenge, Science Trivia etc.)
- submit regular updates and reviews to Science on the GO!
- manage school ambassador webpage – hosted on the Griffith Science on the GO! website

Griffith is offering:

- STEM education support and opportunities
- Griffith University Academic Mentor
- Youth STEM Conference
  - Team building
  - Leadership training
  - Strategic plan
- science events and activities throughout the year
- support throughout the year to implement schools individual strategic plan
- STEM Ambassador badges
- online promotion - Science on the GO! website and social media outlets
- National Science Week grants

Griffith Sciences High School Pathway Programs (internal and external programs)

Griffith Sciences is offering Year 11 and 12 students the opportunity to study a Griffith University first year course while undertaking their senior studies at school. The Griffith High School Pathway Programs are an excellent opportunity for students to experience a University course whilst completing their senior studies without a significant increase in workload.

Students will study the majority of the course content within the normal delivery of the QCAA (Queensland Curriculum and Assessment Authority) Syllabus/ Australian Senior Curriculum specific to their chosen course.

After successful completion of the program students will be:

- awarded with a formal Certificate of Completion by Griffith University*
- eligible for credit for a first semester, first year course at Griffith University*(up to 20CP)
- eligible for a guaranteed offer into specified Griffith University programs*
- one bonus rank when applying for entry into Griffith undergraduate degree programs

High School Pathway Program Options:

- Griffith Chem (online)
- Griffith Phys (online)
- Griffith Maths (online)
- Griffith InfoTech (online)
- Griffith Eng + (on campus requirements)

Length: 2 year program - Years 11 and 12

**students must remain OP eligible and maintain specified achievement levels in specified senior subjects*

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EASY SCIENCE: SHORT TERM GAIN AND LONG TERM LOSS

By Dr Tanya Scharaschkin

The information presented here is based on personal experiences and does not, in any way, reflect any policy or position at QUT. The points below are my thoughts on how I perceive we are teaching science at university and the implications this has for how science is taught in schools. I have compared to my experience of having taught high school biology teaching in Pakistan and Kenya and undergraduate biology at two US universities (University of Michigan, Ann Arbor and University of California, Davis) and two Australian universities (UQ and QUT). As a student, I was taught science at school, undergraduate and postgraduate levels in Pakistan and the postgraduate level in the US.

1. **Expectations at the very start:**
I don't know if this holds true for other Australian universities, but QUT does not expect undergraduates starting a Bachelor of Science degree to have taken any high school science subjects. To accommodate these students, I find myself teaching high school biology at the university level in Australia. We may well be producing Bachelor of "Science" graduates who have not been exposed to high school level science in their non-major areas, and their major does not go much beyond the fundamental concepts. I wonder how our undergraduate students, who did take high school science subjects, will feel when they get to university only to discover they won't get exposed to anything beyond the basics in the first two years of their three-year degree? Are we making entrance into science degrees too easy and are we have lowering the standards to allow more people to get through science degrees? Are our expectations of how much we want our future science graduates to have just too low?
2. **Quality of undergraduate science degrees:**
The breadth and depth of subjects, level of detail and the assessment expectations in the US are extremely different to what I have experienced in Australia. I do not think our future science undergraduates will be able to compete with those from other countries. If an honest appraisal is taken, we will most likely find that we are not providing a thorough and rigorous undergraduate course. A Bachelor of Science (Biology major), for example, does not include much physics and chemistry let alone any non-science subjects, as a comparable US undergraduate degree would offer. The biology subjects that do get covered, are not in any way as comprehensive as those that I experienced in the US or Pakistan, and this goes for non-specialist, basic entry level of subjects like biology, ecology and evolution. The undergraduate science degree in other countries (for example Pakistan, India, Kenya, Botswana and Chile) is not taught in an exciting or innovative manner, but it does provide a really solid foundation in principles, concepts and facts. Students may not have access to fancy labs and modern equipment, but they do know their subject matter thoroughly and can conduct research and teach with confidence in the future.
3. **Qualification of high school teachers:**
High school teachers in Pakistan and Kenya have at least a Bachelor's degree in the subject they taught, although most hold Masters degrees. My teachers were competent, knowledgeable and confident in the subject matter, especially those with Masters degrees. As a student, I respected the teachers who knew their subject matter even if they didn't have an exciting way of teaching it. Teaching skills can be developed, learnt and improved upon; but if there is a significant gap in the understanding and general knowledge about the subject matter, no amount of training in skilful delivery or access to technology is going to make up for that. What expectations should we have for the quality, and basic qualifications, of Australian high school science teachers? Do we want them to be able to present information in an interesting and engaging manner alone or to also be knowledgeable? Will our future students get to enjoy science because they had competent and confident teachers?

Given the three points above, I sadly think our science teachers just do not have the necessary depth of knowledge and confidence in their subject matter as compared to teachers in many other countries. Even if we insist that our high school teachers hold a Bachelor of Science degree, the science degrees we are offering are overly simplified. I have not delved into about science education policy and associated learning and teaching trends, but I do wonder how and why the concept of "content free" teaching has made its way into science degrees?

Solutions? At a very simple level, a potential solution would be to require students entering an undergraduate science degree to not only have studied the three core areas of science (physics, chemistry and biology) at the high school level but also done well at these subjects. Universities could offer additional subjects so that students have the opportunity to meet the necessary pre-requisites (demonstrated competency in sciences at the high school level). This is a common expectation at US universities: if students do not have the necessary background, it does not prevent them from pursuing their chosen goal or changing their career path, but they still have to meet entry requirements by taking additional subjects before enrolling in the desired degree.

We could make things easy for science students (e.g., no or low entry requirements, fewer pre-requisites, high pass rate, easy assessment), but is this strategy going to help us in the long run? Should we not have high expectations of our future scientists and teachers? And should we insist upon a high quality and a reasonable degree of competency even if it means additional years of training to achieve that outcome?

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CENTRAL POLICY ISSUE: RESOURCE ALLOCATION

By Em. Prof. Roger Scott

CENTRAL POLICY ISSUE

Any attempt to solve the presumed problems related to STEM are likely to require changes in the levels of existing public and private expenditure. This is as much a political as a technical challenge.

1.1 SYSTEM MANAGEMENT ISSUES:

- Contests over resource allocation between education and other demands on government and private funds - is STEM more important than hospitals, disability services or lowering of taxation? Will individual taxpayers be prepared to pay more to public or private service providers?
- Contests over resource allocation within the education portfolio – is STEM more important than specific vocational training for apprentices, students with special needs, preschools, new schools?
- Contests within curriculum development branches over STEM against other areas.

1.2 PRIMARY AND SECONDARY SCHOOL MANAGEMENT ISSUES:

'Crowded curriculum' - the range of discrete 'disciplines' emerging in response to needs defined by community organisations and/or politicians: law, economics, psychology and driver education at secondary school; religious education, 'stranger danger', and drug education at primary school.

Localisation of decision-making in School Boards creates inequality and differences in approach.

STEM specialism and the challenge of integrated approaches to education

- Finite number of hours/weeks available unless school day extended by 'enrichment' activities
- Problem of managing 'differential' in student aptitude for mathematics
- Need to identify the ideal quantum of mainstream classes in each year level
- When does 100% cease to be realistic? When is 90% sensible? When is 50% realistic?
- When is 10% realistic and best dealt with through a specialist institution like an Academy?

1.3 POST-SECONDARY MANAGEMENT ISSUES:

- Universities and TAFE sector in competitive environment with price as a factor in both
- Specifying a maths prerequisite for particular courses will generate demand at school level
- Specifying a maths prerequisite may create sub-optimal levels of course enrolment post-school
- How compatible is any requirement for specified level of literacy in English?
- Are there comparable virtues in the study of specific foreign languages for non-native speakers?

2.1 SYSTEM PERSONNEL ISSUES

Perceived general low level of proficiency in STEM seen to require more and better quality teaching at all levels:

- Problem of supply at school level requires specials arrangements - eg price mechanism by increase in base salary plus retention in teaching rather than moving into school management
- Also recruitment of potential teachers from other occupations - social cost to industry, government?
- 'Re-treads' and challenge to new entrants – compare police experience
- School management issue of differential structures and patterns of career advancement
- Teaching skills may be unrelated to formal STEM qualifications
- Long feedback loop if universities require maths for entry to education courses
- Competition from alternative courses with fewer entry hurdles
- Competition from alternative end-product occupations for those with maths aptitude.

3.1 SYSTEMIC VIEWS ON THE PURPOSES OF EDUCATION

- Focus on STEM deficiencies is both long-term in general, usually linked to literacy, and new in specific comparative measurements
- Community support can be identified by key politicians expressing the dominant priority
- Lesson of history in foreign languages - Ryan (Latin), Rudd (Chinese), Shorten (computer coding)
- Lesson of history in History – Donnelly/Wiltshire disagreement with Donnelly mandating History
- Donnelly's exclusivist definition of history in terms of Australia's anglo-centric and Christian past.
- Should schools promote cultural values? Should universities promote cultural values?
- Should schools include life skills and socialization rather than focus exclusively on technical skills?
- Should universities encourage broad education by mandating cultural electives like creative arts and literature? Or foreign languages?

Every answer has implications for resources available to STEM.

3.2 USERS AND CONSUMERS OF EDUCATION SERVICES

- How far should parental preferences determine the answers to each of these questions?
- How far should politicians determine the answers through resource allocation, claiming to represent the taxpayers and the wider community?
- How far should student preference determine the answers?
- At what year level would making STEM subjects mandatory be counter-productive?
- Can the quality of teaching overcome the inherent academic difficulty of STEM subjects compared to descriptive social sciences and creative arts?

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J.D. Story Professor of Public Administration, University of Queensland 1977-1987
Principal of Canberra CCAE and Vice-Chancellor, University of Canberra, 1987-1990
Director-General of the Queensland Department of Education, 1990-1994
Dean of Arts, Queensland University of Technology, 1994-1999
Executive Director of the TJRyan Foundation, 2013 to present
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Policy roles:
Advised state and federal governments on aboriginal education, management education, funding of non-state schools and university governance.

Publications:
An extensive publications list includes books and papers on public policy and the management of schools and of tertiary institutions.