THE WINSTON CHURCHILL MEMORIAL TRUST OF AUSTRALIA

Report by - NEIL BRAMSEN – 2013 Churchill Fellow

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Project

To study programs that successfully engage and enthuse primary and middle school students in MES (Maths, Engineering and Science) or STEM learning to schools, universities and institutions in the USA and UK.

Thanks to the following institutions and hosts that were generous in hosting a visit and sharing their journey. The warmth, openness, hospitality and professional discussion with those below is greatly appreciated.

Preston STEM MS-Scott Nielson, Tracey Winey, Amy Schmer, John Howe

Coconino HS- Christine Sapio, Dave Tessmer

Sinagua MS –Jillian Worssam, Rebecca Yakanin

Northland Preparatory Academy – Kaci Heins

High Tech High – Anne Worrall, Janie Griswold, Lisa Davis, Melissa Daniels, Zoe Randall

National Science Centre/National STEM Centre - Allan Clements, Pauline Hoyle and staff

The Skinners' School - Mark Moody, James Walter and staff

Reed's School – David Atkins

National Science Teachers Conference Boston organisers and presenters

TUFTS CEEO - Merredith Portsmore, Ethan Danahy, Elissa Milto, Riley Meehan

St Katherines STEM - Patty Born-Selly

The School of the Engineering and Arts - Cara Rieckenburg

Thanks also to;

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The NSW Department of Education and Communities for support via approved leave.

My very patient wife Sherida, for tolerating my typing, travel and occasionally absent mind.

Introduction

With the move in Australia to a new national curriculum from 2014 on and new syllabuses for key learning areas including maths and science, an exploration of schools and institutions effectively delivering MES (Maths, Engineering, Science) or STEM (Science, Technology, Engineering, Maths) programs is opportune.

Increasingly we see inquiry or project-based learning identified as a key to student engagement and differentiated learning opportunities along with 21st century teaching and learning strategies such as communication, collaboration, and creativity. STEM programs provide an ideal entry point for schools and educators seeking to incorporate these skills and processes using an engaging subject matter. 1:1 devices, BYOD and integration of the right ICT tool at the right time are essential enablers for student success.

My own school, Mt Ousley Public School in Wollongong, NSW values all of the above and as such these big ideas for student success are reflected in our School Plan where Equity and Excellence and 21st Century Teaching and Learning are two of our strategic directions. The third, Leadership and Management is exemplified through the encouragement of staff such as myself to venture out into the global education world seeking to learn from, and share with fellow educators programs and strategies that not only benefit students but importantly build teacher capacity and professional learning in schools and their systems.

The nature of this report will be to provide an overview of projects and programs of interest at those institutions that generously hosted a visit, and provide some

thoughts and comments on the structures, programs and philosophies that underpin the teaching and learning of STEM in them.

The acronyms in this area abound; STEM, MES, SEM, STEAM even a STREAM school in the US that focused on the R for religion! The importance is not so much the acronym or branding that a school identifies with but how are these essential learning areas valued, considered and the teaching and learning planned.

Look around the room you are in and imagine taking out every object that has some facet of science, technology, engineering or maths involved in its creation. There is little or nothing left….

Neil Bramsen, Assistant Principal, Mt Ousley Public School, McGrath St, Fairy Meadow, NSW, 2519 mobile +61 429941157, neil.bramsen@det.nsw.edu.au

Project - *To study programs that successfully engage and enthuse primary and middle school students in MES (Maths, Engineering and Science) learning to schools, universities and institutions in the USA and UK.*

Key Recommendations (summary only, detail in section 6, p32 of full report)

Project based learning is an effective method of incorporating STEM into the K-8 classroom, it allows for exposure to both deep content and skills. Opportunities exist for collaborative teacher planning utilising teacher skill and interests. Consideration needs to be given to allocated class time, teacher ability, student self regulation, assessment criteria and the balanced explicit teaching of curriculum as required. With PBL all students have equitable entry points and opportunities for success.

Device choice is essential for fully supporting a STEM program. Whether it be dedicated 1:1 or access to 1:1 as a learning moment arises, a commitment to providing equitable access to students is needed. Devices will be used for creating and curating content, coding, collaborating and communicating. Access to apps, software and communication tools is desirable. We live in a connected world and students and staff require ready access.

Integrated literacy and engineering offers an accessible entry point for all teachers to pursue STEM. By using appropriate texts that the teacher is familiar with, engineering and STEM challenges that confront the character in the text can be used to introduce design and engineering tasks. This movement was seen in numerous instances in both the UK and USA.

Integrated STEM subjects mixed with enrichment/outreach opportunities should be utilised to maximise student exposure and opportunity. Integrated STEM subjects within regular class timetabling should leverage staff expertise and collaborative cross KLA syllabus planning. Integrating STEM into the classroom offers scope to hook all students, whereas lunch/after school groups, for example, often cater to students already hooked. Environmental education and sustainability should also be considered for inclusion.

Global connections and the use of experts encourage authentic learning through real connections. Teachers and students need to connect, value and share through building long term partnerships with outside agencies, other schools and the greater community. The walls of a classroom hold up the roof, nothing more. The flat wall class model encourages authentic global sharing and collaboration.

Teacher quality is essential. Consideration needs to be given to staffing, leadership awareness of teacher skill sets and the encouraging staff with differing skills and experiences to collaborate. Schools should build teacher capacity through internal development such as mentoring followed by external options as appropriate. Ensuring quality time for staff and student post lesson reflection is desirable.

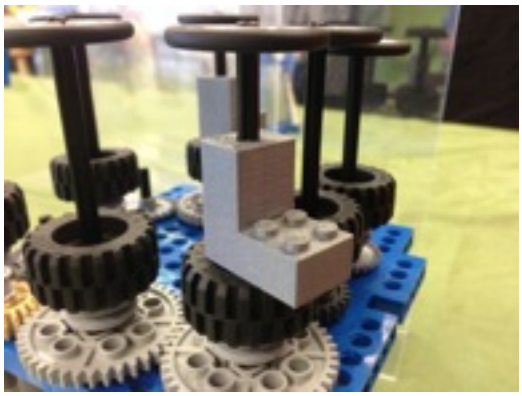
Makerspaces or learning spaces are 21st century spaces for creative learning and making. They encompass easy access, have varied lighting, use modular furniture and are resourced with hands-on equipment such as electronics, pencils, paper, recyclables, computers, toys, play-doh, LEGO, Makey Makey, circuits, building equipment, tools, squishy circuits and more. Schools need to identify a space, plan with student input and resource and timetable appropriately. Curating, celebrating and sharing content or products with the community is essential to making the process for students authentic and valued.

Programme March 8 – April 12 2014
Preston STEM Middle School, Fort Collins, CO
Sinagua Middle School/Coconino High School, Flagstaff AZ
Northland Preparatory Academy, Flagstaff, AZ
Embry Riddle University, Prescott, AZ
High Tech High, Chula Vista
High Tech High Explorer and Middle, San Diego
National STEM Centre, York
European Space Education Research Organisation, York
The Skinners School, Royal Tunbridge Wells, UK
Reed's School , Cobham, UK
National Science Teachers Association Conference, Boston,
TUFTS University– Center for Engineering Education and Outreach, Medford, MA
St Catherine's Centre for Elementary STEM Education, St Paul, MN
School of Engineering and Arts, Golden Valley, MN

Preston Middle

Preston Middle - flight simulator

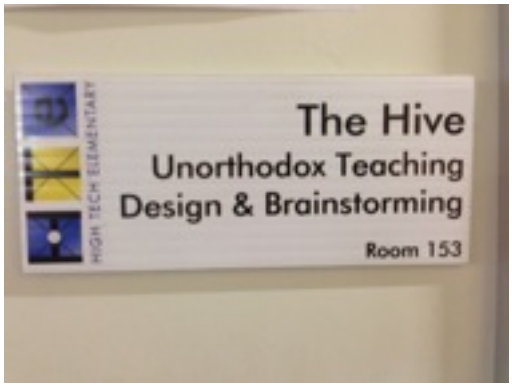
Northland Prep – high altitude ballooning



High Tech High - engineering

High Tech High

High Tech High -project based learning



Hight Tech High –learning spaces

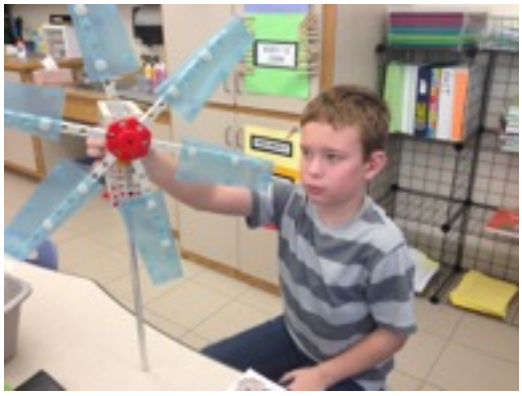
Reed's School - robotics

National STEM Centre –York

The Skinners' School - jewellery design

The Skinners' School – partner school sensory garden via PBL

Reed's School - LEGO studio



SEA School - 20% time

SEA School - 20% time

Main Body

Preston STEM Middle School

Preston STEM Middle School is located in Fort Collins. It is part of the Poudre Schools District and has around 1100 students with strong enrolment demand. The school committed to a STEM focus around five years ago with a view to increasing student engagement STEM; music and arts are also valued.

The Principal and leadership team have developed and implemented a number of strategies to effectively deliver STEM programs.

The building itself feels contemporary with welcoming learning spaces that have been redefined over the past few years. Tables are grouped together to allow student group work collaboration and students utilise corridors and spaces to work together. Lounges and sofas were in some rooms and students were welcome to work from these.

Personal mobile phones are encouraged and students can access the web from their own sim card, many students have elected to install graphing and scientific calculators on their phones to avoid the purchase of a stand-alone calculator.

The school has over 1200 netbooks for student use, and trolleys store and charge the devices. Many classes were operating in a true 1:1 design interspersed with collaborative group work in IWBs. A number of rooms have 3 IWBs in each room to encourage open collaboration and shared learning experiences, an experience to which students responded positively. Coming soon will be a maths class of 60 students, two teachers and 10 IWBs.

An initiative of Preston is an accelerated maths program whereby all students complete Algebra 1 while a number complete the high school Algebra 2 program prior to leaving Preston. The maths rooms had dedicated and passionate teachers with a strong sense of purpose and delivery. A high level of maths talk was evidence such “We are mathematicians, how will we solve this?” Teacher talk was minimal (say 20%) with extensive time given to group and individual problem solving and student discussion (80%). There was lots of thinking time and an expectation that students would engage in discussions and defend or elaborate on their answers or position. A discussion would not take place until 5 students had indicated that they had something constructive to offer. There was a culture of respect, peer acknowledgement and a truly supportive environment with students starting feedback with “I like how… I agree with… My thinking has changed…” for example.

Lessons valued Blooms taxonomy and a teacher maintained a focus on the ability to synthesise during reflection time e.g. At first I thought….now I understand…”

The use of 1:1 devices allowed for self paced learning through Khan Academy support activities.

During an English class students were studying the holocaust and were in the process of demonstrating their understanding of concepts studied. Students using 1:1 devices were creating content using a storyboard type approach by writing statements that were supported with emotive imagery from the Internet.

A Year 6 English class were also on 1:1 devices and emailing individual mentors and experts via Telementor website to support their Genius Hour type individual research project. Student were formulating appropriate questions and submitting

them. A subscription service to science and other experts gave the students and opportunity to make real world connections beyond their classroom.

The school explicitly values critical thinking, communication, collaboration and a creativity. An observation by the Principal was that while 1:1 devices enhance communication between users and act as an enabler, collaboration in the true sense is at risk of being diminished, hence a balance of explicit group work and face to face sharing is evident also.

STEM opportunities include Science Olympiad in over 20 events along with enrichment classes in model rocketry, LEGO robotics, flight simulation, SeaPerch underwater robotics and traditional woodwork for example. 3D printing is becoming increasing popular and offers student a tool to develop complex special awareness and design skills through the construction of concrete materials.

21st century learning paradigms are an essential facet of STEM integration at Preston. Making connections to experts or students in other areas, states and countries is valued. It is not sufficient to simply become aware or increase knowledge but to ask yourself what have you done to help the world and make it a better place. STEM is one element that enables this.

I would like to thank all of the staff for making my visit rewarding and enjoyable. Special thanks go to Scott Neilson, John Howe, Amy Schmer and Tracey Winey for making me feel so welcome and taking the time to delve deep into the learning philosophies and practical implementation of STEM and 21st Century learning practices.

High Tech High

The High Tech High group of San Diego K-12 charter schools began in 1999 and has continued to expand and grow. All students are enrolled via a ballot system to ensure equity for local families and students. The schools focus on a challenging academic curriculum, extensive project-based learning, performance based assessment, digital portfolios and internships. Real world purpose and connections are evident in all classes and the pedagogy is learner centred. Teachers are designers of curriculum and work collegially and in interdisciplinary humanities/arts and science/maths partnerships to teach two classes of around 26-28 students each in middle school with the classes joining to make one large group as required.

As one teacher explained, project–based learning provides an avenue for multiple entry points and it engage students in a supportive equitable manner. PBL is about equity for students and is a model that supports HTH equity principles.

The key points I observed during my visit were;

- lack of bells and interruptions, teachers and students work to a timetable but manage their time. Staggered break times when possible.

- use of halls, floors, corners as learning spaces, round tables and lounge chairs where appropriate, extensive discovery and play equipment in elementary play areas.

- use of ICT devices as needed, used as a specialist support tool (i.e. engineering, robotics, coding, animation), shared use of laptops when learning required it and minimal use of IWBs.

- extensive focus on student generated content through authentic projects and the curating of that content online, in hallways or on walls. Virtually all wall space exhibits student work and explains the design process.

- comprehensive projects with demonstrated depth of skills, content and understandings.

Examples of project based learning across 3-8 that I found powerful and well integrated through humanities/arts and science/maths included;

Grade 3 – Monarch butterfly project incorporating art, a scale model garden, actual garden including various habitat zones, a published information booklet, a weebly web site and a sense of purpose – How can we increase the number of Monarch butterflies in the area?

Grade 5 Music – Rhythm of music and poetry, literacy via songs and music, maths via learning about music and staves, notes including fractions, the design and building own musical instruments including drums and guitar. The performing of poetry and playing of instruments to an authentic parent audience.

Grade 6 Engineering – Studied simple machines including gears, mechanisms, cogs etc. before moving into designing an amusement park with moving rides via LEGO construction, 3D SketchUp modeling of parts and then printing by a 3D printer and detailed explanations of designs and math concepts including ratio and scale.

Grade 7 studied *Sherlock Holmes* – Science/humanities covered the book and the underlying ideas. Students then wrote their own mystery stories that are being published into a paperback. They then completed an in depth exploration of forensic

science via role play – fingerprints, choreography, DNA, anatomy, microscopy – hair analysis and more.

At High Tech High the development of the student is the project; it's about the student not the project itself.

The way in which humanities and science were cohesively programmed into engaging and effective teaching and learning experiences was evident in the above examples.

Thanks to Anne Worrall, Lisa Davis, Melissa Daniels, Janie Griswold and Zoe Randall and the students of HTH for hosting my visit and sharing their experiences and vision.

Flagstaff, Arizona is a STEM city and as such is a community that values STEM and its many STEM experts.

Northland Preparatory Academy

Northland Preparatory Academy is a charter school of grades 6-12. Kaci Heins is the year 6 science teacher and a passionate science educator with a strong interest in space science. Kaci wants her students to be inquisitive, creative, and value the scientific process and opportunities that a STEM career can offer.

Having run after school robotics including First LEGO League, Kaci has now integrated a structured six-week LEGO NXT robotics program into her year 6 science class. During the class, students progress from demonstrating essential maths skills and knowledge required to program the bot through to the actual

sequential process of programming and testing through repeated iterations. Over the course of the unit students explore concepts such as ratio, scale, radius turns and measurement. While not officially meeting maths common core standards the unit strongly combines maths and science into the everyday timetabled class.

High Altitude Weather/Near Space Balloon Launch- During my visit to NPA I was able to participate in a high altitude balloon launch, the third that the school has undertaken. Year 6 students studying weather as a unit complete a balloon launch and all preparations. The hands-on inquiry nature of the project includes the engineering design process, payload research and construction, flight predictions, sensor installation, local geography, the actual launch and recovery followed by data collection and analysis. This was a whole stage project and Kaci believes this project has the biggest impact on students, offering a real 'Aha' moment as theory meets practice during the actual launch. It truly is about making a connection to science and scientific process and understanding.

Arizona Near Space Research and the Coconino Amateur Radio club provided radio support and the tracking team. A couple of parents and one student also joined in the chase. ANSR work with schools to provide supportive and cost effective launches. In the case of this launch some materials were purchased in kit form from Stratostar, a private firm supplying all in one balloon launch solutions for schools. Costs of launches range from approximately $1000-$3000. Air support was also generously provided by Bruce Sidlinger who has a passion to encourage students to pursue STEM related studies and is seeking to provide opportunities within the local community.

Kaci values the forming of partnerships with the local community. Flagstaff has many high technology companies and organisations through the Flagstaff STEM Consortium. Through leveraging these connections she has been able to create links and form partnerships with local radio clubs, observatories and GORE for example.

Amateur Radio on the International Space Station (ARISS) – Please see my previous blog for the Mt Ousley PS experience. MOPS used a landbridge while NPA went for a direct overhead contact via the local radio club. Access to local radio club expertise determines the type of ARISS contact made. The school is also sending a student experiment to the International Space Station this year through the Student Spaceflight Experiment Program. A complex project yet a rewarding and authentic experience for students.

Thanks to Kaci Heins and her students, Bruce Sidlinger and Jack Crabtree for their support and information.

Coconino High School

Coconino High School supports an integrated STEM program; the Coconino Institute of Technology CIT that has been running for over 10 years. Students complete part of their formal studies via integrated physics, biology and chemistry while also completing technology and engineering projects. Students enjoyed the project based approach in the engineering class and were working on an Arduino programming module when I visited.

The Advanced Physics class was completing a circuits module and the class started with a warm up to generate debate followed by group presentations of previous circuit whiteboard problems and a lab practical in groups of 4.

LEGO robotics is also a major focus at the school and students design and build at a number of levels within the LEGO competition structure.

Thanks to Christine Sapio and Dave Tessmer for allowing me to observe and talk with students.

Sinagua Middle School

Sinagua Middle School runs after-school STEM clubs including oceanography and teacher Jillian Worssam has developed a scientist partner program that enables students to be partnered with a scientist to support learning and investigations over the course of the year. The Scientists in the Classroom aims to have every science student at Sinagua Middle School either paired one on one with a scientific mentor all year, or their science class with a mentor agency/business for an entire academic year. This is similar to the Telementor program as used at Preston Middle School.

The Middle School Institute of Technology and Engineering MIT-e program is interesting as it formally integrates STEM into an approved course of study. Students seek admission and undertake a range of project based learning opportunities with a solution or product as an assessment component at conclusion of each topic. Students have developed math skills through water quality studies of a local swimming area and presented their solution to the local mayor. The students that I met with were enthusiastic about the opportunities offered and valued the

hands-on and authentic learning that the MIT-e program delivers. MIT-e is also a pathway into the Coconino High CIT program. MIT-e is approved for grades 6 -8 with specific subjects gaining credit at high school level.

Thanks to Jillian Worssam and Rebecca Yakanin for allowing me to visit and talk with students.

UK National STEM Centre

The National STEM Centre is based at the University of York and is managed by MyScience (an initiative of the While Rose and Sheffield Universities). Funding is supplied by the Department of Education and the Wellcome Trust. A number of programs and initiatives supporting STEM education operate from the centre.

Science Learning Centres - A national network of Science Learning Centres operates across the country offering over 60 programs supporting teacher professional learning and laboratory assistant training. Centres operate at local level through school and institution partnerships. Over 10000 TPL days have been delivered and the National Centre offers onsite residential TPL with depth of course structure. Teachers complete pre-course activities and preparation, face to face sessions and project follow up. The Centre is staffed by teachers and others with engineering expertise.

Physical Collection - The Centre hosts the largest onsite UK collection of STEM teaching and learning resources including print and multimedia materials, teaching resources and an archive of STEM material from recent decades. Over 23000 resources are available for inspection.

eLibrary - The eLibrary offers access to over 8500 teaching and learning resources selected by STEM teacher experts at the Centre. Importantly the resources are of exceptional quality and are sourced from leading science publishers. The site offers primary maths and science portals and secondary portals in clearly arranged and easy to use content based themes. It is also possible to search by skill strands. A range of text, multimedia and interactive resources are available.

Free registration is required and any teacher can register for an account.

UK Curriculum - Computing

One of the interesting aspects of the UK visit has been to discuss changes to the national curriculum leading to the introduction of Computing as a K-12 subject. Previously the term ICT has been used however computing now encompasses, computer science, information technology and digital literacy. Computer science states that students, 'can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation' and that students, '…have repeated practical experience of writing programs in order to solve problems.'

I believe that coding and programming offer great opportunities to engage and enthuse students to understand the maths, logic and programming skills expected of 21st century citizens. By incorporating coding into the classroom, be it stand-alone, or as part of a PBL approach as in High Tech High, we are getting students to investigate in a hands-on fashion with clearly visible levels of success or failure.

Scratch, Beebots, Probots, Arduino, Raspberry Pi, MIT App developer, LEGO NXT and EV3 robotics and VEX robotics are all examples of programming and coding tools and applications suited to an education context.

European Space Education Research Office

European Space Education Research Office ESERO - The UK branch of ESERO is located at the National STEM Centre and has been established as a teaching project to promote STEM interest via space science. Launched in 2010 the UK arm functions as an educational portal for space science and education resources. Its aims include to share good teaching practice, to be a primary point of contact for teachers and to raise the profile of the European Space Agency. ESERO-UK also managed a network of Space Ambassadors across the UK who function as local points of contact for the networking and space education within STEM related areas.

Skinners' Academy

Skinners' Academy is located in Royal Tunbridge Wells. It is a boys' day school from grades 7-12. The school gained specialist science status in 2002. It has a reputation for excellent academic achievement in maths and science. The school has also been awarded Green School status demonstrating a high level of measurable commitment to sustainability including recycling programs along with the extensive use of solar power.

The school has a committed STEM focus driven by an underlying theme of the circular economy and environmental sustainability. Projects wherever possible take

into account the finished product, the materials used and its end of life impact on the environment. The environment serves as a vehicle for STEM delivery.

STEM is delivered through a number of channels including extension and enrichment, partnerships with other local schools and through an approved integrated STEM subject in grades 7-9. As with most other UK schools, grade 10 assessment processes dictate that subjects revert to discreet subject areas at this point.

Students have recently completed a VEX robotics project culminating in attendance at a schools competition. VEX offers a robotic experience with design and construction, testing and programming in robot-c. The robots tend to be larger than LEGO NXT for example and teams of 4-5 can work collaboratively. At Skinners' there is an expectation that senior students will mentor and support junior students while also conducting outreach activities in local schools. A strong pastoral care system is evident and connections to community are valued. In this instance students become STEM ambassadors and actively promote, support and encourage STEM thinking among peers, other students and the community.

One example is a partnership managed by Mark Moody with nearby Oakley School. On my visit to Oakley I was able to observe an environmental and outdoors experiential learning environment very much developed through the support of Skinners' boys and the STEM program. A number of projects had been completed such as a sensory garden, eco-classroom, large biodiversity pond, wildlife cabin and extensive seasonal garden. This initiative while different to many of the more 'high tech' STEM initiatives I saw during my trip is an example of the many faces of STEM, all of which are valid learning experiences.

The integrated STEM subject runs through KS3 and has incorporated the subjects of Design and Technology, ICT and Creative Arts. This blending enables the school and the teaching staff enough flexibility to design projects that offer an engaging STEM experience while meeting curriculum and assessment requirements. The challenges, as expressed by other schools doing similar programs are to have staff with the skill set, passion and ability to deliver what is by nature a broad program. At times the maths and science faculties are called upon to provide content or explicit skills teaching required by students during their STEM time. This can at times prove challenging due to timetabling and inter-faculty commitments.

Head of Design and Technology James Walters would like to see all students innovating by year 9 and to achieve this they need to be developing design skills in year 8. James also believes that a subject such as ‘design creativity’ would be a valuable addition to the program. In this model, year 7 students would have a skills focus, learning about the tools and materials required to design and then innovate. The process is one of skills development, leading to design ability with the accumulated result being innovation.

I was able to observe a grade 9 STEM design lesson. Students had explored the process of casting and the materials that enable jewellery to be formed in a sustainable fashion. Over the course of previous weeks students explored the design process using sketches, the making of a moulds using hand carved cuttlefish or via a CAD design and laser cut mdf option. They then selected appropriate metals and undertook the casting and finishing process. The use of pewter means that any flawed works can be recast and cuttlefish mould is bio-degradable, an example of circular loop economy and the use of sustainable materials.

Thanks to Mark Moody, James Walter, Julian Metcalf and Rebecca for hosting my visit.

Reeds School

Reeds School is an independent boarding school in Cobham, Surrey. The school has a long and proud history and recently celebrated its 200th anniversary when the Queen visited. The school has a strong academic focus and is ranked in the top 20 UK boarding schools.

STEM is delivered through multiple pathways including enrichment, extra-curricula and through an integrated STEM subject in years 7-9. The integrated subject brings together design and technology, robotics and coding over 6-8 weeks for around 2.5hrs a week. Electronics, engineering and Greenpower curriculum materials are also focus areas in 2014.

Enrichment programs run after school and LEGO NXT/EV3 robotics is very popular among year 7/8 students. Weekend STEM workshops for local schools are also popular and regularly book out.

Challenges include ensuring the right balance of staff experience and interest for the skills and topics being taught, and finding a balance between more open-ended project based learning and the need for adherence to curriculum, assessment and timetabling requirements.

The school completed its FutureTech building two years ago. FutureTech aims to be a focus point for innovations, design and STEM learning. It is very much a 21stcentury learning space with wonderfully expansive use of natural light and glass,

gallery and content curation spaces. Dedicated rooms are available for design and technology, robotics and computing. The school is continually reviewing the nature and purpose of the FutureTech centre to best meet the needs of its students from 7-9 and 10-12 during the formal years of study while also providing a base for STEM outreach and workshops.

Thanks to David Atkins for hosting my visit.

2014 National Science Teachers Association Conference

The 2014 NSTA conference was in Boston. Around 10000 teachers, hundreds of trade exhibitors and around 500 workshops day meant for a huge and sometimes overwhelming range of choices. When you narrow down your Thursday 8:00am slot and still have 6 conflicting workshops some quick and hard choices have to be made!

The days were full with a range of keynotes, symposiums, presentations and workshops. Many sessions had an explicit STEM focus ranging from the setting up of an integrated STEM curriculum in a school, STEM school case studies to practical design and build activities for elementary and middle school teachers. A number of sessions that I found interesting included;

The Zydeco iPad app for running an inquiry based science learning sequence. A user friendly interface, multi-modal data collection, sequential questioning and the ability to save provide for an effective science learning tool.

Sparkfun ran a number of hands-on sessions designed to increase teacher skill and confidence. I'm interested in coding and joined in a Scratch and Picoboard programming session. Scratch really does offer an engaging and stable platform designed to not only build games but for data collection and graphing.

A session on Tinkering with Elementary Engineering provided a packed house with many simple hands-on design and make activities.

Connecting Science, Engineering and Literacy in the Elementary Classroom gave an example of cross learning area integration that works so well in the STEM context. The literacy focus is similar to that being investigated at the CEEO Novel Engineering project. It also provides a jumping off point to delve deeper into the project-based learning done so well at High Tech High. A powerpoint is available here.

Attending two keynotes was a highlight. The first by well-known actress Mayim Bialik (Amy on Big Bag Theory) covered Mayim's journey through her science studies resulting in a Phd in Neuroscience along with some acting tales. Mayim is a strong supporter of STEM and the sciences, she says that "maths is a beautiful language that offers so much...'

Later I attended an Aerospace Educators lunch with astronaut Joe Acaba who was selected through the teacher astronaut program, he talked about the similar traits that both astronauts and teachers have including flexibility, discipline, creativity, team players and the like. His bio can be found here.

TUFTS Center for Engineering Education and Outreach CEEO

TUFTS University is located in Medford, near Boston. The Center for Engineering Education and Outreach (CEEO) runs a number of research and outreach programs for students and teachers at the local and international level. A long association with LEGO means that the Center has a well developed and broad understanding of LEGO robotics as a engineering tool for education. The Associate Director Merredith Portsmore and her team took time to share with me some of the programs with strong STEM connections.

STOMP – (Student Teacher Outreach Mentorship Program) is an opportunity for undergraduate, graduate, high school, and industry employees to promote engineering education in K-12 settings. STOMP fellows provide expert engineering knowledge to K-12 classrooms to assist/mentor K-12 teachers and students. Simultaneously, STOMP fellows learn about K-12 learning from the teachers and students.

Currently, the STOMP program engages 59 Tufts students from a variety of academic disciplines. Undergraduate and graduate student employees work between 5 and 10 hours each week, including classroom time, preparation, and weekly development meetings.

InterLACE (Interactive Learning and Collaboration Environment) project aims to support high school students in carrying out collaborative inquiry-based lessons. The InterLACE toolkit provides both features and teacher-customisable content that encourage discussion, debate, self-assessment, reflection, and collective sense-making. It very much makes use of the flipped classroom model and encourages openness, sharing and collaboration in a supportive visual manner.

DrEschallenges is a web platform providing users anywhere in the world with a virtual community exploring LEGO WeDo. Monthly challenges are set and users can upload media of their project for others to view. Dr Ethan Danahy states that the goal for this site is to create a set of challenges to promote science, math, and engineering education in classrooms. We hope that the site provides opportunities for kids to help and learn from each other, and for teachers to find a valuable support community for trying engineering in the classroom.

https://wedo.dreschallenges.com/

LEGO Engineering is a site dedicated to LEGO robotics and offers support at many levels from beginner to expert. A variety of tutorials, demonstrations, code and articles are available.

An exciting initiative is the five year nationally funded Integration Engineering and Literacy project. Using an interdisciplinary model the goal is to support classroom teachers to merge literacy comprehension through novel studies with a STEM engineering component.

Rationale for the project can be found at http://ceeo.tufts.edu/research/projectsIEL.htm while a new website for teachers has recently been launched at novelengineering.org. Students identify a problem or challenge in a text and set about designing and building a solution to that problem. Examples of texts and the challenges the characters face can be found at http://novelengineering.org/what-is-novel-engineering/get-started/book-ideas/

I see great value in the project. It offers teachers who are not confident with the design and make process, a supportive way in through using texts that they are

familiar and at ease with. By combining both literacy and STEM, an integrated project learning experience is accessible and students have an engaging and challenging environment in which to succeed.

I was keen to hear more about 21st century learning spaces and the term ‘makerspace’ is one we hear increasingly. A makerspace is a space for students to create and make, there is no one set model and each school would design and grow its makerspace around student and teacher input. Examples might include books as needed, teacher lead experiences or student choice. Core elements might include modular and adjustable furniture, few horizontal surfaces along with plentiful that tools should facilitate expression of ideas. These could include LEGO bricks, SAM animation, squishy circuits, curated content and wall storage. The CEEO is working with a local school to design its own makerspace that will benefit not only the school but also surrounding schools through a community outreach program.

In the near future the CEEO aims to grow educational influence and further translate its research findings into effective teacher practice. It aims to increase its online STEM graduate engineering courses while acknowledging that it can take 3-4 years to change teacher styles and practice.

From a research perspective, Merredith is keen to pursue avenues that offers a construct of what kids can and cannot do while considering what do we value in learning and how do we measure it. It is also important to get students to push back through questioning and challenges rather than spoon-feeding them content. We need to ask students, Why is it fun? What do you like? How do you interact with your peers?

Thanks to Merredith Portsmore, Ethan Danahy, Elissa Milto and Riley Meehan for hosting the visit.

National Center for STEM Elementary Education

The National Center for STEM Elementary Education is a part of St Catherine's University, St Paul and seeks to improve teacher effectiveness, advance student performance, strengthen STEM literacy and increase individual candidate appeal in competitive job markets. Patty Born-Selly is the Executive Director and spent some time outlining the Center's key features. Importantly and from an undergraduate perspective all students undertake three STEM subjects as a part of their degree. This is combined with fieldwork and the EcoSTARS program whereby students spend time in schools implementing environmental education initiatives through the international GLOBE program. The Center is also delivering post-graduate STEM studies and is looking to grow this area of their expertise. Outreach is also an integral component, and dependent on funding, includes supporting local school districts with programs such as curriculum development, teacher professional learning and workshops on robotics and the like. Recent initiatives include workshops for elementary and middle school students including girls only sessions using Coderdojo to teach programming skills in Scratch and MIT AppInventor.

School of Engineering and Arts

The School of Engineering Arts (SEA) is a STEM magnet school located in Minneapolis. The school is K-5 and was established two years ago on an existing

school site. Enrolment is through ballot and there is an extensive demand for places due to the STEM program and strong academic results.

Cara Rieckenburg is the Program Director and helped establish the school along with Principal Kim Hiel. We talked about the STEM journey, met with K-5 students and toured the school.

SEA is like a number of other schools I visited looking to integrate STEM teaching and learning into everyday curricula. Again, using literacy studies and novels as a way into the engineering design process was evident in the school. Texts by Gary Paulsen such as *Hatchet* and *Julie of the Wolves* and *My Side of the Mountain* by Jean Craighead George were given as strong examples of appropriate texts.

Year 3 students were working on their 20% or Genius Hour projects when I visited and it was rewarding to see one of the girls using a circuit board and multi-meter to construct a circuit. Other students were building wind turbines, pulling apart remote control helicopters to make a drone and working on backdrops for animations. The nature of topics was diverse and students were self-managing their time and progress while seeking teacher and peer assistance if required.

Year 5 students have 1:1 Chromebooks and talked about how much they enjoyed the learning opportunities provided. Coding and game design with Scratch, iMovie trailers and other multi-media content were showcased by the students. Students take their Chromebooks home and often complete work after school hours for personal interest.

The school has made the best of turning its traditional building into a 21st century learning space including new modular and mobile furniture, multiple projectors in the

library media space and extensive science supplies and makerspace equipment. Students were collaborating in small groups around corridors and in the library media room; sitting and working on the floor is encouraged.

Cara talked about the need for extensive teacher professional learning through regular mentoring, along with 1:1 teacher sessions on term goals, software use and 21st century pedagogy.

Visiting SEA was a wonderful way to finish what has been a rewarding journey into current practises in STEM teaching and learning.

Thanks to Cara and Kim for hosting my visit.

Conclusions and Recommendations

The new National Science and Maths syllabuses provide schools with timely opportunities to re-examine and explore their commitment to the teaching of science and maths. In this age, when the likes of the Melbourne Declaration and a focus on 21st century teaching and learning perspectives (such as Wagner) encourage reflection and change in term of teaching styles, technology use and the expectations and the role of the teacher. Redefining the student as an active and an engaged learner, self-managing and global citizen offers further scope for change.

I commenced my trip with some ideas of what I thought worked well in my school, some preconceptions of things that might work well and an open mind to the many experiences that the trip would offer. Over the course of five weeks, and on reflection since, I've been able to clarify and identify some key ideas or opportunities that I believe can support our schools in creating meaningful, important and valued STEM learning experiences. As so many educators enthused, we need to hook students into the maths and sciences while they are young, i.e. 8-12 years old ideally during the formative years when interests can be developed and grown.

The following recommendations are by nature as broad as schools are unique and are aimed at school leadership teams that will choose to initiate and customise programs that support the ethos, culture, direction and needs of their students.

Project based learning (PBL) is effective method of incorporating STEM into the K-8 classroom. Inquiry learning, challenge based learning and purpose based learning are similar models. PBL allows for exposure to both deep content and skills. Opportunities exist for collaborative teacher planning utilising teacher skill and

interests. Consideration needs to be given to allocated class time, teacher ability, student self regulation, assessment criteria and the explicit teaching of curriculum as and when required. Schools can introduce PBL models through in NSW for example through Human Society and its Environment (HSIE), Science and Maths curriculum outcomes. Popular science programs such as the current *Primary Connections* provide strong support for teachers lacking confidence or skills in teaching science but importantly should also be used as a jumping off point to develop PBL opportunities. I value the comments of staff at High Tech High who state that PBL offers multiple entry points for students and enables them to achieve equitable success in a given area.

Device choice is essential for fully supporting a STEM program. Whether it be dedicated 1:1 or access to 1:1 as needed, a commitment to providing equitable device access to students is needed. Devices will be used for creating and curating content, collaborating and communicating, making, sharing, coding, designing and creating. A connected world is that which our students live in, they need access as required to make those connections, design solutions and share successes.

Integrated literacy and engineering offers an accessible entry point for all teachers to pursue STEM. By using stage appropriate texts that the teacher is familiar with, engineering and STEM challenges that confront the character in the text can be used to introduce design and engineering tasks. Sufficient time needs to be allocated to allow for the design and make process. This is ideal for group work and offers great scope for creativity and engagement with a text in previously unexplored ways. TUFTS CEEO has generated a list of texts used during its pilot program and these can be found on the website www.novelengineering.org

Specialist STEM subjects and enrichment/outreach should be utilised. Integrated STEM subjects could include programming and coding in Scratch for developing maths logic, LEGO robotics for measurement, Sketchup for 3D shapes, Garageband for music and notation, Arduino programming and the like. Staff expertise should be utilised and syllabus planning undertaken. Integrating STEM into the classroom offers scope to hook all students whereas lunch and after school groups cater for those already hooked. Integrated STEM subjects especially in grades 6-9 can leverage staff expertise ad student interest to provide a comprehensive cross curricula STEM opportunities. Enrichment and outreach are valid avenues (and in some cases the only avenue) to offer STEM specialty clubs and projects (e.g. Science club, First Lego League, VEX robotics, school environmental initiatives) to students, however as mentioned previously, the students that put their hand up for these opportunities are already often convinced that STEM is an area of curiosity or interest for them. The challenge remains in the mainstream classroom where all students need to be exposed to STEM opportunities that are differentiated and engaging.

Global connections and use of experts encourages authentic learning through making real connections, Teachers and students need to leverage, connect, value and share in partnerships through building long term partnerships with outside agencies, other schools and the greater community. PBL, Scientists in Schools, Skype and face to face mentors are some examples. The walls in a school are designed to hold up the roof, that is all. Connections and global sharing are key tenants of the 21st century teaching paradigm and cannot be ignored. Social media networks through Facebook, departmental platforms (e.g. Yammer in NSW) and

Twitter offer access to professionals with similar interests or specific expertise that can be leveraged to benefit student learning.

Teacher quality via extensive professional learning is essential for a successful STEM program. Consideration needs to be given to staffing positions, leadership awareness of teacher skill sets and encouraging staff with differing skills and experience to collaborate and possibly mentor/team teach. Enhancing skills and knowledge through internal development first and external options if appropriate. Teacher quality was raised by all institutions visited as extremely important to a successful STEM program. Teachers with effective classroom management strategies, a responsive nature, powerful questioning and communication skills and an ability to create a culture of mutual respect are well positioned to maximise teaching and learning opportunities and outcomes for their students.

In NSW the Quality Teaching Framework provides the structure and research to inform quality teaching in schools. Combined with the influential work of John Hattie, the Australian Institute for Teaching and School Leadership and the Australian Curriculum and Reporting Authority, leadership teams in NSW and Australia are well supported in developing and implementing quality teacher professional learning and development initiatives.

Makerspaces/learning spaces are 21st century spaces for creative learning and making. They encompass easy access, are open to all, have varied lighting, use modular furniture and are resourced with hands-on equipment such as electronics, pencils, paper, recyclables, computers, toys, play-doh, LEGO, Makey Makey devices, circuits, building equipment, tools, squishy electrical circuits and more.

Schools need to identify a space, plan with student input and resource and timetable appropriately.

Dissemination

The findings of this tour and the recommendations will be distributed and promoted through:

The website and blog at neilbramsen.edublogs.org

The use of social media such as Twitter via @galaxyinvader

Expected presentations at the NSW STA 2014 conference, CONASTA 2015, Illawarra/Wollongong Teach Meets.

The forwarding of the summary findings to;

NSW Department of Education and Communities – Minister and State Office

NSW Catholic Education Office

NSW Independent Schools Association

Federal Minister for Education

Education Faculty – University of Wollongong

ACARA

Australian Academy of Science

National Science Teachers Association inc. an article in Teaching Science Journal

NSW Science Teachers SEN Journal

All schools and institutions visited