educationconference

Creating innovative futures through STEM

Deakin University STEM Education Conference, Online

18 – 19 October 2021

Convened in association with the Geelong Tech School at The Gordon

Conference proceedings: Selected Works

Edited by: Linda Hobbs, Coral Campbell and Lihua Xu

GEELONG TECH SCHOOL | the Gordon | DEAKIN UNIVERSITY | Skilling THE BAY | VICTORIA State Government | Education and Training

Deakin University

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Front cover:

Logo design by Hugo Rieniets, St Joseph's College, Geelong Tech School Student Ambassador: https://www.geelongstemhub.org/ambassadors

"What STEM means to me is being able to have the freedom to create whatever is on your mind and to bring something from a computer into the real world. When Science, Technology, Engineering, and Math are all combined together something great is made." (Hugo Rieniets)

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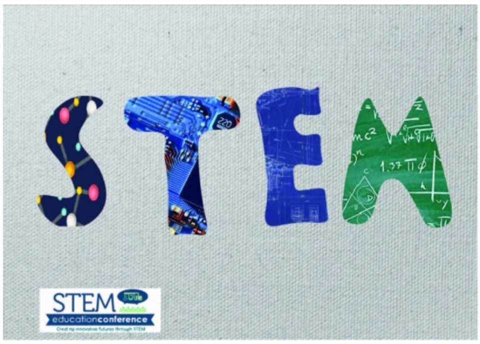

Luka Bradar
St Joseph’s College

“I am a Geelong Tech School Ambassador because I am interested in technology and STEM related projects.”

INTRODUCTION

These proceedings feature selected works prepared by presenters from the Deakin STEM Education conference, held October 18-19, 2021.

This is the third Deakin Science Education Conference, but the first to be held entirely online. The intention had been to host the conference at the Geelong Tech School, but COVID-19 restrictions pushed the conference online. Thanks to the presenters who stuck with us through two postponements and this final shift to online. Shifting an interactive workshop to an online workshop is particularly challenging, so thanks to all workshop presenters.

The conference featured two keynote presentations, including Dr Tien Kieu MP, (Victoria's STEM Education Ambassador), and Professor Kate Smith-Miles (mathematician and mathematics educator), both well received. The program consisted of 25 paper presentations and 34 workshops. Presenters were teachers, researchers and teacher educators, facilitators and program leaders, and industry leaders. In addition, a panel discussion featured girls and teachers involved in the Girls As Leaders in STEM (GALS) program, a Deakin program ran by Coral Campbell, Lihua Xu and Linda Hobbs, and funded by The Invergowrie Foundation.

As an online conference, a dedicated online program allowed access to the sessions. The website featured logos developed by Geelong Tech School student ambassadors, all of which are featured throughout these proceedings. Thanks to the Geelong Tech School and the ambassadors for these amazing designs.

Deakin University and Geelong Tech School

Deakin University is dedicated to science, technology, environmental, mathematics and STEM education through delivering courses for pre-service and in-service teachers, as well as through building teacher capacity through professional learning programs. We are leaders in STEM education research, and our research informs the work we do with schools and teachers. You can see more of our work with schools on our Geelong STEM Hub website (https://www.geelongstemhub.org) and our STEME research group website https://deakinsteme.org/ .

Deakin University researchers have been associated with the Geelong Tech School from its beginnings. As a face-to-face conference, we had planned to utilise the amazing spaces, equipment and expertise that the Geelong Tech School offers. Moving to online, we were still able to showcase Tech School programs and activities through a number of applied learning workshops and presentations showcasing the program offerings of the Tech School. Student Ambassadors created STEM designs, shared their thoughts around STEM and were to be involved in the onsite program.

The Geelong Tech School is proud to support the Deakin STEM Education conference. In the Geelong region, Tech School programs support teachers to integrate STEM projects and multidisciplinary learning into their curriculum. Through workshops and a range of opportunities teachers and students develop technology skills, experience design thinking, and practice project based learning that has ‘real world’ connections with local industry.

Augie Messer
Matthew Flinders Girls Secondary College

“I like to think of STEM as STEAM, because I think that art is just as important, and it is also the area I particularly like to focus on. To me, STEAM is all about learning and growing, and trying to understand a little more about our universe than what we may instinctively perceive.”

KEYNOTE

2021 STEM EDUCATION CONFERENCE
deakin.edu.au/stem-education-conference-2021

Lucy Heitmann
North Geelong Secondary College

"I really enjoy STEM! I like that there's an endless amount of things to find out, learn about and explore. I enjoy using what I am learning to solve problems, and having options to try something new if the first attempt doesn't work as expected. It is both predictable and exciting - predictable in that there are formulas and methods and procedures to follow, and exciting in that you're always challenging yourself and learning something new. STEM is a possibility to change the world."

STEM Education Ambassador

Dr Tien Kieu MP

Victoria State Government

Thank you to Deakin University for giving me the opportunity to speak you. I begin by acknowledging the Traditional Owners of the lands on which we are all individually located this afternoon. I pay my respects to their Elders, past, present, and emerging, and to all Elders or Aboriginal people taking part today. I also acknowledge our MC, Linda Hobbs, Associate Professor for Science Education at Deakin University, conference convenors, Associate Professor Coral Campbell, and Dr Lihua Xu at Deakin University, and all the STEM educators and professionals joining us this afternoon.

As you know, I am the Victorian Government's STEM Education Ambassador. I am also a physicist and Member of the Legislative Council for South-East Metropolitan Region. I was once a Vietnamese refugee. I travelled on a boat to Malaysia, where we lived in a refugee camp until we were offered passage and resettlement in Brisbane, Australia. I worked as a labourer before enrolling at the University of Queensland, beginning an academic career in theoretical physics. This work took me to the University of Edinburgh and Oxford University. I also worked in the United States as a Fulbright scholar at Columbia University, Princeton, and the Massachusetts Institute of Technology. In Australia, I worked at the University of Melbourne, my last position was as a Professorial Fellow, and also at Swinburne University of Technology where I currently serve as an Adjunct Professor.

STEM was my ticket to a new and prosperous life in this country and it remains my great passion. As a physicist and now a politician, skills such as analytical and critical thinking, problem solving, collaborating, and communicating have stood me in good stead. Last year, the Minister for Education, James Merlino MP, announced that I had been made an inaugural Ambassador for STEM Education in Victoria. I am proud to have been given the opportunity to take on this important role. This position supports me to continue my lifelong passion and commitment to the academic pursuit of Science, Technology, Engineering and Mathematics, and of STEM education.

In my view, the great challenges that face the world, like the pandemic and climate change, will not be solved without the help of STEM disciplines. The jobs of the future find their roots in STEM. Furthermore, as a nation we must ensure our technological sovereignty, such as medical sciences, biosecurity, vaccinations, cybersecurity, and nuclear technology, through building on our pedigree as an innovative State.

My role as STEM Education Ambassador is to work with schools, Tech Schools, teachers, and employers across Victoria to champion STEM education and pathways. I am particularly keen to focus on connections between schools and industries, key STEM initiatives and the investment of specialist education facilities. I have visited schools and Tech Schools whenever possible over the past 18 months to build my understanding of how STEM education is developing in Victoria. I provide the Minister for Education and the Department of Education and Training advice and assistance on how best to encourage Victoria's students to explore the world through STEM subjects, and how to further strengthen our State's STEM education.

It is also my great honour to be working with Dr Amanda Caples, Victoria's Lead Scientist, to identify ways schools and STEM industries can join forces to give students more opportunities for hands-on learning. I am excited to continue my lifelong advocacy for STEM in my role, with its focus on preparing Victorian students for the jobs of tomorrow. As you would appreciate, STEM industries play an important role in Victoria's economy and our nation's economy.

Employers are increasingly looking for workers who are creative problem solvers, innovative and critical thinkers, able to use new technologies and even contribute to the development of new technologies. They seek people who are team-players willing to work with others to solve problems. STEM skills set us up for more than just getting a job. STEM skills are critical to young people becoming active and informed citizens. New technologies will define the job market for decades to come.

STEM is one of the Government's priorities in its vision for Victoria as the Education State. It's why this Government has opened 10 Tech schools alongside the six existing Science and Mathematics Specialist Centres. And there is our partnership with Deakin University to deliver the Primary Mathematics and Science Specialists and the Secondary Mathematics and Science initiatives — both addressing workforce challenges.

This focus on STEM education is particularly important as we look to our economic recovery from the impacts of the coronavirus pandemic. This recognises that our future prosperity is greatly reliant on a workforce that is increasingly STEM-literate. The coronavirus pandemic has changed the way we live, work, learn and travel. Parents and teachers have had to find new ways to innovate, engage and adapt to keep students engaged with their studies. The challenge has been especially acute in subjects that normally require access to labs and other specialist facilities. I believe the pandemic will accelerate the existing push to ensure our economy has the skilled STEM workers it needs. Yet there really is a positive side to the pandemic. Scientists, particularly doctors and epidemiologists have become household names. They speak alongside state and national leaders at press conferences. Their views are broadcast on every platform. Indeed, many of these experts are women. Professor Sharon Lewin, the inaugural director of the Doherty Institute, has led the national modelling to create a pathway out of coronavirus restrictions. Epidemiologists like Professor Catherine Bennett (Deakin) and Professor Marylouise McLaws (UNSW) are regular expert commentators. Never has the importance of STEM been so clear.

With our nation's small population, it is vital we fully mobilise our Human Capital to drive innovation, forge new industries and compete globally. To find solutions for the many challenges still ahead of us — climate change being the most urgent and daunting. The Government's investment in STEM education involves developing a broad base of core STEM skills from early childhood, through primary and secondary school and into tertiary education and training. The reality is, however, that participation is low among some student groups — particularly women. Our reforms are addressing challenges to STEM education in Victoria, such as:

- The under-representation of girls, rural students and Koorie students in STEM.
- The need to build better analytical and critical and creative thinking skills in our students.
- Ensuring that children and young people are exposed to industry perspectives and develop the STEM skills needed.

Importantly, we are building the confidence and capability of educators to deliver high-quality STEM learning through the specialist training I mentioned earlier. There is also the Teacher Financial Incentives Program. This program aims to attract high-quality teachers where they are needed most. This includes rural and regional schools and in STEM subject areas. So far, more than 263 teachers have taken the opportunity to contribute their skills and experience in schools and subject areas that need it the most.

STEM education begins at home. Research shows that while parents would like to help their children with STEM learning, they often lack the confidence and knowledge to do it. The Department has a wide range of resources for parents of young children to spark that passion for STEM subjects early. We are training our educators to support parents to do this. The resources available give parents the vocabulary and strategies to extend their children's STEM learning. These include getting children to describe what they are observing and make predictions. Tech Schools open days and events are encouraging the parents of older children to have those important discussions about the role of STEM in our lives and our futures. Through play, through noticing, talking about and exploring our own innate curiosity about the things we experience in our everyday lives, we can all help nurture tomorrow's scientists, engineers, inventors, and innovators.

In summing up, we know that STEM skills are increasingly important to people's future. A great education system widens opportunities for all. It reduces the impact of disadvantage, and empowers people with the skills, knowledge and experience they need to build healthy, happy, and prosperous lives – contributing to a just and prosperous society. As demand for STEM skills increases, it is critical to attract and retain Victorians from all backgrounds into STEM careers. Creating opportunities in these fields will create a diverse, innovative workforce and will encourage strong economic growth in Victoria. It's so important that we continue to discuss how we can improve on the work we are doing in this field. I was delighted to hear and learn about the ideas and outcomes from this conference.

Thank you for the opportunity to speak to you.

PAPER PRESENTATIONS

Sienna Donatucci
Matthew Flinders Girls Secondary College

"I became a Geelong Tech School Ambassador because I want to use technology efficiently in the future and would like to know how to use it properly."

MED-E-SIM Webinar: Inspiring Australian senior secondary school students to careers in healthcare during the COVID-19 global pandemic

Alberto Au, Louise Palmer and Catherine Carbery

RMH Clinical Simulation Centre, The Royal Melbourne Hospital, Australia

Abstract. Globally, the shortage of healthcare workers is projected to be greater than 14.5 million in year 2030. Research suggested that promoting awareness and interest is essential to guide academic and career pursuits. The authors have previously conducted a study demonstrating that, MED-E-SIM, a one-day educational programme incorporating hands-on simulated learning could help improve Australian senior secondary school students' decision in pursuing future study and career in health ($P < 0.001$). Due to the COVID-19 pandemic enforced lockdowns and social distancing restrictions, the challenge for health educators is to explore contactless learning experience that can improve secondary students' understanding of healthcare and inspire them to pursue future studies and careers in the healthcare field. MED-E-SIM Webinar is a health professionals led webinar discussion forum aimed at inspiring senior secondary students in pursuing a healthcare career/further study. In order to evaluate the impact of MED-E-SIM Webinar, 43 senior secondary school students who participated in the webinar were invited to complete the post programme evaluation survey. We observed increases in students' self-perceived understanding of health profession after the participation in MED-E-SIM Webinar. Furthermore, our study also showed that MED-E-SIM webinar participation could help improve participants' decision in pursuing a future career in health ($p = 0.001$).

Introduction

Globally, the shortage of healthcare workers is projected to be greater than 14.5 million in 2030 (World Health Organization [WHO], 2016). Similarly, Australia's health workforce shortage is projected to continue to increase exponentially, with a deficit of 109,500 nurses and 2,700 doctors by 2025 (Health Workforce Australia [HWA], 2012).

Research suggested that promoting awareness and interest is essential to guide academic and career pursuits (Harackiewicz et al., 2016). The authors have previously conducted a study demonstrating that MED-E-SIM, a one-day educational programme incorporating hands-on simulated learning, could help improve Australian senior secondary school students' decision in pursuing future studies and careers in health ($P < 0.001$) (Au et al., 2020).

Due to the COVID-19 pandemic enforced lockdowns and social distancing restrictions, this has rendered the original MED-E-SIM programme to be cancelled in 2020 and the likelihood of its delivery in 2021 (and beyond) remains highly uncertain.

Whilst social distancing and lockdown restrictions are essential and unavoidable new norms, the COVID-19 pandemic also reaffirmed the alarming issue of a global healthcare workforce shortage. The challenge for health educators is to explore contactless learning experiences that can improve secondary students' understanding of healthcare and inspire them to pursue future studies and careers in the field. To address this challenge, through the collaboration between The Royal Melbourne Hospital and The Bendigo Senior Secondary College (BSSC), MED-E-SIM Webinar was designed and implemented. MED-E-SIM Webinar is a health professionals led webinar discussion forum aimed at inspiring senior secondary students in pursuing a healthcare career/further study.

The aim of the current study was to evaluate whether MED-E-SIM Webinar can improve Australian high school students' understanding of the health profession and inspire them to pursue future studies and careers in healthcare.

Initiative such as MED-E-SIM Webinar could be a valuable and safe strategy to raise the much-needed awareness and interest of pursuit in a health-related career amongst our younger generation during the pandemic lockdown restrictions.

Methods

Participant selection and study setting

Two MED-E-SIM webinars were delivered in June 2020 and August 2020, and consisted of 21 and 22 registered participants, respectively. All participants were enrolled year 12 students at the BSSC, Australia. The recruited participants were nominated by the BSSC School Student Engagement Coordinator as part of the school's career discovery curriculum. Parental/ legal guardian informed consents for webinar participation and evaluation were obtained prior to programme commencement. Ethics approval was obtained from the Human Research Ethics Committee at Melbourne Health, Australia (QA2020074).

MED-E-SIM Webinar

This webinar enabled students to converse with a diverse group of health professionals ranging from entry to practice to specialty consultant levels. A typical MED-E-SIM webinar would consist of the following personnel: a medical consultant; a registered nurse; a nurse consultant; a physiotherapist; an academic teaching specialist; and two to four medical students. The secondary school students were encouraged to ask the panel questions about their typical workday, academic experiences, and professional rewards and challenges. All webinars were conducted via online video conferencing format using Cisco Webex™.

Evaluation form design

The evaluation form was designed to evaluate the self-perception of the participating students in three areas of interest: (1) participants' health profession preference, (2) webinar's content suitability, and (3) webinar's impact and recommendability. No personal data were collected, and the results were analysed only as a group, not individually.

Data analysis

Post-webinar evaluation surveys were collected electronically via SurveyMonkey® (Appendix). The aimed target response rate was set to be >80%. Thirty-five post-webinar evaluation surveys were successfully obtained from the 43 registered participants (81% response rate), indicating that the study target response rate was met. Data were collected in an anonymous fashion. Each survey was assigned a unique code that was not associated with any personal information.

The weight of responses was measured using a 5-point Likert scale (Likert, 1932), ranging from "strongly disagree" to "strongly agree" or "very uncertain" to "very certain", and was presented in terms of count and percentage of total respondents.

Within the post-webinar evaluation survey, participants were also asked to rate their level of certainty in pursuing their nominated healthcare career of interest before and after attending MED-E-SIM Webinar (Appendix). A Wilcoxon signed-rank test was performed to compare the participants' certainty in pursuing health professions where P values of <0.05 signalled statistical significance between pre- to post- programme participation. STATA/ MP 16.1 was used for the statistical analyses.

Results and discussion

With respect to health profession preference, the majority of participants indicated their preference for nursing (62.86%) (Table 1). This is somewhat not surprising, as according to the latest demographic data, the nursing profession still represents the largest chosen health profession in Australia (HWA, 2014).

Table 1. Participants' health profession preference.

	Count	Percentage
Medicine	3	8.57%
Nursing	22	62.86%
Midwifery	3	8.57%
Nursing and Midwifery	1	2.86%
Paramedicine	3	8.57%
Occupational Therapy	1	2.86%
Social Work	1	2.86%
Childcare	1	2.86%

When asked whether the content of MED-E-SIM was pitched at an appropriate level, 88.57% of participants responded "strongly agree". This was followed by the vast majority of participants indicating that the programme has improved their understanding about the health profession (Table 2).

Table 2. Participants' evaluation regarding programme content suitability.

Item	Response	Count	Percentage
The content of the webinar was pitched at an appropriate level for my learning.	Neutral	1	2.86%
	Agree	3	8.57%
	Strongly Agree	31	88.57%
Today's webinar has improved my understanding about the health profession.	Agree	8	22.86%
	Strongly Agree	27	77.14%

Participants were also asked to rate their level of certainty in pursuing their nominated healthcare career of interest before and after attending the MED-E-SIM webinar (Table 3). A Wilcoxon signed-ranked test detected a statistically significant difference ($Z = -3.308$, $p = 0.001$). This data indicated that the participation in MED-E-SIM Webinar could strengthen a student's decisions in pursuing a future healthcare study and career.

Table 3. Participants' evaluation of their level of certainty in pursuing their nominated health career of interest before and after attending the MED-E-SIM Webinar.

	Before attending MED-E-SIM Webinar		After attending MED-E-SIM Webinar	
	Count	Percentage	Count	Percentage
Very Uncertain	1	2.86%	1	2.86%
Uncertain	2	5.71%	0	0%
Neutral	4	11.43%	2	5.71%
Certain	16	45.71%	13	37.14%
Very Certain	12	34.29%	19	54.29%

Furthermore, the programme also received an explicit level of endorsement with 100% of participants indicating that they would recommend MED-E-SIM Webinar to other students wishing to pursue a future study/career in the health industry.

It is well-documented that interest is a powerful motivational tool to promote learning and career trajectories for students (Hidi & Harackiewicz, 2000; Renninger & Hidi, 2016).The MED-E-SIM Webinar aimed to promote interest in healthcare amongst participants, with situational interest (SI) in particular. SI is defined as the interest experienced in a particular circumstance or moment, and it fosters both affective and cognitive qualities to the learners (Hidi & Renninger, 2006).

One way to trigger SI is by assisting novice learners to see the reason and value of a field of study and this can in turn promote fascination, increased attention, engagement, and persistence in academic and career trajectories (Eccels, 2009; Harackiewicz & Hulleman, 2010; Hulleman et al., 2008). MED-E-SIM webinar intended to trigger SI by integrating individual interest processes through the "ask the expert" discussion forum setting. In an informal webinar discussion format, the multidisciplinary health expert panel helped the students to understand the meaning, value, challenge, and reward in becoming a health professional. The panel also helped the students to identify the essential short-term and long-term goals.

Lastly, implementing initiatives like MED-E-SIM Webinar can also offer multiple levels of community benefits. Locally, MED-E-SIM Webinar fosters meaningful collaborative partnership between the hospital, the secondary school and the greater community as a whole, despite the disruptions and isolation restrictions caused by the COVID-19 pandemic. Globally, given the growing shortage of healthcare providers projected in the future (WHO, 2016), webinars such as this could be a feasible strategy to help increase the number of our younger generation who pursue a health-related career.

Limitations

There are a few limitations associated with this study that should be taken into account in future research. Firstly, the participants in this study were recruited from only one secondary school and thus may not be representative of other schools in Australia and/or internationally. Secondly, the current study lacks longitudinal analysis and hence it is not possible to evaluate whether the influence that MED-E-SIM Webinar had on the participants would have a long-term effect. For example, it is not known whether these students have actually chosen to enter a healthcare-related degrees post completion of their secondary school certificate. Future studies should take this into account and incorporate longitudinal analyses into their study design.

Conclusion

During the COVID-19 pandemic enforced lockdowns and social distancing restrictions, MED-E-SIM webinar may be used as a safe contactless strategy to increase the pursuit of a health-related field by young people and help address the global healthcare workforce shortage.

Acknowledgements

The authors thank the students, teachers and collaborating health professionals who made this project possible. The authors specially thank Dr Digsu Koye for his statistical expertise and support.

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Appendix

MED-E-SIM Webinar Evaluation Survey (post-webinar).

<table>
<tr><th>Question</th><th>Response Options</th></tr>
<tr><td>1. The content of the webinar was pitched at an appropriate level for my learning.</td><td rowspan="2">Strongly Agree
Agree
Neutral
Disagree
Strongly Disagree</td></tr>
<tr><td>2. The webinar has improved my understanding about the health profession.</td></tr>
<tr><td>3a. Which health profession are you interested in pursuing?</td><td>Medical
Nursing
Allied Health
Other</td></tr>
<tr><td>3b. Please rate your level of certainty in pursuing the health profession indicated in 3a, before attending MED-E-SIM Webinar.</td><td rowspan="2">Very Certain
Certain
Neutral
Uncertain
Very Uncertain</td></tr>
<tr><td>3c. Please rate your level of certainty in pursuing the health profession indicated in 3a, after attending MED-E-SIM Webinar.</td></tr>
<tr><td>4. I would recommend this Webinar to other students wishing to pursue a career in the health industry.</td><td>Agree
Disagree</td></tr>
</table>

Teaching the future workforce: currency, connection and co-design

Yasmin Chalmers[1], Carley Brennan[1]and Katelyn Sharratt[2]

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Abstract. Transferring industry skills and practices into vocational educational practice as it relates to teaching and learning is fundamental to driving curriculum advances. The advent of “work-integrated learning” is rapidly challenging the traditional styles of education to adapt curricula to expose the student to more work-simulated and skill learning related to the job role. To drive this change, it will be necessary to equip education providers with the appropriate entrepreneurial and innovative skills and mindsets to explore and implement new approaches to teaching and learning. Co-designing learning with industry to enhance student education journeys ensures that our teaching methodologies align with the training skill needs.

Introduction

Australia’s workforce is experiencing a paradigm shift, defined by rapid and profound technological advances and major economic and societal transformation. Recent research reveals that:

- 10 per cent of current jobs have the potential for machine replacement, with 60 per cent having at least one-third of their activities automated (Lee Walsh, 2018)
- Machines can now outperform 80 per cent of the skills trained in the last 50 years (Lee Walsh, 2018)
- The McKinsey Global Institute states that for advanced economies, up to a third of the total workforce may need to learn new skills or find new work in new occupations (McKinsey & Company, 2017)
- In the Geelong Region, it is estimated that upwards of 75,000 jobs will be impacted by technical revolution in the next 10 years (O’Connor et al., 2011)

The rise of automation, smart devices and instantaneous media are just a few of the innovations that are fundamentally reshaping the way we think about information, learning and the future of work. In the face of this transformation, the Australian workforce demands constant upskilling. Furthermore, traditional approaches to training and education are being challenged and must be adapted to reflect the current and future needs of employers and the economy.

Today’s educators must be prepared to adopt innovative teaching methods that prepare students to adapt to new skill sets demanded by industry to meet and create future opportunities. This will require more revolutionary education programs that align with STEM-related capabilities and knowledge, including skills in science, technology, engineering and mathematics (STEM). Connecting with industry and integrating their intelligence into the development and delivery of courses is paramount to producing students with work-ready skills.

While a significant focus has been placed on how the K-12 and university sectors can help equip the workforce with the STEM-related skills and knowledge necessary for the changing economy, the unique ability of the VET sector to provide a significant contribution to the training and skills in the technical workforce has been severely overlooked and under recognised. Research by the National Centre for Vocational Education Research (NCVER) (Farrell, 2016) has identified Vocational Education and Training (VET) as an important actor uniquely positioned to deliver the STEM skills required in the twenty-first century. NCVER states that:

> *"VET employs a learning model uniquely suited to teaching STEM skills in real or simulated workplaces, in close collaboration with industry and employers. This model makes the VET sector an ideal provider of skill development."* (Farrell, 2016)

This paper outlines The Gordon TAFE's innovative approach to delivering high-impact, vocational education programs that meet the current and future skills demanded by industry.

The Gordon's education vision

The Gordon TAFE's Education Strategy (The Gordon, 2021), released in 2022, is focused on unlocking student potential through innovative, flexible and quality education. The purpose is to create lifelong learners who are job-ready and able to navigate the new world of work. Developing synergistic partnerships with industry to continually empower the current and future workforce and raise organisational productivity and sustainability will be a crucial driver to achieving this focus. The following trailblazer actions will realise this vision:

- Industry immersion
- Collaborative industry projects
- Community engagement/service/volunteering
- Flexibility in education delivery with a focus on effective online and blended learning systems
- Micro-credentials – stackable learning for employees
- Not a one size fits all approach but rather tailored training – the change in workforce demographic profiles requires agility to meet diversity and inclusion needs.

Our strategic purpose is focused on delivering education that responds to the changing nature of work to ensure people are equipped with relevant job-ready skills. The Gordon's approach delivers learning programs that:

- Are more agile and responsive to industry needs by designing training to meet the industry skills demand and job trends, that is, flexible skills sets or micro-credentials.
- Build trust and respected collaborations and/or partnerships to raise workforce capability and promote regional career advancement by offering accessible education pathways or "transition-to-practice" programs via placement, traineeships.
- Develop accessible education pathways for students by engaging secondary schools (students, teachers, career advisors) to consider a vocational learning pathway, that is,VET in Schools (VETiS), Geelong Tech School, Geelong Tertiary Futures Programs (GTFP).
- Empowering a dynamic teacher workforce that is industry-focused via teacher scholarships and industry immersion programs.

Education pathways and industry collaboration

Ensuring that learning programs have a strong industry connection is crucial to producing job-ready students. In our research, local industry has expressed that they require their employees to have greater awareness of and stronger practical knowledge about real-life industry issues. They demand staff to have an awareness of the value of collaborative work across disciplines and to have greater exposure to this prior to joining the workforce. Thus, developing partnerships with industry to fulfil current and future workforce demands is a key driver to providing successful education pathways. The Gordon has developed training programs closely linked with industry by:

- Offering pathways or "transition-to-practice" programs that focus on student and employer success, that is, traineeships.
- Exposing students to research and innovation to bring skills and a practice-based understanding into workplaces.
- Teacher-Industry immersion programs.
- Simulated work-learning environments.
- Engaging secondary school students – Geelong Tech School, VETiS, GTFP, Northern Futures.

An ability of employees to work in multi-disciplinary teams is the nature of modern, creative work practice and can add to a graduate's employability skillset in an increasingly competitive world. Despite the recognised importance of these skills, graduates are often not equipped with these capabilities. In response to employers' needs, The Gordon is proactively:

- Partnering with peak bodies, key stakeholder groups and advocacy organisations.
- Supporting industry in understanding workforce and training development requirements.
- Providing options for socio-disadvantaged community members to undertake foundation skills training.
- Supporting females in advancing STEM pathways.

Together with industry stakeholders and community partners, The Gordon is leading change in how 'pathways to work' can be encouraged at the secondary school level to enhance interest in vocational education and training. Importantly, The Gordon is also working with industry partners to create new pathways into learning and work.

Skilling the Bay (STB) is a regional collaboration led by The Gordon and delivered in partnership with Deakin University and the Victorian Government. Since 2012, STB has worked to improve education and employment outcomes for people in the Geelong and Barwon region, with the guiding purpose to promote, strengthen and supplement pathways for people of all ages into sustainable and decent work.

STB Education and Pathways initiatives aim to inspire and engage secondary students in learning and the world of work by promoting the value of vocational education and training and highlighting career pathways in a changing regional economy. Initiatives align with the Victorian Government's Review into Vocational and Applied Learning Pathways in Senior Secondary Schooling (Firth Review) (Firth, 2020) and the implementation of significant changes to senior secondary education.

STB Education and Pathways objectives include:

- Offering integrated taster programs aimed at Year 9 and 10 students.
- Providing meaningful industry immersion experiences in growing industries.
- Promoting a better understanding of VET pathways.
- Raising awareness of career pathways to foster student aspiration and confidence.
- Facilitating regional collaboration between school, community, and industry.
- Preparing students to develop twenty-first century skills for the workplace.

Geelong Tertiary Futures Program (GTFP – a Skilling the Bay initiative) aims to raise awareness of vocational pathways to further study and employment and is featured as a case study in the Firth Review (Firth, 2020). The program for Year 9 students combines vocational previews with work skills to form a comprehensive career pathways program, actively delivered on-site at The Gordon (in an adult learning environment) and in a blended online learning environment.

It is a dynamic program catering to hundreds of students, and in 2022 will expand from five regional schools to nine regionals schools. The performance measures indicate that 88 per cent of students are better informed about their career choices as a result, and 82 per cent have a greater understanding of the work skills they need to develop. It also provides comprehensive exposure to secondary students, teachers, and parents about career pathways (and introduces them to vocational education and training, courses and facilities). The recent data shows that 40 per cent of participating students return to The Gordon in some capacity within five years of participating in a taster program.

Entrepreneurship and innovation

We live, work, teach and learn in a world characterised by rapid change, complexity and uncertainty. The advent of "work-integrated learning" is challenging the traditional styles of education to pursue more work-simulated, adaptable curricula. Teachers need to be agile, adaptive and responsive in their teaching practice by building habits of inquiry, questioning and evidence-gathering in their teaching methodologies (Hutchings, 2013).

Applied research is the development of innovative solutions to real-world challenges. It tackles practical problems by applying the latest technology and knowledge to create new products, services and processes or improve current products and practices.

Boyer's work (Kern et al., 2015) three decades ago took what was a "private act" of teaching witnessed by students to thinking about teaching as questioning (examining) or exploring what is going on and how to explain what is going on. Equipping teachers with the appropriate entrepreneurial and innovative skills and mindsets to explore and implement new approaches to teaching and learning is what we are exploring further at The Gordon.

Fostering active research and innovative methods (Victorian TAFE Association, 2019) in TAFE is important to:

- Proving "what works" while (perhaps) addressing "what is not working".
- Focusing on "how students learn" and "learner characteristics" and the impact of teaching on students' learning.
- Treating our classrooms as laboratories with our teaching practices as the sources of our experiments.
- Building or refining theory and practice in a particular sector/industry or discipline.
- Influencing changes to thinking and practice (e.g. policy, curriculum or within a particular sector/industry).

The Gordon has built successful entrepreneurial and innovation programs, for example in partnership with the Wade Institute of Entrepreneurship. In 2020 the Gordon collaborated with Wade Institute to develop an exciting three-day TAFE teacher professional development program in entrepreneurship education called UpSchool. This program gave TAFE educators across all disciplines the skills, experience and connections to support Australia's next generation of thinkers, doers and creative problem solvers. Facilitated at The Gordon and Wade Institute's purpose-built entrepreneurial space, the UpSchool workshop introduced TAFE teachers to the materials and tools necessary to teach entrepreneurship. UpSchool workshops were immersive and intense. Participants experienced first-hand the methods and processes involved in building a sustainable business or entrepreneurial project while also gaining actionable implementation strategies for their classrooms.

Applied research processes provide hands-on opportunities for learners to work alongside employers and industry to solve real-world challenges. Furthermore, it has extended The Gordon's other endeavours in work experience, practical placements and apprenticeship and traineeship activities. Embedding students in applied research projects offer real-world experience, particularly the highs and lows of change management and innovation that employers seek. Graduates with applied research experience entering the workforce often demonstrate strong problem-solving skills and an appreciation of the ebbs and flows of workplaces.

Conclusion

The proactive engagement of education and industry is highlighting the importance of:

- Creating student learning pathways/journeys that align to gaining a deeper understanding of current industry skills and training needs.
- Gaining industry input on emerging workforce development and training needs.
- Developing teaching capability and excellence that is agile in responding to industry changes and advances.
- Producing work-ready students, with the skills to navigate ongoing industry change.
- Fostering sustainable partnerships to meet complex and evolving education and employment challenges.

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A New 21st Century Learning Theory

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Abstract. Constructivism, a dominant learning theory in Australia, is qualitatively based. Hence, its guidelines are open to interpretation which can lead to wide variations in teaching standards. Within the Australian NSW school sector, Cognitive Load Theory (CLT) has been promulgated. CLT employs a more formal approach that models how learning occurs and is used to inform teaching strategies and guidelines that claim to optimise student learning. However, CLT lacks a reliable metric and hence it is also qualitatively based. Cognitive Load Optimisation (CLO) models knowledge as a diagrammatic schema (mental pattern of knowledge), which is quantitatively optimised to create the easiest possible learning path. Importantly the schemas are not only the basis of instructional design and teaching but they are also given to students. During the learning process students internalise the schemas. Trials indicate using CLO in the school, TAFE and university sectors results in significant improvements in STEM learning outcomes.

Introduction

According to the UNICEF report, 'Australia's ranking of 39th out of 41 EU/OECD countries in terms of quality education raises serious red flags for children's learning and development, which can severely impact their chances in life' (UNICEF, 2017). In 2019 it was reported that, 'Australian students have recorded their worst results in international tests, failing for the first time to exceed the OECD average in maths while also tumbling down global rankings in reading and science' (Baker, 2019). There are different factors that impact on ranking, but in the final analysis, there is arguably a problem.

20th century learning theories

A learning theory provides guidance on how to teach and how to guide students to acquire new knowledge. It is also used as the basis of writing instructional materials. There are many different learning theories, but Constructivism is probably the main one in Australia. According to this theory students are guided to 'construct' their own knowledge (Peters, 2003). There are a number of problems with this learning theory, as outlined below.

1. It provides subjective guidelines that are open to different interpretations which may result in wide variations in the quality of educational outcomes.

   'In a ten-year study over thirty STEM units in seven nationally accredited institutions (two colleges, five universities, including a five-star teaching university) in two different countries were analysed to evaluate their educational quality using a range of criteria and benchmarked against the finalists of the 2010 IEEE global award for academics. Unit content and teaching were found to be almost exclusively based on Constructivist based principles. However, Constructivism provides subjective guidelines open to different interpretations. The analysed units demonstrated considerable variation in pass rates and educational standards. Some units consistently achieved circa 100% pass rates but at the expense of the standard of learning outcomes – far below any reasonable expectations. Some units achieved a higher standard of learning but with pass rates consistently below 30%'. (Maj, 2021)

2. It does not provide a method for determining if there are gaps in the knowledge being taught.
3. Gaps in the knowledge being taught forces students to come to their own conclusions which may be wrong, resulting in student knowledge that is incomplete and/or incorrect, that is, misconceptions.
4. Misconceptions, that is, knowledge that is incomplete and/or incorrect handicaps further learning

'Once integrated into a student's cognitive structure, these misconceptions interfere with subsequent learning. The student is then left to connect new information into a cognitive structure that already holds inappropriate knowledge. Thus, the new information cannot be connected appropriately to their cognitive structure, and weak understandings of the concept will occur'. (Nakhleh, 1992)

5. It is inefficient – learning by trial and error. In effect what you do not explicitly teach is equally, if not more important, than what you actually teach.

20th Century Learning Theories are problematic because, based on a detailed analysis of six exemplar schools it was concluded:

> *'It is suggested that there is also a need for more "scientific" evidence of 'what works in classrooms rather than more qualitative studies.' Furthermore, 'As a consequence, there is much criticism of educational research including that it lacks rigor, fails to produce cumulative findings, is theoretically incoherent, ideologically biased, irrelevant to schools, lacks the involvement of teachers, and is poorly communicated and expensive*. (Holkner, 2008, p85)

What is knowledge and how do you learn?

A learning taxonomy is used to define and evaluate learning outcomes. Blooms Taxonomy (Bloom, Engelhart et al., 1956) is a widely used learning taxonomy, however a useful alternative is the Structure of Observed Learning Outcome (SOLO) with the advantage that knowledge is modelled by elements and their relationships (Biggs and Collis, 1989). This taxonomy consists of five levels with associated verbs as evaluation metrics:

Deep learning

5. Extended abstract: Generalise to a new domain. Evaluation metrics – generalise, originate, etc.
4. Relational: Many interdependent elements. Evaluation metrics - explain, calculate, etc.

Superficial learning

3. Multi-structural: Several relevant elements. Evaluation metrics - list, define, etc.
2. Uni-structural: One relevant element. Evaluation metrics – name, recognise, etc.
1. Pre-structural.

The goal of teaching is for students to acquire deep learning, that is, relational knowledge (SOLO level 4 and above). Relational knowledge consists of many interdependent elements which confers the ability to explain cause and effect. Complex relational knowledge is therefore hard to teach and learn. By contrast, multi-structural knowledge consists of several relevant elements and is easy to teach and learn. Elements and their relationships are important in Cognitive Load Theory (CLT), the basics of which are schemas, cognitive load, different types of memory, and how learning occurs.

1. Short Term Memory (STM) is of limited capacity and duration.
2. Long Term Memory (LTM) has unlimited capacity and duration.
3. A schema is a mental pattern of knowledge that is resident in LTM.
4. All learning is mediated by STM.
5. Complex relational knowledge schemas overwhelm STM handicapping learning.
6. The complexity of knowledge is evaluated by cognitive load. Complex relational knowledge has a high cognitive load. Superficial learning has a low cognitive load.

The fundamental problem is that complex relational knowledge has many interdependent elements that represents a high cognitive load. The cognitive load is exacerbated if in the schema there are: missing essential elements; missing relationships; incorrect element relationships, etc. (Figure 1), which, as discussed above, forces students to come to their own conclusions which may be wrong – that is why students fail. Finally, there needs to be a metric that can be used to organise all the elements in a coherent manner.

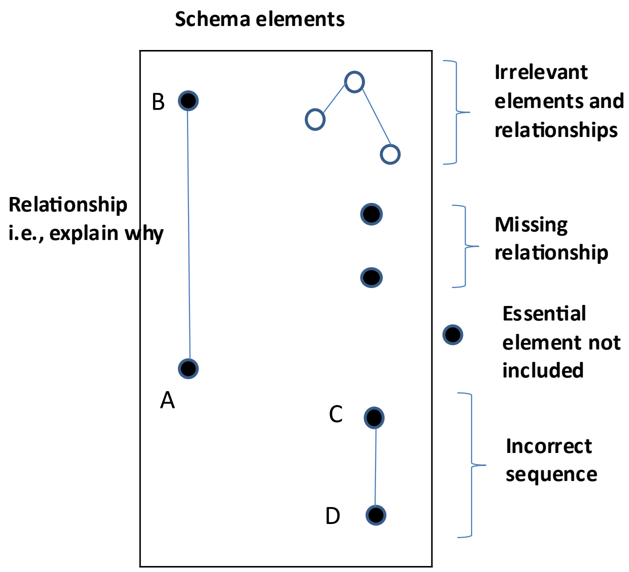


Figure 1. Elements

CLT has been used to provide strategies and guidelines for instructional design and teaching (Centre for Education, 2017). Within the Australian NSW school sector, CLT has been promulgated by teaching strategies that claim to optimise the load on students' working memory. Strategies include: (1) tailoring lessons according to students' existing knowledge and skill, that is, element interactivity effect; and (2) using worked examples to teach students new content or skills, that is, worked example effect (Centre for Education, 2021). However, all these strategies and steps are subjective guidelines without a formal method of organising elements in order to address the problems above. CLT has different measures for assessing cognitive load, however the efficacy of these metrics has been questioned (de Jong, 2010).

Cognitive Load Optimisation (CLO), a new 21st century learning theory

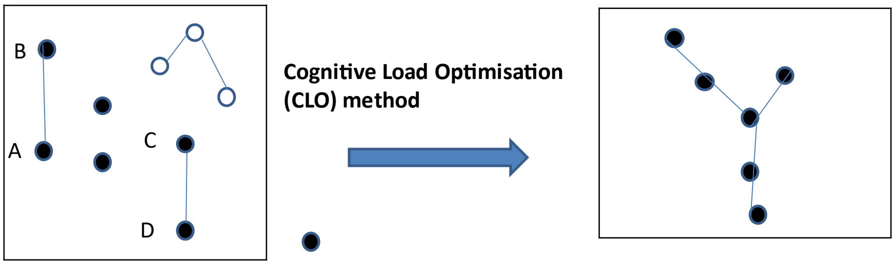
Cognitive load optimisation (CLO) solves the problems associated with CLT by mapping elements as a diagrammatic schema with a tree structure. Furthermore, CLO has a simple, quantitative metric for measuring cognitive load, hence this schema can be quantitatively optimised to create the easiest possible learning path (Figure 2). Optimisation can be done manually or by software, but this is beyond the scope of this paper. This optimised schema is the basis of instructional design and teaching. Importantly, it is given to students who internalise it during teaching. By contrast, in Constructivism, students are guided to construct their own knowledge.

CLO has been extensively evaluated across all educational sectors (primary and secondary school, college and university) and results in significant improvements in learning outcomes in all STEM disciplines (Maj 2018, Maj 2020, Maj 2021, Maj 2021, Maj 2022, Nuangjamnong & Maj 2022).

A CLO case study

A textbook in digital technologies (years 7 and 8) was analysed to assess the section on hubs and switches (Grover, 2017). Illustratively, according to this textbook:

> *'When a hub receives a message, it transmits it to all the linked computers, Hubs also act as repeaters. A repeater strengthens signals travelling over large distances. The problem with a hub is that it is likely to cause even more collisions between data than direct connections, because all the computers can transmit at the same time'.* (Grover, 2017, p56)



Relational knowledge (explain)

- Missing elements
- Missing relationships
- Incorrect sequence of elements
- Elements included that are not relevant
- Complex relational structure

Hence:

- High cognitive load
- Overloads Short Term Memory (STM)
- Hard to teach, hard to learn
- Students guided to 'construct' their own relational knowledge

Relational knowledge (explain)

- Lowest possible cognitive load
- Does not overload STM
- Easiest possible learning path
- Easy to teach, easy to learn
- Basis of instructional design and teaching
- Given to students, internalized during teaching

Figure 2. CLO method

A hub as a repeater is an irrelevant element. Furthermore, what is a large distance – one kilometre, ten kilometres? Collisions are in fact normal. This is arguably representative of superficial learning. The CLO schema of hub and switch technologies identifies the most important elements and organises them into the easiest learning sequence from the simplest to more complex (Figure 3). The simplest elements are at the bottom and are common for both devices. Each device then has unique elements that distinguish how they work. The CLO schema appropriate for teaching at school level is a sub-set of a more advanced schema (Figure 3). Even though it is a subset, it is still deep learning because it represents the fundamentals of device operation which underpins more advanced learning. TAFE and university students are also taught this subset, but at a faster pace and also are taught more advanced elements. Hence, the same optimised schema for a hub and switch can be used for all educational levels. The relationship between the elements confers deep learning, that is, SOLO level 3 understanding. For example, because a hub is a shared medium, there are collisions. Because there are collisions that need to be a medium access control protocol etc. Illustratively, the CLO sub-set schema for a hub along with a partial contextualised teaching scenario (italics), at secondary school level, is as follows:

1. PCs are all connected to a hub using Ethernet cables, that is, a shared communication medium. *A classroom is a shared medium*
2. Because it is a shared medium any PC can transmit, receive and broadcast (1 to all). *In a classroom, students and teachers can speak and listen. Teacher typically broadcast.*
3. Because any PC can transmit or broadcast at the same time collisions can occur. *In classroom, two people attempting to speak at same time is a collision.*
4. Because collisions can occur there needs to be a protocol to determine which PC transmits and when, that is, Medium Access Control.
5. A hub uses the CSMA/CD Medium Access Control method. Carrier Sense (CS, that is, listen and do not transmit if the medium is busy), Multiple Access (MA, that is, shared medium), Collision detection (CD, that is, PC will stop transmitting when after starting to transmit another PC also starts to transmit, resulting in a collision.
6. Because of CSMA/CD communications are half duplex – alternate, two-way communications. In effect only one PC can be transmitting at a time. Inefficient if there are a lot of devices on the shared medium. *In a classroom, even with many students, there can only be one person speaking at a time. Students are not permitted to have private conversations.*

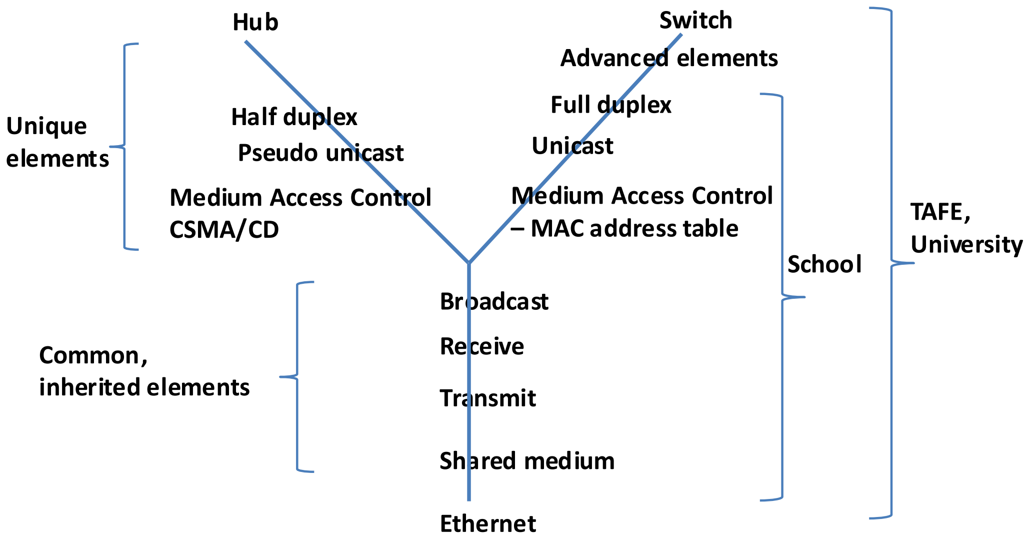


Figure 3. CLO schema for hub and switch

Conclusion/Summary

Trials of CLO in a wide range of STEM disciplines (mathematics, technology, engineering, etc.) at different educational levels (primary and secondary schools, TAFE and university) indicate significant improvements in learning outcomes in all delivery modes (face to face, blended and remote online only). However, more extensive trials within the school sector are needed. CLO is theoretically applicable to pre-primary and other disciplines.

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What will it take to embed STEM education within the curriculum for all Australian students?

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Abstract. What will it take to embed STEM education within the curriculum for all Australian students? The findings from a recently completed PhD identified three challenges facing the implementation of STEM education in the Australian context. This paper presentation will suggest how these challenges could serve as pointers to embed STEM education in the Australian curriculum. The research first investigated the factors and the role of key stakeholders in the emergence and subsequent prominence of STEM education internationally and in Australia. The factors included the changing political, economic and social conditions and approaches to curriculum design. The key stakeholders included governments, business and industry, professional organisations, researchers in the science, technology, engineering, mathematics, and education. This research also provided insight as to how stakeholders could influence the design and direction of education including curriculum policies and programs related to the implementation of new initiatives. Three research methods were used to collect and analyse data that led to the identification of the three challenges. First, to better understand how the key Australian stakeholders presented STEM education and how their stance (position) was reflected in the expected (or intended) outcomes, a document analysis of a selection of publications from the stakeholders was undertaken. The analysis included the status of the document, for example, government or professional association, the type of document, for example, policy or program, and the intended audience and expected outcomes. Five themes emerged from the analysis of the documents: engagement of students, access and equity of access, curriculum, assessment, and pedagogy. Second, a Delphi study using these themes was undertaken by a selected group of participants (representative of the Australian key stakeholders). The Delphi study (three questionnaires) was designed to determine both the similarities and differences in how the participants perceived STEM education policies, programs and outcomes. The analysis of the responses from the participants led to the development of three visions for STEM education in the Australian context and a list of the requirements for their successful implementation. Third, a set of semi-structured interviews with a larger group of participants was conducted to further explore how the participants conceptualised STEM education and how this was reflected in their choice of vision and the requirements for its successful implementation and possible future directions. The analysis of the participants' responses identified that one vision was preferred by more participants but there was less consensus with the requirements for its implementation and its future directions.

Introduction

There is an acceptance now that STEM education is necessary to ensure continuing economic growth and prosperity in Australia (Finkel, 2016). However, Australia was late to embrace STEM education when compared with other countries, for example, USA, UK, European Union, and Singapore (Blackley & Howell, 2015; Breiner, Harkness, Johnson and Koehler, 2012; Wong, Dillon & King, 2016). The concept of STEM (and education in STEM) was first introduced in Australia in 2013 by the then Australian Chief Scientist, Dr. Ian Chubb (Chubb, 2013). He argued that a highly skilled and knowledgeable STEM workforce was essential to maintaining Australia's high living standards and active participation in global trade. Chubb (2013) further emphasised the need for innovation and creative thinking when developing new STEM related industries and pivoting existing industries to have a greater focus on STEM. Fast forward to today and STEM education has firmly cemented itself within the education lexicon in Australia. But what exactly is STEM education?

When we walk past a grand entrance to a building, what do we see? Does the entrance reveal the building's purpose or the opportunities it presents? STEM education can be thought of as a grand entrance that needs to be carefully explored (and gently coaxed) to reveal its many facets. Education research has revealed many of the facets of STEM education including how best to characterise or define STEM education and what it includes (Johnson, 2012a, 2012b), and how best to implement programs to which students and when (English, 2017; Johnson, 2013). A field of key and diverse STEM education stakeholders (for example, National Academy of Engineering and National Research Council (NAE & NCR) 2014, European Union (EU) 2016, HM Treasury 2002 and Science Centre Singapore 2014, PwC 2016) has emerged leading to many debates and discussions about what STEM education is or should be and its implementation. However, I believe that much less attention has been paid to the challenges it faces to become embedded in the curriculum for Australian students instead of being an 'add on' or a 'fad'.

Researching the CHALLENGES FACING STEM education and its implementation

There is a plethora of policy documents and published research available that has explored the origin, emergence, and implementation of STEM education (Osman, 2020). In the first phase of my research, the analysis of thirty-two published international and Australian documents revealed the diversity of stakeholders, policies and programs, including, as expected, governments (international and Australian), business and industry groups (PwC, The World Bank), professional associations (for example, Engineers Australia (EA)), and research (for example, Rosicka, 2016). More unusual stakeholders included out of school hours groups providing STEM activities for families (for example, STEMinc Singapore) and philanthropic organisations (for example, The Invergowrie Foundation). For the purpose of document selection and analysis, these stakeholders were referred to as the published authority and also included statutory authorities responsible for curriculum, assessment and reporting, researchers and UNESCO Education sector.

Five categories of STEM education documents were identified using a framework suggested by Bowen (2009). These were:

- Published curriculum documents related to policy, content and structure.
- New approaches to or trends in education relevant to STEM education including curriculum, assessment and pedagogy.
- International and Australian Government policies and reports that led to introduction and implementation of STEM education.
- Published research related to curriculum, pedagogy and assessment policies and practices associated with STEM education.
- Publications from other stakeholders.

Each document was analysed to determine the status of the authorship (government, committees, academics, research, organisations), the type of document (policy, programs, advice, commentary or opinion piece), the intended audience (curriculum writers, schools and their communities, governments, developers of policy), the intended outcomes, and the timeline for action and evaluation and resourcing (including funding) provided. This detailed analysis of thirty-two documents across these categories identified five recurring themes. These were engagement of students, access and equity of access, curriculum, pedagogy, and assessment.

The second phase of my research was the use of a Delphi study (Linstone & Turoff, 1975) to gather the opinions and ideas of the eleven selected participants from across Australia. The participants demonstrated through their interests and experiences and their current or past positions, a long history in influencing and contributing to the development of education policies and programs in Australia or were in positions to shape and influence STEM education in the Australian context. The Delphi study consisted of three questionnaires, which all participants completed. The first questionnaire used open-ended questions to determine the purposes and requirements they believed were necessary to implement STEM education. The second questionnaire used the analysis of this data to construct a list of purposes and requirements for STEM education that the participants were asked to rank from highest to lowest (see Appendix 1). The analysis of data collected from Questionnaires 1 and 2 was used to construct possible visions (discussed in the next section) and pivotal statements (see Appendix 2) for STEM education in the Australian context that were presented in Questionnaire 3.

The responses provided by the participants in the Delphi study were further explored in the semi-structured interviews (Trainor, 2013). An additional six participants (identified as Non-Delphi participants) also completed the semi-structured interviews (to provide another source of data) to determine if a preferred vision for STEM education in the Australian context was possible. The responses from the semi-structured interviews from both the Delphi study and Non-Delphi study participants provided an understanding of how the participants' conceptualisations of STEM education would likely impact on its implementation and future sustainability in the Australian context. The semi-structured interviews also explored what were the challenges facing STEM education and its implementation in the Australian context.

Findings

So, what did the participants think about STEM education?

Each participant's conceptualisation of STEM education was unique and shaped by their beliefs and experiences as reflected in the diverse range of responses to the four questions asked in this questionnaire. For example, some participants who shared particular purposes for STEM education did not always share the same requirements necessary for the implementation of the purposes listed. What was clear was that STEM education means different things to different people, so it is context and person dependent and this impacts on approaches to its implementation.

The themes of engagement of students, access and equity of access, curriculum, pedagogy, and assessment were present in the purposes and requirements for STEM education, which was consistent with the findings from the document analysis (refer Appendix 1). In addition, three additional themes emerged as part of how the participants conceptualised STEM education. These were: the benefit of STEM education to the community or society, an uncertain and changing future, and addressing current or real-world issues.

The participants as a group focused on three components of STEM education. Firstly, knowledge, skills and understanding including decision making and solving issues or problems were integral components of STEM education. Secondly, consideration must be given to exploring the local and global issues that are important to students now and those that may impact on their future. Thirdly, the participation of the community, individual governments, business and industry, and education organisations was required to ensure the opportunities STEM education could provide were understood, particularly the employment and career opportunities in STEM and STEM-related fields.

The emergence of these three components suggested that any vision constructed for STEM education in Australia would need to be flexible so that it could accommodate the different conceptualisations of STEM education held by those advocating for STEM education or who have an interest in or responsibility for its development and implementation. It was apparent that any vision would also need to be inclusive of the multiple purposes and requirements for STEM education. Any vision constructed would therefore need to support a cohesive and inclusive STEM education that would assist all young Australians to meet future challenges and to ensure sustainable economic prosperity within a changing world.

In response to this variation, three visions for STEM education were constructed from the research:

- Vision 1: STEM education contributes to a broad suite of learning experiences that enable all young people to participate in and contribute to building sustainable communities.
- Vision 2: STEM education provides the skills that enable all young people to contribute to growing the nation's economy and global competitiveness.
- Vision 3: STEM education equips all young people with the knowledge and skills required to understand the complex and challenging nature of the world in which they live, now and into the future.

Whilst Vision 3 was preferred by more participants in the research than the other two visions combined, the pivotal statements supporting this choice varied. Some of these pivotal statements were also used to support the choice of the other visions. This suggested that if a single vision for STEM education in the Australian context was to be constructed, and if the intended outcomes of this vision were to be achieved, it would need to accommodate individual conceptualisations of STEM education and varied approaches to its implementation. However, two pivotal statements were used to support the implementation of each of three visions. One of these focused on pedagogical practices (refer Appendix 2, statement 3) and the other focused on the provision of professional learning for teachers (refer Appendix 2, statement 4). These were regarded as crucial to the successful implementation of the highest quality STEM education for all young Australians.

Key messages from the research

Although there was a diversity of opinions amongst the participants, there were some shared ideas and beliefs as to why STEM education has gained importance, who is driving its implementation, and what it could realistically be expected to deliver when properly resourced. The participants were generally positive about STEM education but were prepared to express reservations about its likely achievements, longevity, and sustainability.

In general, the participants suggested that the implementation of STEM education goes beyond preparing young Australians for employment. It also provided opportunities to address the issues of engagement of students and their access and equity of access to a high-quality education (Hobbs, Jakab, Millar, Prain, Redman, Speldewinde, Tytler & van Driel, 2017). STEM education was seen also as offering opportunities to provide better outcomes for all students and to enable them to make informed decisions about their futures.

In considering the provision of high-quality education for all young Australians, one participant best captured the sentiments of all participants when suggesting that an informed member of the community when presented with new things that they can't understand should be sufficiently resilient and confident to realise:

> *You can do something about it, you're not stuck with this idea that I either get it or I don't. I think that's a real stumbling block. But broadly speaking is that there is a community narrative that understands that it is important that everyone becomes literate, and two, you can do something about it … active and empowered citizen and consumer.*

What then are the challenges facing STEM education?

From my research, I suggest that there are three challenges that must be faced if STEM education is to be embedded in the curriculum for all Australian students. First is to understand how people conceptualise STEM education and how this may impact on their approach to implementation. This will mean acknowledging and accepting that there are differences in how people conceptualise STEM education and how it should be implemented. It is important not to assume that there is only one way to develop and implement STEM education but rather to give people time to articulate and share their conceptualisations and that these may lead to multiple effective ways to develop and implement STEM education programs.

Second is to establish and sustain collaborative partnerships to implement STEM education that are inclusive of all students, regardless of ability or gender or ethnicity or location. This means the recruitment of people with an interest and expertise in the different facets of STEM education to design curriculum, assessment, and pedagogical practices and programs that are relevant to the students and are sustainable and well resourced.

Third is the use of local contexts and issues to investigate global issues within an accountability framework. This will require ongoing and flexible interactions with a school's local community to determine how best to use its resources to develop the necessary knowledge, skills and understanding to expand students' horizons beyond their community. In turn, attention will need to be paid to how student achievement is measured and reported within an education system that requires accountability for teaching and learning and student outcomes.

Shaping how STEM education is embedded in the curriculum

I suggest that to embed STEM education in the curriculum requires that the three challenges are addressed by shifting the type of questions being asked about STEM education away from those related to specific details to those that are broadened in scope and include, for example:

- Should STEM education be included in the education of all young Australian? Why or why not?
- If STEM education is included, at what year levels? Why and how?
- What will be required to implement, sustain and evaluate the implementation of STEM education?
- Will providing students with STEM education learning experiences that are relevant to them and their future and better engage them with their learning?
- Does providing a general or liberal education better equip all students to participate in and contribute to a STEM driven economy?

Such questions encourage 'big picture' thinking and visionary responses that will flow to discussions that set aspirational and flexible curriculum, assessment and accountability policies and practices that allow for flexibility and local contexts and are fully resourced.

Conclusion

With the focus of STEM education to generate and support continuing economic and social prosperity for all Australians, now and into the future, the spotlight is on the provision of a high-quality education accessible to all young Australians. This presents educators trying to embed STEM education within the curriculum for all Australian students with challenges that are complex and similar to those of other countries. Perhaps the following two questions may provide a starting point to surmounting these challenges:

- How do you and your team conceptualise STEM education and how should it be best implemented in your school to ensure maximum benefits for students?
- How would you explain what STEM education is and why it is important to colleagues, students and their parents/guardians to justify its inclusion in the curriculum?

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Appendix 1 List of purpose and requirements for STEM education

Purposes

1. Equip people with the knowledge and skills necessary to drive economic and social prosperity in the 21st Century technology-rich workplaces and careers
2. Build students' understanding of the world around them and how they can contribute to making it a sustainable place to live now and into the future
3. Provide pathways for entry into the digital workforce and for the next generation of specialists in STEM fields.
4. Engage students with 'real-world problems' that require input from each of Science, Technology, Engineering, and Mathematics to solve
5. Improve access to careers in STEM fields for previously under-represented groups (for example, girls/women, rural, indigenous)
6. Introduce students to the use of evidence to make ethical decisions about contemporary and complex issues

Requirements

1. A shift from a focus of acquiring specific content knowledge to the achievement of outcomes where acquisition of skills has a greater importance in the development of curriculum and assessment tasks.
2. Sustainable partnerships between schools, universities, TAFEs, and industry/business as applicable that support and collaborate on the delivery of high-quality STEM education in schools.
3. Use of age-appropriate applied investigations and activities to demonstrate how knowledge and skills from multiple disciplines are used to solve problems.
4. Development of a transdisciplinary approach to teaching and learning that incorporates the elements of STEM disciplines and draws from other disciplines as required to investigate issues important to students/community.
5. Development of a curriculum for Early Years to Year 12 that links learning areas (disciplines) in ways that support students to solve 'real-world problems'.
6. Building community understanding of the relationship between studying STEM subjects and future employment including supporting parents to become STEM aware.
7. Review of assessment requirements of senior secondary STEM subjects to accommodate projects completed using an inter-disciplinary approach

Appendix 2 Pivotal statements used to support choice of visions

1. The curriculum for STEM education accommodates the development of knowledge and skills within each discipline and across the disciplines of STEM.
2. The assessment practices for STEM education focus on the application of knowledge and skills to identify and solve 'real world' problems.
3. The pedagogical practices used to deliver STEM education inspire young people to choose STEM-related subjects at school and to pursue these into higher and/or further education and careers.
4. Ongoing high-quality professional learning for teachers is provided that increases their competence and confidence (and experiences) in delivering STEM education.
5. Implementation of STEM education is co-ordinated to maintain high-quality and consistency across jurisdictions.
6. Informed communities actively support young people to consider pursuing STEM subjects, careers, or employment.
7. Employment opportunities are available that are attractive to young people who are job capable in STEM and STEM related fields.

Fostering critical thinking in a Year 7 integrated STEM project with the Cognitive Apprenticeship Model

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Abstract. Australia's future workforce will need to possess sophisticated STEM (science, technology, engineering and mathematics) skills and transdisciplinary skills such as critical thinking. The purpose of this study is to contribute to the development of critical thinking skills in Year 7 students by providing information and strategies for curriculum developers and teachers to engage and extend students with integrated STEM projects. Interdisciplinary curricula and teaching approaches are considered to be important to foster engagement, develop higher order thinking abilities, and to prepare children for 'twenty-first century skills'. This research used an interpretive case study design to examine the way a teacher embeds critical thinking skills into their teaching and how teacher skills and resources were deployed to effectively implement interdisciplinary projects. Qualitative data sources for this study include pre/post teacher interviews and classroom observations. This presentation will focus on data collected from a Western Australian secondary school implementing a Year 7 STEM program over two school terms. Students used the engineering design process and a device called a Makey Makey to build a solution to solve a real world problem of their choice. The instructional model used by the teacher resembled the cognitive apprenticeship model. Teaching strategies such as coaching, modelling, scaffolding, articulation, reflection, and exploration were used to embed and support critical thinking within STEM lessons. Given the importance of students' interactions with both teacher and peers, and the small class size of 15 students in this case study, future research will look at whether the cognitive apprenticeship model can be scaled up and used in larger classes.

Introduction

There is a worldwide call for Science, Technology, Engineering and Mathematics (STEM) education to improve students' twenty-first century skills such as critical thinking (Hobbs et al., 2019). Most STEM education addresses one or more of the STEM subjects separately, however there is a pedagogical shift in favour of integrating STEM disciplines into one class based on the connections among the disciplines and real-world problems (Moore & Smith, 2014). In the Australian Curriculum, teachers are expected to teach critical thinking to the extent it is incorporated within learning area content (ACARA, 2022). Critical thinking in integrated STEM may include discipline specific critical thinking such as scientific reasoning, computational reasoning, engineering design-based reasoning, and mathematical reasoning. Critical thinking involves cognitive skills such as the ability to interpret, analyse, evaluate, explain, and make inferences based on discipline specific knowledge. It also includes generic skills and dispositions such as self-regulation, and habits of mind needed to analyse one's own thinking including open-mindedness and self-confidence (Ennis, 2018). Given that integrated STEM is a relatively new approach, this research aims to provide information and strategies for teachers and curriculum developers to help them embed critical thinking skills within integrated STEM projects.

Integrated STEM can broadly be defined as "the seamless amalgamation of content and concepts from multiple STEM disciplines" (Nadelson & Seifert, 2017, p. 221). Well integrated instruction can encourage students to use critical thinking skills but many teachers seem reluctant to use an integrated approach due to lack of implementation guidelines (Toma & Greca, 2018; Stohlmann et al., 2012). Kelley and Knowles (2016) provided a conceptual framework of integrated STEM based on situated learning and connected engineering design, scientific inquiry, technological literacy, mathematical thinking and community of practice as an integrated system. The foundation of situated learning theory is that the application of knowledge and skills in authentic and relevant contexts fosters transferable learning (Brown et al., 1989). The exposure of students to authentic or situated problems has been demonstrated to have positive effects on critical thinking skills (Abrami et al., 2015).

Cognitive Apprenticeship Model

Cognitive apprenticeship is a process where students learn cognitive and metacognitive skills and processes from a more experienced person (Dennen & Burner, 2008). The model, formulated by Collins et al. (1991), is situated within the social constructivist paradigm and reflects situated cognition theory, Vygotsky's zone of proximal development and traditional apprenticeship (Ghefaili, 2003). Learner tasks are slightly more difficult than they can accomplish independently therefore they must collaborate with teacher and peers to succeed (Dennen & Burner, 2008). The cognitive apprenticeship model consists of six steps: modeling, coaching, scaffolding, articulation, reflection, and exploration (Collins et al., 1991). Modelling, coaching and scaffolding are designed to help students gain skills through observation and supported practices, articulation and reflection help students gain control of their own problem-solving strategies, and exploration encourages learner autonomy through intentional fading by the teacher (Collins et al., 1991; de Bruin, 2019). However, the level of support required depends on the learners' zones of proximal development, the difference between their ability to accomplish a task without help and their ability to complete a task with help (Dolenc et al., 2020). Many studies of the cognitive apprenticeship model focus on adults (Dennen & Burner, 2008) as it is a useful instructional model for teaching complex tasks (Collins et al., 1991). There are a few recent studies of cognitive apprenticeship in secondary school STEM. For example, the cognitive apprenticeship model has been used to build interest in STEM and develop skills in engineering, science and computational thinking through robotics courses for high school students (Dolenc et al., 2020; Larkins et al., 2014). The use of the cognitive apprenticeship model within the Year 7 case study will be discussed next.

Case study

This research uses an interpretive case study design to examine the way a Year 7 teacher embeds critical thinking skills into their teaching of an integrated STEM project. The STEM project was designed and taught by a teacher with 13 years teaching experience. Qualitative data sources for this study include pre/post teacher interviews and three classroom observations. Students used the engineering design process and a device called a Makey Makey (circuit board, alligator clips and USB cable) to build a solution to solve a real world problem of their choice. Most students had not encountered engineering in primary school, so the focus of the project was on engineering with a minor focus on science, maths and technology. Twenty-five percent of students in the class had learning difficulties and the teacher aimed to build student confidence in problem solving and an interest and passion in STEM. Student assessment consisted of an end of project written report and video. Observations and interviews were analysed using thematic analysis and themes emerging from the data articulated well with the Cognitive Apprenticeship Model (Collins et al., 1991). The findings will focus on teacher behaviours and how teaching strategies described in the cognitive apprenticeship model may foster critical thinking.

Evidence of the cognitive apprenticeship model is revealed in the following snapshots of teacher interviews and classroom observations.

Modelling occurred when the teacher modelled activities and thought processes so that students could observe and learn disciplinary knowledge within the problem-solving context. For example, the teacher demonstrated during a think-aloud: *"What you have built is a circuit, it works because it's in a loop so you can get electricity through it, if there's no loop it can't work"* (Class observation). The teacher modelled critical thinking dispositions throughout the project. For example, students were tasked with brainstorming several ideas for products that could solve the problem and were asked to identify strengths and weaknesses of each idea. During the process the teacher modelled open mindedness by listening to all students' ideas and encouraging different perspectives.

Coaching occurred when the teacher offered guidance and feedback. For example, *"I like to talk to each kid at least once a lesson and sort of touch base with them and see where they're at, guide them if they need to get on the right track or give them a bit of confidence if they need it, or push them, push their ideas further if they need it, so sort of figure out what each kid needs and then give them what they need verbally"* (Teacher interview).

The teacher also coached students by using open questions such as what, why and how, to help them clarify their thinking about design options. For example, students were asked to sketch several ideas and then choose one idea to develop and build. The teacher coached students who got stuck by discussing the students' ideas, being a sounding board as well as guiding them by saying things like "what if you do this?". The teacher asked students to think, imagine and visualise their solutions, and extended students through deeper probing and questioning.

Scaffolding was provided in different forms during the project. A project booklet was given to each student to help guide them through the engineering design process and break up the task into smaller parts. Further, students first researched their chosen problem in detail and were given four guiding questions: (1) statistics of how many people are affected by the problem they are solving; (2) what causes the problem; (3) what issues the problem causes for those affected by it; and (4) what current solutions are available to solve the problem. Before choosing their own problem to solve, students first completed group 'mini projects' including making a musical instrument using a Makey Makey, creating a piece of interactive art, and making a video game controller for someone with a physical disability. Collaborative learning was used to build confidence in problem solving. As the teacher explained, "So *starting with large groups, groups of 4, doing a little mini, one lesson idea project that they've got to come up with a solution to the problem. Then do the pairs work for the Makey Makeys, then individually, problem solving. It's sort of a stepped-up process all along - so breaking it down from a larger thing to a smaller thing. I think if you took out one of those steps, the step-ups would be too big for the kids to grasp and they'd get overwhelmed"* (Teacher interview). The teacher also taught four lessons during project to activate prior knowledge and ensure students had sufficient content knowledge to complete the project. They explained, *"At the start they don't really have the skills involved so you're just trying to increase their knowledge in the areas like knowing about circuitry, knowing the maths involved about statistics, conductivity, that sort of stuff."* (Teacher interview).

Articulation is when the teacher encourages students to explain their knowledge and thinking. For example, in peer review activities, the teacher asked students to explain to their peers how their prototypes work, based on a set of criteria such as choice of materials used and how their solution solved the problem. Students had to create a set of criteria to judge the success of their products and get a minimum of five other people to test their product and give it scores for each criterion. During the process students had to explain and justify their thinking. The teacher explains, *"Formally, there's a process at the end where they test each other's work. But all through the process I do suggest in some ways but also just let them share their ideas with each other, build on their ideas as a group because often one idea leads to another idea so it's like that little stepping stone they need to get an idea off the ground."* (Teacher interview).

Students also came to the teacher to explain their ideas and the teacher helped them expand their thinking: *"One student, she's gone through this idea process, verbalizing the process, so then she says I got to this point, and now I'm stuck, so where should I go from here? So I sort of lead her on to the next point to get her through her road block"* (Teacher interview).

Reflection occurs when the teacher asks students to evaluate their performance and thinking in comparison to others. For example, after students tested their own work, the teacher asked students to reflect on the strengths and weaknesses of their prototypes. Students then began their peer review testing and the teacher asked them to reflect on those results and identify what improvements could be made. "*In their testing of their own work and each other's work, they're comparing their own interpretation of their results versus other peoples. They compared the data from their own point of view to their peers' points of view. I think that really showed them that what they see isn't necessarily what the world sees and that sheds some light on things for students.*" (Teacher interview). However the teacher felt that asking the students to reflect on their own critical thinking may decrease their confidence. They explain, "*I think a lot of them in year 7, I just don't think they're at that point. I think they would just say, 'I'm wrong'. It's just trying to build that confidence in them at this age. I've just found so far with the year 7s, they just don't have any self-confidence in their creativity or their problem-solving skills at all. And if you say analyse your technique, they sort of freak out and go 'I can't do this'.*" (Teacher interview).

Exploration is when the teacher encourages students to problem solve mainly on their own. In the project, exploration occurred while the students were building their prototypes. The teacher set general goals at the start of the lesson and students led their own learning to complete the task. The teacher deliberately stepped back, allowing students to make mistakes and correct themselves. The following interaction exemplifies exploration in the Year 7 classroom:

> Student: "*My circuit is not working.*

> Teacher: *Well think about it, why? Maybe you can do some research to find out. Does that conduct electricity?*
> Student: [Researches] *Nope.*
> Teacher: *Ok well, there's your problem, figure out what else you're going to use"* (Classroom observation).

They explained that, "Being able to step back and just let them do it, is a really important skill to have, because it's hard to not just step in and go you're doing it wrong. No, just let them, they're going to learn more from doing it wrong and then learning to problem solve to find a solution then me going you are doing it wrong, do it like this. I deliberately step back so they have to do all the thinking themselves. In the initial stuff like the mini projects at the start, its more teacher led because obviously they need to be able to develop those skillsets, the confidence. But definitely in the project I stand back." (Teacher interview).

Key ideas about STEM

Cognitive apprenticeship has proved successful in promoting students' higher order thinking by motivating and engaging learners in authentic activities, enhancing metacognition skills and encouraging transfer (Ghefaili, 2003). It is inferred from evidence in this cases study that the cognitive apprenticeship model may foster both critical thinking skills and dispositions. Teacher interviews and class observations demonstrated that modelling, coaching and scaffolding support the activation of prior knowledge, learning new content and skills, when and how to apply different disciplinary thinking strategies, development of critical thinking dispositions and motivation to learn. Articulation and reflection supported students' metacognition. It helped students expand their thinking, develop confidence in their ideas, encouraged openness to others' perspectives and monitoring of their learning to guide subsequent practice. Exploration allowed students to practice using their knowledge, skills, thinking strategies and self-regulation. In the process of applying and transferring their learning they engage in critical thinking.

Teachers may encounter challenges when using the cognitive apprenticeship model as they must be aware of how much support each student requires to complete the project successfully (Ghefaili, 2003). Providing too much support may discourage student effort and motivation while providing too little help may provoke anxiety and frustration in students (Dolenc et al., 2020). The teacher in this case study remarked on the importance of knowing when to step back and knowing when to push and extend students further to encourage critical thinking. However, even for an experienced teacher it was sometimes difficult to know how much support some students needed. Large class sizes limit teachers' abilities to interact with and assess individual student's needs. It was not a factor in this example as there were only 15 students in the class (Dennen, 2004). Diverse cultural and communication styles may inhibit teacher ability to meet students' needs with cognitive apprenticeship (Denne, 2004). In this case, students with low literacy struggled with defining the problem they were trying to solve however this was not known until students had written their reports. Writing is a tool for supporting the process of learning to think critically therefore a writing scaffold for those students may have improved performance (Wass et al., 2011).

Conclusion/Summary

Teaching strategies used to foster critical thinking skills and dispositions during the year 7 integrated STEM project articulated well with the cognitive apprenticeship model. Key elements were the teacher's ability to understand the way students were thinking and provide immediate feedback to guide and support students. The balance between providing help and deliberately stepping back was also important. This raises questions about the skills and experience teachers require to teach critical thinking effectively within integrated STEM. Given the importance of a student's interactions with both teacher and peers, and the small class size of 15 students in this case study, it is recommended that future research will examine whether the cognitive apprenticeship model can be scaled up and used successfully in larger classes.

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Tech Schools Mediating School-Industry STEAM Partnerships Using Design Thinking

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Abstract. This paper presents research from a three-year study on Tech Schools as mediating organisations for authentic STEAM partnerships between schools and industry. Findings from two case studies are provided to illustrate some different ways that Tech Schools involve industries in school projects. First, through the co-design of interdisciplinary programs with industry. Second, using industry-based design challenges. This paper includes an overview of the seven stages of the design thinking process used in some Tech Schools as well as a table with industry links. A strategic and sustainable approach is needed for school-industry partnerships, allowing teachers to meet curriculum outcomes and for industry to meaningfully engage. Tech School programs provide a useful structure for diverse forms of industry engagement, as well as highlighting a need for educational organisations which can mediate school-industry partnerships.

Introduction

Engaging with industry and community provides teachers with opportunities to connect curriculum to authentic issues through STEAM projects (STEM plus arts and humanities). This can foster aspiration in STEM careers which is one of 10 recommendations by Education Services Australia (2018, p. 15). Yet, according to The Australian Industry Group (2017) the process of partnering with industry can be unsustainable for schools and industry if it is poorly coordinated.

Tech Schools in Victoria are developing structured approaches to school-industry partnerships which go beyond the usual excursion or incursion (Sacrez, 2020). Using seven stages of design thinking, teachers can strategically draw on industry at key points of a project from co-designing a unit, to interviewing, rapid prototyping and pitching solutions to industry.

This paper will firstly outline the seven stages of the Tech School design thinking process. Following this outline, two case studies will be presented with a focus on different parts of the design thinking process and the role of Tech Schools in mediating school-industry links. Some key insights are presented for teachers who may wish to run an integrated STEAM unit with authentic industry and community links. These insights are informed by findings from a three-year comparative case study on STEAM program design as well as literature on using design thinking in education projects. This research study was conducted by Sacrez (2021) as part of his doctoral study on the role of Tech Schools in mediating STEAM program design in schools. Finally, a generic unit structure is presented as a table in the Appendix, with strategies for connecting with industry at each stage of the design thinking process.

A Snapshot of the seven stages of design in a unit

The seven stages of design thinking presented here are based on a structured process used by many Tech Schools in designing and implementing STEAM programs. Terminology may vary from one Tech School to another, yet the structure is typical. Tech Schools have based their design thinking process on the original version by the Stanford University d.school (Plattner & Institute of Design at Stanford). An overview is now provided of how the Tech School design thinking stages can be used for a school unit.

1. ***Enterprise:*** Teachers consider the types of skills and knowledge to be developed as well as the curriculum to be taught across subjects. An overarching unit theme can be developed, and potential industry partners contacted and engaged in co-designing a program.
2. ***Empathise:*** Collecting information about the user and the problem to be solved. To authentically understand the user and their needs, relevant communities and industries can be visited. Interviews and surveys are examples of empirical research which can be conducted by students.
3. ***Define:*** Teachers and students create a problem statement based on understandings of the user's needs. Industry experts in the field can provide research resources as well as present to students online or in person. Preparing questions to ask experts can be an incentive for students to research the topic.
4. ***Ideate:*** Group brainstorming to collect a high volume of diverse and creative solutions. Industries that use a design process may provide examples of how they develop new ideas. Some industries have a designated R & D (Research and Design) department focussed on the design and development of innovative solutions and products.
5. ***Prototype:*** Constructing a physical representation to help conceptualise the solution. A low-tech prototype can be built at school, with a high-tech version manufactured at a Tech School or through a partner industry. Laser cutters, 3D printers, VR and AR are examples of high technologies which are used in Tech Schools.
6. ***Test:*** Sharing the prototype with the user to gain feedback for modification and redesign. Testing and presenting student prototypes are an opportunity to gain feedback from the community through an event or online. Market testing evaluates the suitability and viability of the solution to the user's problem, while materials testing can assess the suitability of an aspect of the prototype. Industry can provide authentic examples of product testing.
7. ***Present, Reflect & Iterate:*** Students communicate their solution to the problem to an audience including community and industry leaders. Organising a public event, video recording student pitches and creating a school webpage are examples of authentic platforms for connecting schools with community and industry. Reflection involves team self-evaluations about successes and failures, what was learned through the design thinking process, and how the team could improve the prototype. Ideally, this stage leads to a new iteration as a design cycle towards an improved solution.

These seven stages of the design thinking process provide teachers with diverse ways of connecting with community and industry throughout a project. An industry partner may be involved in the entire project or at key points such as: at the start in the enterprise, empathise and define stages; midway with ideation and prototyping; or at the end with testing, pitching, and presenting work. There is also the possibility for teams that produce high quality solutions to undertake a new iteration of the design with support from an industry. As school-industry partnerships become increasingly valued for promoting careers in new industries, schools can benefit from a structure that supports informal partnerships as well as large-scale interinstitutional projects (Pillay et al., 2014).

To illustrate the practicalities of fostering school-industry connections, two examples from case studies are provided. Case study 1 exemplifies how running a co-design session with industry can support the enterprise, empathise, and define stages of a unit. Case study 2 provides an example of an industry-based competition integrated into a secondary school STEM subject with a focus on ideation, prototyping, testing, and presenting.

1. Co-designing units with industry

One of the defining characteristics of Tech School programs is that they are designed with input from industry. An example is provided of the Bendigo Tech School's approach to co-design using the design thinking process. Representatives from relevant local industries were invited to the co-design workshop which included members from the council, renewable energies developers, a local wine producer, telecommunications experts, and a mining technologist. The theme of the workshop was "new energies, food, and fibre".

The co-design workshop began with an introduction by the industry representatives and an overview of the design thinking process used in the student programs. In teams, the industry representatives were guided through the process of empathising, defining an issue, and ideating a solution to meet the needs of a potential user from their industry. The teams also made a simple prototype of their solution with LEGO, carboard and small electric sensors. Each team presented to the whole group on their user's need and a potential solution. All ideas were collated into a master document and voted on by a programs advisory board, including schoolteachers to design a student program. The final program required students to design a farming solution using IoT (internet of things). While this co-design workshop only involved industry, including teachers and students could have been beneficial in building a relationship between schools and industries, and fostering student agency.

Key Insights for Teachers: Co-Design as a Learning Process for Teachers:

2. Integrating an industry competition in a school

Tech Schools design and run diverse competitions and design challenges for school students to participate in. These design challenges connect with national organisations and industries in STEAM, which creates an authentic audience for students to present their work. An example is provided of the 2019 Thales Design Competition which was used for a case study involving the Bendigo Tech School and a local secondary school.

Thales (an international technology, sensor, and engineering corporation) partnered with four Tech Schools to challenge secondary school students in teams to use sensor technology to “make life better, to keep us safer”. Schools were encouraged to provide time in class for participating students to complete their projects. In addition, 10 hours of out of school time with a technology mentor was provided by the Tech School as well as workshops and an immersion day.

Students from a participating school involved in the research study produced solutions including: a pollen sensor to help people with asthma and allergies; a bushfire detector for rural properties; a bicycle crash emergency signal; and a sleep monitor for nocturnal epilepsy sufferers. These prototype solutions were presented to a panel of industry experts through a five-minute pitch at a regional level competition. The winning team then refined their prototype and presented at a state-level pitch. During interviews, the students and their STEM teacher commented on the high level of student agency and authenticity of learning achieved through the Thales Design Challenge mediated by their Tech School.

Key Insights for Teachers: A Structured Approach to STEAM Integration

- Integrate: Many Tech School competitions are curriculum-aligned which promotes interdisciplinary units across all school subjects.
- Showcase: Provide a public platform for young people to present to industry and community
- Replicate: The design thinking process is a template which can be used by teachers to design their own industry-based design challenges.

Conclusion

Connecting school learning to industry experiences and professions is an important aspirational aspect of secondary education. Yet, industry-based learning can be time consuming, difficult to connect to curriculum and logistically challenging to integrate into school timetables. Tech Schools have developed a structured model of industry-based projects using a design thinking process. Co-designing workshops and competitions are two examples of authentically working with community groups and industries at key stages of the design thinking process. Victorian secondary schools are encouraged to contact their local Tech School for more information on the diverse ways of partnering with industry and developing integrated STEAM programs. A table of the seven stages of design thinking with key connections to industry is provided in the appendix. Teachers are encouraged to use the table as a template for their own planning of community and industry focussed projects.

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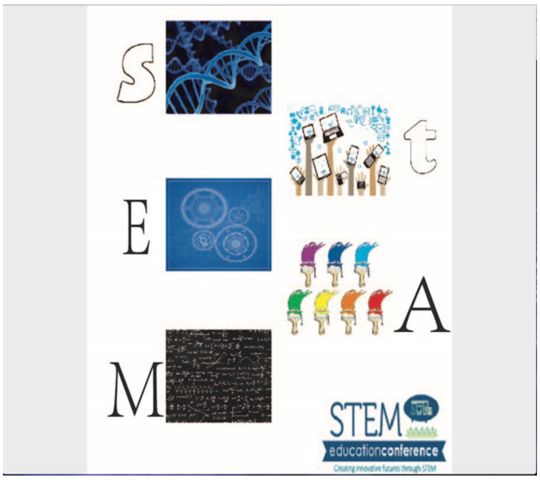
Appendix

Design thinking stages to integrate industry links into STEAM programs

Design Thinking Stages	Industry Linked Activities	Key Ideas for Teachers
Enterprise	Connect with an industry Co-design a program	Make connections to the curriculum and real-world issues Research industries, make contact, and gauge their level of commitment Utilise an intermediary organisation or join existing programs
Empathise	Interviews and excursions	Use classroom discussions and student research to design interview questions
Define	Guest speakers student research	Virtual tours, zoom, and pre-recorded interviews are alternatives to meeting in person Utilise industry web sites and resources to examine the issue
Ideate	Explore R & D processes used in industry	Draw on the creative and critical thinking capabilities from the curriculum
Prototype	Build low and high-tech prototypes	Organise PD, training, and mentoring in the use of industry tools and technologies
Test	Market tests and materials tests	Use evaluation criteria that reflects industry practice and subject curriculum
Pitch/Present Reflect Iterate	Showcase event & student pitch Evaluation of the product & process Next stage of designing and prototyping	Invite industry and community, lever digital platforms such as video and websites Consider the sustainability of the product and the prototyping processes used Select teams for follow up visits to interested industries for advice and training

WORKSHOPS



Joseph Fratantaro
Newcomb Secondary College

"Learning about STEM means that I will understand more about technology because we have more and more technology in our everyday lives. I hope STEM will help me get a job that involves technology :)"

Getting you out of the black hole – empowering STEAM teachers to teach the 21st century skills[1]

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Abstract. Digital transformation and emerging technologies have disrupted the workplace, from the skills employees need in the workplace to the entrepreneurial mindset they require in this dynamic and globalised economic system. While the workers of today are navigating this transition, students who will be the workforce of the future, require skills to lead the working landscape of the future. These skills, known as 21st century skills (many of which resonate with what is termed enterprise skills), are generic skills that are transferable across different jobs and are a powerful predictor of long-term job success and will be increasingly important into the future. The Australian curriculum lists these skills as problem solving, communication, presenting and pitching, digital literacy, teamwork, critical thinking, creativity, and financial literacy. Therefore, 21st century education requires a shift to help students grow in confidence to practice these skills, especially those in STEM disciplines where they are hardly ever exposed to these soft skills. To answer this call, this paper bridges the knowledge and resource gap that Australian STE(A)M teachers have by explaining the development of a specially designed platform to teach the 21st century skills and enterprise skills.

Introduction

The skills of the 20th century emphasised compliance and conformity over creativity. During that time, these skills were necessary within a professional or corporate environment and to secure a good job for decades. However, these skills are now a relic of the past! So... What are the 21st century skills required of our high school students today? Building on the digital technologies of the third industrial revolution (also known as digital revolution) and foreseeing the 4th industrial revolution (and the convergence of digital, biological, and physical), 21st century high school graduates need to be able to manage this social transformation at a global scale. This means that high school students need to be prepared for dynamic, fast changing workplaces in a context of continuous innovation and economic development. The Australian Curriculum lists these set of new graduate skills as problem solving, communication, presenting and pitching, digital literacy, teamwork, critical thinking, creativity, and financial literacy. Thus, 21st century education requires a shift to help students grow the confidence to practice these skills, especially those in STEM disciplines where they are hardly ever exposed to these soft skills.

Many of the 21st century skills resonate with what is termed enterprise skills. Enterprise skills are used to describe certain abilities that are crucial for today's graduates in achieving future career success. These skills will help ensure that students are equipped to keep up with the rapid pace of change in the dynamic landscape in which they will work. The skills range from critical thinking and problem solving, to creativity and innovation, communication, and collaboration. There is a focus on a range of skills that fall under the umbrella of 'information, media and technology' and they include information literacy, media literacy and information, communications, and technology literacy. Finally, 'life and career skills' encompass flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, accountability, leadership, and responsibility (Fadel,

[1] Funded through the Advancing Educational Pedagogies program at Griffith University

2008). Each skill is unique in how it helps graduates, but they all have one quality in common: 'they are essential in the age of the Internet' (Stauffer, 2020, p.1).

Science, Technology, Engineering, Maths with an 'A' added (STEAM)

Developing STEM skills is imperative to Australia's economic competitiveness (Andrews, 2015). This is even more true today. Jobs within STEM have been prioritised by global governments as they see the skills they provide, that is, the technical and enterprise skills of engineers and scientists as a means of dealing with the problems and opportunities that have been presented by the COVID-19 pandemic (Australian Industry and Skills Committee 2021). Reports such as the Australian Academy of Science (2011), Department of Education Science and Training (2006), and Office of the Chief Scientist (2012) all emphasise the critical role STEM plays in relation to innovation and entrepreneurship as the major change mechanisms for economic prosperity. There is a lack of clarity in Australia in the way that STEM is defined across government, industry, business, and educational sectors. For example, Medicine is not included in the definition found in the Australian STEM workforce report from the Office of the Chief Scientist (2016). Technology is also conceptualised differently, with the Chief Scientist in 2016 defining technology as Information and Computer Technologies (ICTs) only, aligning it more closely with Engineering (Panizzon and Corrigan 2017). This paper is adding another dimension to the STEM acronym through the inclusion of Arts; thus, the acronym becomes STEAM. We contended that by including Arts into the STEM acronym enables the application of personal expression and purpose into the hard sciences. Art can be used as an effective means to express and communicate the sciences, such as incorporating graphics, images, and pictures into science projects. Bosch (2021, p.1) purports that 'the natural environment inspires artistic expression, and art inspires environmental stewardship'. Additionally, educators believe that incorporating Art to STEM based thinking enables the duality of the brain to be used resulting in innovative thinkers. For the remainder of this paper, STEAM will be used to reflect Science, Technology, Engineering, Arts and Maths.

Platform activities[2]

Gyurova and Zeleeva (2017) have found that today's teachers have little to no experience of learning about the 21st century skills and that their knowledge of such skills must come from their university education, where they get the basic training and/or upgrading qualifications courses. Many high schools in Australia provide little teaching of the 21st century skills to students in STEAM disciplines. This project emerged following a call from several high school teachers located in Victoria who requested activities and tools to teach the 21st century skills. Following talking to a random sample of high school teachers based in Victoria and in Queensland, we identified the need to have such tools available to them, with an Australian slant as well. Therefore, to combat the gap in the lack of resources for high school teachers within STEAM and to help STEAM teachers who may not have experience of the 21st century skills, we have created a 'one stop shop' type platform. Through engaging with the online platform, the STEAM high school teacher will have access to content that has been specifically curated and/or developed for them, that is, journal articles, exercises, and case studies focusing on STEAM entrepreneurs. This would then enable the STEAM high school teacher to embed the 21st century skills into their curriculum.

The platform in more detail

Each skill area includes an introduction that explains why the skill is important and how to use the skill once learnt; videos explaining the skill to teachers and students, case studies that highlight where and how the skill was used by the entrepreneur, plus many activities that provide opportunities for students to practice the skill in a safe, fun way.

Videos with entrepreneurs: Eleven interviews were conducted with entrepreneurs, with ten interviews being professionally recorded. The interviews ranged from 45 to 160 minutes. From the interviews, we made short videos that highlight the 21st century skills and enterprise skills. The first set of videos can be found in the 'Meet the entrepreneurs' tab on the platform, where each entrepreneur is given a dedicated tile. By clicking on the

[2] To see a sample of the platform please go to the following website: https://sway.office.com/KyyCTOSiEwEfrsie?ref=Link&loc=play. Alternatively contact: n.birdthistle@griffith.edu.au

entrepreneur's name, one is presented with a video, which can be shared through YouTube, and which profiles the entrepreneur and his/her business. By clicking on the name of the business one gains accesses to the written case study on the entrepreneur. Other videos are interspersed throughout the platform and are all linked to 21st century skills and enterprise skills. These videos are made to showcase the practical importance and relevance of these skills. In each video, several entrepreneurs are featured to give their view on a skill and their experiences in relation to the specific skill. The purpose of the videos is for STEAM high school teachers to learn more about each skill and, if needed, they can share these videos directly with students. The videos showcase answers about the importance of specific skills that the entrepreneurs are passionate about and why and how the skills are relevant to their work. The videos allow high school teachers and students to learn from STEAM entrepreneurs about the importance of the skills and how these are used in practice. In addition to the videos focusing on a particular skill, there are also videos made to share with students where the entrepreneurs provide advice for finding employment to budding entrepreneurs. With the need to encourage more girls into STEAM, the platform also hosts five videos, which feature five women from Victoria who are in STEM, including Kim Ellis, a space lawyer and training to be Australia's first female astronaut to go into space. In addition to the videos are written cases and lesson plans that the teacher can use in the classroom.

Instructional videos: Based on the expertise of the team, we developed some tailor-made instructional videos with activities for some enterprise skills. The instructional videos were developed for the slightly more complicated activities that we have included on the platform. Each instructional video outlines which skills are relevant for the activity, the learning outcomes, and a run-through of the activity. The videos are to be viewed by the STEAM high school teacher (not students) to explain the purpose of the activity, when it is useful (and in what context), and some tips about using it in the classroom. The platform also provides links to lesson plans to help guide the STEAM high school teacher in its implementation.

Entrepreneurs case studies: The team wrote a case study about each of the eleven entrepreneurs that is tailored to one or several enterprise skills. Each case outlines the motivation for being an entrepreneur and how they came up with the idea for their venture(s). Each case highlights specific challenges and opportunities that the entrepreneur faced when starting and/or operating their business. The case also highlights skills the entrepreneur displays, for example, how their creative process of finding ideas occurs, their approach to negotiation, or how they overcame an unexpected change. Thus, each case connects with several enterprise skills. The cases all end with three to five questions that STEAM high school teachers can use to guide the discussion with students in the classroom or online.

Additional resources: To complement the internally developed resources (e.g., case studies, lesson plans, etc.), for each 21st century skills we also included a selection of content curated from external sources to help users locate additional resources. It was decided by the team that this should leverage both the learning and teaching experience of the platform users. The process for selecting the resources was as follows. First, team members independently identified research articles, news articles, case studies, videos, podcasts, tests, and quizzes relevant for at least one of our 21st century skills (Creativity and Innovation, Problem solving, Design and prototyping, Pitching, Communication, Networking, Negotiation, Teamwork, Leadership, Funding, Financial literacy, Design, Confidence building). There were no limitations on what resources should be identified other than reliable sources with a contemporary relevance.

All the identified sources were placed in an Excel spreadsheet and mapped across the 21st century skills. For each intersection, the resource (row) was categorised on whether it is extremely relevant, somehow relevant, or not relevant to the skill (column). This exercise was done independently by two researchers at first. Then, the mapping from the two researchers was compared and a final map of those resources was put together identifying what resources best complemented the identified 21st century skill. The criteria considered for the final mapping and selection of resources was based on (i) relevance of the resource, (ii) variety of the type of resource, and (iii) complementarity of the resource to the learning and teaching experience.

Testing the platform

A pilot test of the platform occurred in a workshop with high school teachers who attended the STEM Education Conference hosted by Deakin University. The workshop was 50 minutes in length and was delivered online. Participants were given access to a specially designed platform of resources for teachers which focused on the 21st Century Skills. Since it was a pilot, only three 21st century skills were hosted on the platform and they were: (i) creativity, (ii) prototyping and minimum viable products (MVPs), and (iii) pitching.

The remaining time of the workshop focused on doing an exercise called the ‘Bugs report’, which can be found in the ‘Creativity’ tile on the platform, that helps to teach three 21st century skills. The participants had to identify something that really bugged them and then they had to creatively conceive how they could make it better. Each participant was then put into a team of four others and asked to pitch their bug and how they might make it better. The team chose the idea that suited them the best and were then tasked with developing their digital literacy skills through creating a video which showcased the team solution to the bug. Assistance on creating the video was found on the ‘prototyping and MVP’ section of the platform and they had 20 minutes to complete this task. The teams had to pitch their solution to the bug and they were guided to go to the ‘Pitch’ element of the platform and use the ‘Gaddie approach’ that was housed on the platform. Each team had to include their video in the pitch.

The workshop concluded with a ‘Go fish’ exercise where they were given the opportunity to interact with the exercises on the platform. Participants were asked to provide feedback on the exercises and the platform that they interacted with and if they would use the resources in their teaching and if not, what could be done to make them interact with the platform.

Concluding comments

The feedback given by the high school teachers provided the team with some rich feedback on the platform, with some teachers indicating that they ‘loved it and have forwarded the link to the staff already: love this!’ and ‘wow, it’s so comprehensive. A great resource’. Another teacher said that he ‘could implement some of this in my year 7 class’. The next steps include adding some guidance on the use of the resources, that is, which resources are appropriate for year 9 students and which are appropriate for year 10 students. Additionally, each skill should identify the time it takes to complete the exercise along with any resources the teacher might need. Furthermore, two members of the team have written a Teachers’ Handbook with an accompanying Student Workbook on the 21st century skills and a link to this resource will be added to the platform. It is anticipated that the promotion of the platform will occur in the middle of 2022, and this will be done through email to teachers and principals directly. The platform will be reviewed on a bi-annual basis to ensure it is up to date and current.

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Bitlink Internet of Things Kits: An Inquiry-Based Approach to Technology Education

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Bitlink and University of Tasmania

Abstract. Bitlink is a technology education company based in Launceston, Tasmania. The Bitlink team spent two years working with primary teachers in northern Tasmania to codesign an Internet of Things hardware kit and range of accompanying teaching resources. The kit was developed to provide a novel way of teaching the ACARA Design & Technologies and Digital Technologies curriculum areas. In this workshop, James Riggall and Troy Merritt presented the resources that were created as part of the project as well as sharing lessons learned from running a codesign process with teachers. The workshop also featured hands on lessons, which showcased the flow of the first few lessons covering how to write a basic program with a BBC micro:bit.

Introduction

Prior to the development of their Internet of Things (IoT) Education Kit, the Bitlink team had been working with schools across Tasmania to deliver in-person STEM workshops covering a range of technologies including programming, electronics, games design, and robotics. While these programs were well-received, their impact was limited to the time that Bitlink staff were able to spend in classrooms and did not help upskill teachers to meet new curriculum needs.

Bitlink received funding to help accelerate the development of a new hardware kit of electronics and associated teacher resources, aimed at helping teachers to improve confidence in teaching the new ACARA Design & Technologies and Digital Technologies curriculum. This funding enabled Bitlink to run a codesign process with STEM teachers in ten northern Tasmanian primary schools. This funding also enabled the manufacture of 600 kits of electronics, curated by the Bitlink team, and for classroom sets (fifteen kits per set) to be donated to forty primary schools in the greater Launceston area.

The codesign process

To develop these kits and resources, the Bitlink team worked with teachers in ten pilot schools over an eighteen-month period. These teachers helped the Bitlink team make key decisions about the contents of the kit, the types and format of the accompanying lessons and how teacher tools would be structured. Through a series of interviews early in the project, we identified some key design considerations:

- **Real world themes:** Learning to code often involves learning somewhat abstract concepts. Where possible, teachers wanted student to learn by building things that had a real-world application.
- **Challenges and inquiry learning:** Teachers wanted students to learn through experimenting and problem solving, not by following a tutorial or sample code.
- **Careful scaffolding:** Sometimes a range of concepts need to be understood to successfully complete a project. Teachers wanted a logical flow to the lessons, that would introduce concepts just-in-time and reinforce new ideas by revisiting them in future lessons.

- **Robust and safe hardware:** Many teachers had used products before that were either too complex, too fragile, or potentially unsafe for classroom use. Whatever we selected needed to stand up to use in classrooms.
- **Multi-modal lessons:** To support students with varying lessons of literacy, lessons should make use of multimedia to help reach as many students as possible.

Once these design considerations were understood, sample kits were curated, and prototype lessons were developed. Bitlink piloted these new lessons with the pilot schools across three pilot phases. The pilots started with off the shelf kits with prototype lessons in the first phase, to a curated kit of electronics and well-developed lesson plans in the final pilot phase.

The end result

Following the pilot phase, a final design phase selected the kit components, and all remaining lessons and supporting resources were fully developed. Once complete, the resources that comprised the final product were:

- **The Bitlink Internet of Things Kit:** This curated kit of hardware included a BBC micro:bit controller, an Elecfreaks sensor:bit breakout board, and 10 assorted sensors and actuators from the DFRobot Gravity Series. Each component is packed in a stickered antistatic bag and packed in a calico bag for storage.
- **Lessons:** The Bitlink team designed twenty lessons to support the kit, across four modules: What is IoT?, Smart Homes, Smart Farms, and Smart Cities. Lessons use real-world themes to help students engage with the content. Lessons were comprised of challenges that scaffolded students towards a final project for each lesson and an open-ended design challenge at the conclusion of each module.
- **Goal videos:** We created video examples for every challenge so that students could see what success would look like. Videos and images introduced every new device and block of code that the students would encounter.
- **Short documentaries:** We created short introductory documentaries for each module, which made the connection between what the students were learning in class and how Internet of Things technology is used in industry more explicit. Each video features interviews with Tasmanians who frequently use Internet of Things technology (ranging from people who design and build Internet of Things devices, through to farmers, city planners and startup founders who use such devices in their work).
- **Makers Treehouse:** We created short videos to introduce and conclude each lesson, which we titled "Makers Treehouse". Each video features teenagers (the makers) who use the technology in the Internet of Things Kit to solve problems. Each lesson has a segment to play at the start that would introduce the problem that the lesson would tackle, and a segment for the end that recapped key ideas from that lesson. Along the way they model soft skills like problem solving, co-operation and resilience.
- **Teacher tools:** In addition to the resources that have been designed specifically for students, each lesson also includes a range of supporting materials for teachers. These include learning intentions, success criteria, guiding and reflection questions, example solution code, slide decks and ACARA curriculum links (Grades 3-6, Design and Technologies and Digital Technologies).

Description of activities

While originally intended to run as a face-to-face session, the workshop session was delivered online as per restrictions relating to the COVID-19 pandemic.

In the first phase of the workshop, we discussed the rationale and design decisions that lead to the creation of the IoT kits, as detailed above. We also presented some of our observations from the codesign process, and some of the lessons that we learned along the way. Some of the key observations were as follows:

- **Codesign works:** Working with teachers to design this product led to far better outcomes than would have been achieved through a less collaborative design process.
- **Every teacher is unique, and so is every class:** While working with ten pilot teachers we saw a lot of different teaching styles. This led to resources being designed in a flexible way to support teachers in the way they wanted to teach, rather than trying to push them to teach in a certain way.
- **Professional learning isn't the only way to build STEM confidence and capacity:** We designed the kits to have the lowest barrier to entry possible. This was not only to benefit students and help them get

started quickly; it was also to enable teachers to learn alongside their students and build confidence through practice, rather than through preparation or specialised training.

The second phase was a hands-on activity in which participants could follow along with some of the early lessons in the Bitlink resources and experience the lessons from a student perspective. To do this, we used our slide decks, in the same way that we do in primary school classrooms (though, in this case, screen sharing the slides rather than displaying them on a projector or television).

We also used micro:bit Classroom to create an interactive session where participants could code their own solutions to the first few challenges and facilitators could observe as participants worked on their projects. As we could not distribute hardware for the participants to use, we used the micro:bit simulator built into MakeCode to test the code that had been created. All participants were able to complete the first few challenges in the series by writing and testing their micro:bit programs in their own web browsers, with the facilitators watching on and assisting as required via micro:bit Classroom.

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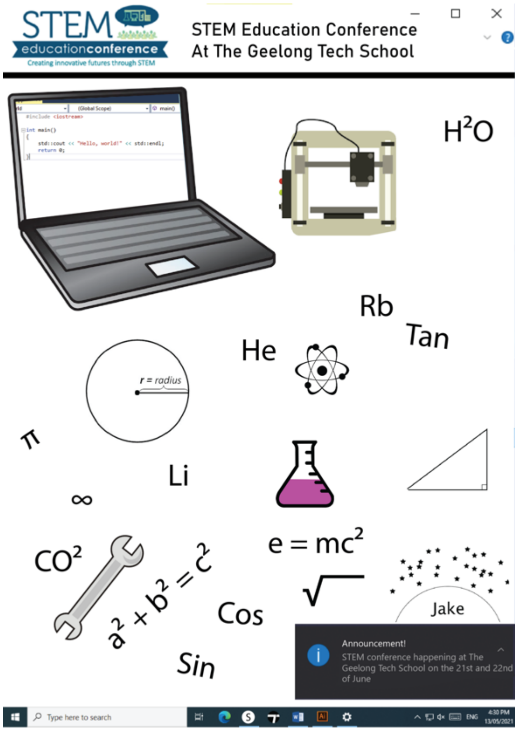
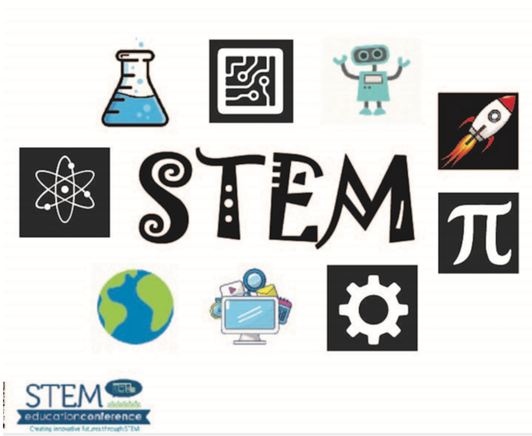


Jake Duraj

St Joseph's College

"What STEM means to me is being able to have the freedom to create whatever is on your mind and to bring something from a computer into the real world. When Science, Technology, Engineering, and Math are all combined together something great is made."



Yunrong Fan

The Geelong College

"I think STEM is very important for every aspect of our lives. Without STEM we wouldn't be able to create things that can change the world."

Charlotte Hawkins

Sacred Heart College

"STEM creates an outlet for me to express myself in a different way. At times, it can be easier for me to create or influence something through STEM. I love the idea of exploring new innovative ideas and creating the unknown through technology; as we see many important pupils do today. I can't wait for my future in STEM and what I will create!"