Connecting Teachers, Students and Pre-Service Teachers to Improve STEM Pathways in Schools

Catherine Lang[a], Greg Powell[a], Fazeela Ibrahim[a] and Nathan Moore[b]

Corresponding author: Catherine Lang (C.Lang@latrobe.edu.au)
[a]La Trobe University, Melbourne, Victoria
[b]Charles La Trobe College, Melbourne, Victoria

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Abstract

This paper presents an example of collaboration between teacher educators, pre-service teachers, current teachers and school students that had a primary aim to increase student interest in STEM activities through a MakerSpace STEM club, while improving pre-service teachers' confidence in delivering the Australian Curriculum: Technologies. The benefit of close relationships between universities and schools provides the framework for collaborative learning opportunities for pre-service teachers and school students. University academics were facilitators in the process, managing the external grant application and wider community workshops as well as embedding the activities in the university curricula. The school teachers managed the internal delivery of the MakerSpace club and promotion of STEM activities in their schools. All worked collaboratively to provide two professional development workshops, supported by a grant from the Google CS4HS[1] program. Outcomes of this research demonstrate a student-centred approach to digital technology education. This model of collaboration between teacher educators and schools is replicable and has a positive impact on preparing pre-service teachers to be classroom ready.

Introduction

In Australia there has been a government-led strategy to improve the access and delivery of Science, Technology, Engineering, and Mathematics (STEM) in schools. The Chief Scientist (2013) produced a report outlining how this was in the national interest (Office of the Chief Scientist, 2013) for the country's future economic growth. The Australian Curriculum, Reporting and Assessment Authority (ACARA), the federal body that determines school curriculum, released a new curriculum in 2016 that required all teachers, regardless of discipline specialisation, from Foundation year to Year 10, to use digital technologies in their teaching (ACARA 2015). The reasoning provided for this is:

> *It ensures that all students benefit from learning about, and working with, traditional, contemporary and emerging technologies that shape the world in which we live. In creating solutions, as well as responding to the designed world, students will contribute to sustainable patterns of living for themselves and others* (ACARA, 2015).

[1] GOOGLE computer science for high school (CH4HS) is an annual funding program to improve the computer science (CS) educational ecosystem by providing funding for the continuation of CS teacher professional development worldwide (Google, 2015).

While this is a valuable and future-thinking strategy, the flow-on effect is for a greater impetus for all teachers, not just those teaching Digital Technology subjects, to be not only competent using digital technologies but to also be creative and confident in exploring and experimenting while doing so.

We present an example of how collaboration between teacher educators, pre-service teachers and school teachers resulted in curriculum initiatives and growth of student and teacher interest, creativity and confidence in STEM activities in secondary schools. Using a social constructivist approach of shared learning journeys and the pedagogy of computing outreach (author1), the benefit of close relationships between universities and schools is demonstrated. The approach provides a framework for collaborative learning for school students, teachers and pre-service teachers to work side by side to become learners in their own classroom. University academics were facilitators in the process, managed the external grant application, and established professional partnerships for teaching.

STEM club project

The project described in this paper was to support interest in Science, Technology, Engineering and Mathematics (STEM) through the delivery of Maker Space activities in a club context. There was also a commitment to deliver two teacher professional development workshops to share the model of collaboration and showcase school student and pre-service teacher creativity. There are declining numbers of students studying Digital Technology in secondary schools, a declining interest in the higher level mathematics classes and some branches of the sciences. The inter-disciplinary approach of a STEM Club was seen as an attractive way of promoting creativity through technologies, demonstrating student-led learning and exploration of mathematical and scientific phenomenon at the same time.

The specific aims of the project were to:

1. Promote creativity and experimentation through the STEM Club facilitated by pre-service teachers and school students.
2. Build upon existing relationships with secondary schools.
3. Promote pedagogies of student-led learning and peer mentoring.

There was also a degree of happenstance in the project. One of the schools involved had been gifted some new technologies and had reached out to one of the university researchers for suggestions on ways to implement them in the classroom. This led to a co-submission for a Google CS4HS[i] grant.

The metropolitan school involved (School A) is a P-12 school in the northern suburbs of Melbourne. It is a relatively new school, created in January 2010 through an amalgamation of several smaller schools, and has many unique features: one of which is the strong partnership with the university located nearby which allows collaborative practices to support pre-service teacher training (Lang, Neal, Karvouni, & Chandler, 2015).

School B is a large co-educational Year 7-10 school in a regional city in the same state. School B is also relatively new, established in 2009, and is adjacent to a regional campus of the same university. It also is a partner in many teacher education projects. In the following section we present a selection of literature that underpinned our passion in the development of the STEM club.

Literature underpinning practice

Gonzalez, Moll and Amanti (2005, ix) argued that learning does not simply take place 'between the ears', but is eminently a social process. Other researchers posit that play, questioning and imagination lie at the very heart of 'arc-of-life learning' (Thomas & Brown 2011, p. 19). With the availability of technology in the classroom, the traditional concept of the teacher as the expert and knowledge-provider is changing. These concepts underlie the pedagogy of the STEM club and have implications for both teacher and pre-service teacher professional development.

Livingston and Shiach (2010) argued that teacher educators have important responsibilities supporting and challenging the development of teachers for the future. She asserted that teachers need not only a strong foundation of initial teacher education but they also need to understand themselves as learners, ready to learn and adapt their practice throughout their careers, supported and challenged by a range of different opportunities. (Livingston & Shiach, 2010).

In setting up the two STEM clubs we were also strongly influenced by the 'Makers' Movement' (Libow & Stager, 2013) that was being promoted worldwide through computer science education forums and the Department of Education in the state where this project was being undertaken. The Makers' Movement is based on socio-cultural pedagogies of student-led learning and peer-to-peer mentoring in action. 'The maker movement represents a bright spot in a world that too often uses computers biased towards the least empowering aspects of formal education' (Martinez & Stager, 2013, p.19). Libow and Stager (2013) claimed that 'Tinkering is a powerful form of learning by doing, an ethos shared by the rapidly expanding maker community' (p.3) and that '… every classroom can become a makerspace where kids and teachers learn together through direct experience with an assortment of high- and low-tech materials' (p.3).

Learning is an emergent process and as Bruner (1996) stated, 'Knowing is a process, not a product' (p.72). Friere (1978) similarly observed that 'Knowledge emerges only through invention and reinvention' (p.58). The problem-posing approach favoured by Friere encourages students to question, be curious and to explore. Similarly, Bonwell and Eison (1991), after extensive literature reviews on active learning, concluded that it led to improvements in student attitudes, thinking and writing. Responding to the challenges of the 21st century, with its complex environmental, social and economic pressures, requires young people to be creative, innovative, enterprising and adaptable, with the motivation, confidence and skills to use critical and creative thinking purposefully (ACARA, 2014). In this vein we believed that the STEM Club would provide opportunities for students to solve problems that were challenging, enjoyable, fostered creativity and innovation, within collaborative learning environments through access to a range of technologies.

For the pre-service Masters of Teaching students, the STEM Clubs provided opportunities to practice their teaching skills with students from a range of year levels. It enabled them to make connections between discipline-based theory and the daily practices teachers are exposed to within the school environment. These authentic teaching practices were evidence of learning and its context, planning the teaching, supporting and guiding the students and providing opportunities for reflection of their own teaching and learning. As Johnson and Lynch (2004) stated, transformative curriculum provides opportunities to produce knowledge and new findings. William Glasser's choice theory (1998) reminds educators that before learning can take place, all students must feel they belong, have freedom to make choices, experience fun and enjoyment in their learning, and have a sense of control or power over their learning. The STEM Clubs provided for such learning.

STEM club setting

The STEM Club was a testing ground for pre-service teachers to develop and create interactive curricula. The STEM club ran for school two terms, during which the school students participated in hands-on activities using technology tools such as Makey Makey, Little Bits, Arduino (Galileo), Ozobots and Beebots, Make-do, and 3D Printing and Design as well as low-tech materials such as cardboard, tape, glue and aluminium foil.

Initially, the STEM clubs were held once a week at lunchtimes, allowing students forty-five minutes on their chosen activities. This was increased to twice a week in the second term. Students were presented with a weekly challenge by the teacher based on the tools available. The club started with the first challenges to explore what simple games could be created. Students worked in collaboration to build, design, and test their activities and models. These ranged from accessing block programming as well as using fruit and alfoil to create music. The activities strongly focused on student-led learning strategies in an active STEM learning environment that used direction, mathematical and scientific ideas to complement the delivery of the new AC: Technologies.

In each of the participating schools, Digital Technology teachers led the club and also served as supervisors for the pre-service teachers. The pre-service teachers guided and supported student engagement in the activities. The school students were encouraged to discuss their activities with the pre-service teachers on a weekly basis. The pre-service teachers were required to reflect on their experiences while in the school and make judgements on the level of school student involvement in the activities. The pre-service teachers were also required to design a unit of work using the concepts and materials used in the club that could be transferred to a classroom setting and was part of their final assessment.

Participants

The lunchtime club was frequented by a small number of mainly male students in each location. The numbers ranged from 6 to 10 students from Years 4 to 10. Participation was voluntary and stimulated by student interest in technology and personal commitment. There were five pre-service teachers involved, all completing the Digital Technology Method subject in their secondary teaching course (2 female and 3 male). They volunteered to support the STEM Club and completed an assessment task as part of their course requirements, and attended the club every week for two semesters.

Research design and method

The research was conducted within the qualitative paradigm of social constructivism and inquiry. All of the participants were collaborating to construct new knowledge. The format of the study and the club followed that of the pedagogy of an outreach model of academics, teachers and pre-service teachers collaborating to promote peer-to-peer learning and creativity in STEM classes (Lang, Craig, & Casey, 2017).

> *Teachers and preservice teachers can learn from each other, in the same manner that students learn from each other using creativity and experimentation in student-led classroom environments* (Lang et al., 2017, p.1499).

This pedagogy crosses discipline boundaries and was best suited to the integrated design and digital technology activities undertaken in the club. This approach encompasses five guidelines for outreach activities in computing that were deemed ideally applicable to the STEM Club. They were presented to the teachers and outreach organisers summarised below as:

- Aim to not be the expert.
- Allocate play time into the class schedule where students get to explore tools and applications by providing them with little more than a general introduction with access to further information.
- Encourage group work activities.
- Allocate time for peer demonstration of new knowledge.
- Facilitate student-led learning by encouraging expert students to work with their less experienced peers. (Lang et al., 2017, p.1497-8)

Ethics approval was gained from the University involved and was focused on gathering data related to the pre-service teachers' reflections and experiences, as well as post-workshop feedback from practising teachers. These were obtained from several sources, the first was from pre-service teachers' guided reflections submitted weekly, addressing the following prompts:

> *1) What process did you go through in this lesson?*
>
> *2) What problems did students encounter while they were working today? How were the problems solved?*
>
> *3) What resources did students use while working today? Which ones were especially helpful?*
>
> *4) How do you feel about the work completed in the club today? What parts of it do you particularly like? Dislike? Why?*
>
> *5) Did you and/or the students find anything particularly frustrating today?*
>
> *6) If you were the teacher, what comments would you make about the STEM club today?*
>
> *7) If someone else were looking at the club, what might they learn about how it operates?*
>
> *8) One thing I would like to improve upon about this week's club would be…*
>
> *9) What things do you think the students might want more help with?*

These reflections were supplemented with notes, audio and video recordings of the projects that students had created captured by the classroom teachers. School students were participants in the STEM Club, but not individually interviewed or identified.

It is important to note that all the activities of the STEM Club were managed by the school teacher who supervised the pre-service teachers. They were co-learners and volunteers, and the time spent in the STEM club was credited towards the professional experience hours required by their course. A research assistant, employed by the university, captured reflections and field-notes, which provided rich data on the experiences as well as the perceived learning outcomes associated with the club. The research assistant was perceived as neutral because she had no influence in any assessment task that the pre-service teachers were required to undertake.

At the end of the first semester, the five pre-service teachers participated in a focus group discussion to explore their views, beliefs, and experiences with STEM Club activities. The research assistant conducted this on university premises. Pre-service teachers discussed their perceptions of the type of activities offered to the students and they responded to the activities. The results are presented in detail in the next section. This allowed the researchers to reflect on how this partnership experience supported pre-service teacher education.

Additionally, as part of pre-service teachers' assessment requirements, they were required to develop two units of work that would satisfy the AC: Technologies, which they presented to practising teachers in the professional development workshop delivered at the end of the program. The day was a mix of hands-on activities as well as formal presentations with the purpose of building stronger links between pre-service teachers and practising teachers, while upskilling all for the AC: Technologies. Eight school students from School A and School B and the five Masters of Teaching pre-service teachers demonstrated the skills they had learned from the STEM Club to the visiting teachers in mini hands-on workshops. The skills were integrated with mathematical and scientific concepts (measuring slope, shadow, the heights and angles of eaves, for example). The five Masters of Teaching pre-service teachers also presented the units of work (curricula) they had created as part of their university course work assessment tasks that also satisfied the Victorian Curriculum requirements for Years 7-10 (samples of the unit of works are presented in Appendix A).

Data were also collected from the in-service teachers who attended the workshops. They were asked a series of questions to which they responded using a 5-point Likert scale from *Strongly Agree* to *Strongly Disagree*. Questions were related to the content of the workshop in general, if they had learned useful strategies, new topics, whether materials presented were pertinent and useful, and whether they intended using some of the activities demonstrated in their own classes. The final question asked if they had any ideas on how to build on this session for follow-up activities.

Data analysis

Data from the field notes and open-ended survey responses were analysed using digital tools (NVivo11). The focus group discussion was transcribed and uploaded to NVivo, as well as the reflective journal entries from the pre-service teachers. Initially, free nodes (open coding) were created under the headings of challenges, early experiences, perceived benefits, and ways of using technologies. Indicators were used to identify sources of the data (Table 1).

Table 1: Transcript indicators

Indicators	Meanings
FG	Focus Group
RJ	Reflective Journal
PST (1..2..3..4..5)	Pre-service teacher (The number assigned to each participant)

In the second process, the earlier nodes were examined for consistency and to determine if categories and sub-themes were needed. An example of a category and sub-themes (axial coding) is illustrated in Table 2.

Table 2: Example of axial coding

Main category	Sub-categories	Participants' conversations
Popularity of STEM club	Teachers' perspective	This was my first introduction into STEM clubs and how they operate and I was surprised by all the innovative and creative activities students were able to be involved in (RJ, PST 2)
	Student engagement	Students were engaged in creative construction with a range of technologies, inspired by and demonstrating the power of learning through tinkering. I felt proud of our students' confidence (RJ, PST 1))

The research team discussed these nodes and then agreed on the themes presented in the next section, acknowledging the limitation of an inherent bias of participants in the research. The students in the STEM Club were volunteers and gave up their lunchtimes to participate, indicating a pre-established tendency to engage with digital technologies. A positive bias also resided with the pre-service teachers who were training to be digital technology teachers when they graduated.

Findings

Several themes guided our data analysis, and are presented in this section broadly titled: (1) exposure to digital technology teaching and learning; and (2) popularity of the STEM club activities. These first two themes focus on the data provided by the pre-service teachers. The third part of this section is a reflective piece from the teacher who coordinated and ran the club in School A.

Theme 1: Exposure to digital technology teaching and learning
Recalling Glasser's choice theory (1998) as well as the other research theorists mentioned in the literature section, we believed that exposure to digital technology teaching and learning in a collaborative and creative environment could positively affect teachers and pre-service teachers' attitudes to using digital technology. Keeping in mind that our project aim was to facilitate confident, competent and creative teachers and students, the sub-themes we created were digital technology readiness and the digital technology curriculum.

Digital technology readiness
The data from the interviews revealed that four of the five pre-service teachers involved had not had wide exposure to digital technology teaching experience in the past. For example, despite having studied an Information Technology (IT) subject in secondary school, pre-service teacher 1 reported: 'My memories of IT … are that of an observer. The world of information technology was one that I dare not enter'. While pre-service teacher 5 was the only one who considered herself experienced in digital technology although she stated: 'I had … gained a breadth of significant corporate experience in the twenty years since my computer science degree, however, I was wary of today's students and the web-enabled technologies that they

have access to.' The research shows that a shift in learning-teaching boundaries requires teacher comfort and confidence as crucial individual characteristics contributing to successful digital technology implementation in the classroom. These responses suggest that that these pre-service teachers' approach to digital technology implementation does not have a one-to-one relationship with their prior experience, skills or education. All five pre-service teachers reported that they were positive towards implementing digital technology in the classroom. They had each volunteered for this project because they valued digital technology as a tool to improve and engage student learning for every subject in the curriculum. They all reported that participation in the STEM club contributed to increased confidence in their ability to use digital technology effectively in their teaching and complemented the theory aspect of their teaching degree.

Practice and theory continuum

Throughout their reflective journals the pre-service teachers recognised that the digital technology subject they were studying at university during this pilot contributed to a growing confidence around the position of digital technology in the curriculum. The subject included discussion about the nature of digital technology education and its place in the Australian Curriculum. The subject provided a social platform for the pre-service teachers to work in a collaborative manner. All pre-service teachers agreed that the university subject complemented the practical nature of the STEM club and allowed them to build confidence, broadened their knowledge related to teaching pedagogies as well as provided them with a wide selection of resources to use as a teacher. The following statements illustrate this point:

> *This ended up being a wonderful experience and I think I learnt a great deal and by the end of it I felt a lot more comfortable having IT as one of my methods. Enough to reconsider my idea of ignoring IT side, and that It could actually now be a very real possibility of having a job teaching IT.* (PST 3)
>
> *All doubts disappeared completely on the first day of the subject with Dr …. The discussion of requisite teacher qualities struck a particular cord with me at the intensive and my lingering reservations as to whether I would be "techie" enough to take on such a role were soon forgotten. Replaced with a tremendous excitement as to the path that I am now embarking upon, the classes have given me a resolve to be the type of teacher that inspires students to embrace ICT*. (PST 1)

Theme 2: Popularity of the STEM club activities

We found that the STEM Club activities were well received by pre-service teachers and students alike. The following sections provided perspectives from each of these two groups. This is provided to demonstrate that the creative hands-on activities that were challenging at times have had a positive effect on student engagement.

Pre-service teachers' perception

For all five pre-service teachers this was their first introduction into STEM clubs and their first experience in operating MakerSpace technology. Seeing the STEM club program in action helped them to position its importance in building digital technology confidence and interest in students. It also developed their own pedagogical content knowledge and understanding of the importance of digital technology integration in schools. The loss of time in setting up packing up materials for the lunchtime club was the main concern expressed by the pre-service teachers. Being constrained by scheduled lunchtime breaks challenged them, and there was limited time available to provide directions to students who were unsure or needed extra help to engage with the range of the technologies available.

PST 5 reported:

> *I had high expectations for what I hoped to implement in the club's launch year, … I loved the freedom and inventiveness displayed by students as they participated, particularly those that became regulars, and enjoyed facilitating students' engagement with making and linking with STEM ideas. I disliked the short 35-40 minute maximum duration, which always felt rushed, and didn't allow much time for reflection and sharing to conclude lessons, or coaching of students pursuing more advanced challenges and projects.*

Overall, the pre-service teachers reported that, in their opinion, the STEM club had been successful in providing a positive and prominent profile for STEM learning in a student-centric environment of risk-taking and innovation. They also noted that the open setting of the club in the library provided exposure to other students and teachers, provoking curiosity and inspiring new students to join in the activities.

Student engagement

The weekly reflections from the pre-service teachers revealed that the STEM club activities gained popularity among the students because they were not grade-oriented, thereby allowing them to feel more comfortable and enjoy what they were doing. They also reported that the opportunity for collaboration with students (at different year levels) on a specific task provided an opportunity for peer-to-peer learning and confidence building. They reported that the level of commitment from the school students increased as the term progressed, as did their sense of accomplishment in their tasks. The following PSTs' comments elaborate these points:

> *It is great to see students engaged with STEM activities. The enthusiasm is fantastic and shows the potential for more STEM activities to be integrated into the broader curriculum*. (PST 1)
>
> *Students were engaged in creative construction with a range of technologies, inspired by and demonstrating the power of learning through tinkering. I felt proud of our students' confidence*. (PST 5)
>
> *As students are in the program at their own desire, I see students that are motivated, driven and excited about the possibilities of a career in IT*. (PST 2)

While the pre-service teachers agreed that the STEM club provided a platform to motivate students to bring their ideas to the fore, the majority of the pre-service teachers felt that the constraints of time hampered its success. Operation of the STEM activities during lunchtime was challenging and difficult to implement consistently, due to staggered start times for lunch and the restriction of not allowing food in the library space.

The effect of the STEM club: The school's perspective

At the beginning of this project, School A was aiming to develop a learning environment that was student-centred and would provide an outlet for students to extend their technology and STEM skills. There was a desire for the space to be project-oriented and constructivist in approach, as well as catering for a broad range of interests and ages. There was also the intention of modelling a MakerSpace environment for teachers to observe and interact in - to create the classroom of the future. Partnering with the University for the Project, allowed us to access pre-service teachers with a high degree of technical expertise and ability to work with children.

In setting up the STEM CLub and pop-up MakerSpace, we had several preconceived understandings and beliefs about Maker programs. We believed that students are naturally curious, inclined to experiment and play in their learning, and were drawn to STEM activities. We believed that students would give up their lunchtime to participate in MakerSpace activities. We also believed that students would have projects or ideas they were interested in and would be happy to choose from a range of tools and activities to complete them.

As we launched and began to work in the STEM club across the year we went through a process of evolution and made changes to better meet the needs of students and the school. We moved the location from a classroom to the central library shared space to deliberately make the program visible and central. The activities and tools were reduced from a wide number of tools per session to a small number that were connected to challenges in each session. We also widely promoted the STEM club across the middle and senior school.

Overall, we found the project to be successful and were happy with the outcomes of the STEM club in the first year. We found that making the activities central in a shared space meant that teachers walking past would stop and engage with the student and activities. This allowed STEM and MakerSpace education to receive a higher profile in the school. Students showed a higher level of interest and engagement, and participating students began to bring a friend to join in. The pre-service teachers were able to develop programs and build their understanding of ways and options for delivering a student-centred STEM curriculum. Since the initial development of the STEM club, the school has extended implementation in the following ways:

- Development of STEM extension groups - a project-based learning class for students to work on extended projects across the year. Students enter projects in a number of externally run competitions, including ‘F1 in Schools’, ‘Young ICT Explorers’ and ‘Print-a-Car’.
- Extension of the STEM Club to an afterschool group to cater for extended project development
- Development of a dedicated MakerSpace environment in addition to a pop-up lunchtime MakerSpace

Discussion

In this case, the STEM club initiative has had a positive effect in creating more capable, confident and creative pre-service teachers. The university believes that it has satisfied the initial aims of the project by demonstrating a framework for collaborative learning in schools, allowing school students, teachers and pre-service teachers to work side by side as learners. The comments from the pre-service teachers and the units of work they created demonstrate that their interaction with the club enabled them to develop their STEM pedagogical knowledge and skills. The comments from the supervising school teachers indicate that this semester-length program has had a flow-on effect on the position of STEM in the school curriculum as well as in the wider community. Visibility has increased through students being engaged and motivated to participate in external national competitions, and by inference growing the profile digital technology across the curriculum.

The pedagogy of outreach model (Lang et al., 2017) was demonstrated in the development and delivery of this program. The combined input of university academics and professional organisations complemented the schools’ resources and the teachers’ knowledge and enthusiasm. The activities contributed to the pre-service teachers' assessment and immersed them in a student-led learning environment. Research into school-based clubs demonstrates that adopting the student-centred explorative pedagogical approach in the classroom is extremely beneficial to student engagement.

Conclusion

Collaborative projects that are curriculum-focused have wider implications for practice in initial teacher education at university and schools. The value of the project provides an insight into ways in which educators and students in schools and universities can work together in an immersive experimental STEM environment. We have provided a springboard for ongoing collaboration that incorporates professional experience and pedagogical practices. One lunchtime club has created curriculum change with a new project-based subject in the school, a stronger external profile in technology competitions and a second afterschool club. There may only have been a small number of pre-service teachers involved, but each of these five are now graduate teachers, able to have a positive impact on at least fifty school students a year. The school teachers who attended the workshop at the end of the program left with a copy of each of the units of work created by the pre-service teachers, enabling them to implement a similar club or at least some of the activities in their own schools and classrooms. These outcomes confirm that authentic collaborative activities between schools and universities to improve STEM pathways provide an ideal opportunity to increase student engagement in STEM curricula.

Limitations

We acknowledge that this is a small sample and the findings are non-generisable. We also acknowledge the positive bias of participant teachers and pre-service teachers in the project as well as the school students who gave up their lunchtime to participate in the STEM club.

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Appendix A: Making and creating summary of units of work

Student 2 sample

Title: La Trobe MakerSpace – what will you create?

AusVELS, Levels 7-10: Information and Communications Technology, Mathematics, Science, and more!

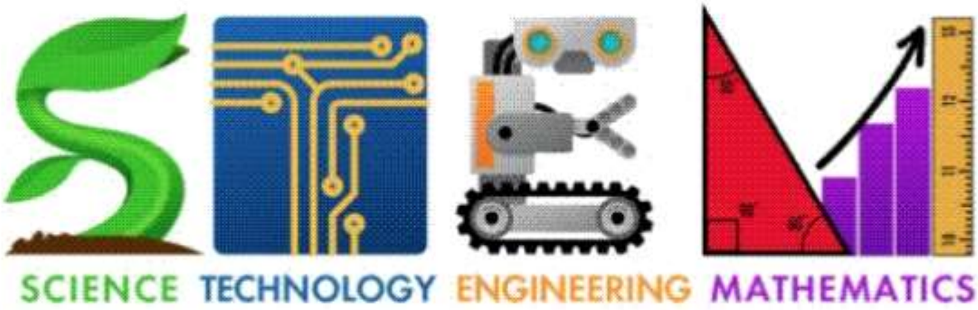

Image source: http://www.bigbend.edu/wp-content/uploads/academics/stem-center/STEM-logo.gif

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Contents

La Trobe MakerSpace – what will you create?

Unit Overview
Unit Title
La Trobe MakerSpace: what will you create?
Unit Summary
Students of the 21st century face challenges unlike those ever seen before. They will work in a global economy that is continually evolving, one in which "new technologies and smart companies lead" (STEM: AUSTRALIA'S FUTURE, 2014, p.5). The ability to embrace technology and rapidly acquire new skills will be paramount. This means rethinking how education is approached and finding fun and engaging ways to equip students with 21st century skills. STEM, an acronym for science, technology, engineering and mathematics, "refers collectively to a broad field of distinct and complementary approaches to knowledge". "A STEM education does not merely impart content knowledge in these fields – it seeks to provide frameworks in which new problems can be tackled" (STEM: AUSTRALIA'S FUTURE, 2014, p.34). This unit is designed to provide students with a STEM education using a lunchtime MakerSpace club; thereby providing a relaxed and collegial environment in which students can engage and explore different technologies. The essential question, "What will you create?" will be considered over the 10 weeks of a term, with two 50 minute lunchtime sessions each week. Aimed at students of varying levels from Year 7 to Year 10, the unit will use a flexible teaching program to provide students with opportunities to learn about various technologies using introductory videos and teacher demonstrations, as well as the opportunity to then experience those technologies using hands-on project worksheets or their own ideas. The unit will focus not only on the technologies themselves but also the methodology for successful project planning and design, as well as broader skills such as communication, independent learning, team work, and reflection. The unit will culminate with a Maker Faire (held in the last week of the term) so that students can showcase projects and share their experiences with the school community.
Curriculum Links
• Information and Communications Technology • Mathematics • Science • Interpersonal Development • Personal Learning • Thinking Processes
Year Level
Years 7-10, AusVELS Levels 7-10
Approximate Time Needed
20 x 50 minute lunch time sessions (2 sessions per week).
Unit Foundation
Standards/Syllabus Outcomes
ICT – Progressing towards Level 8 standards • Students select and apply ICT tools and editing functions that support the filtering, classifying, representing, describing and organising of concepts, issues and ideas. They use rule-using software to assist with problem solving and decision making. • Students retrieve and modify successful approaches to visualising thinking for use in new situations. They explain what features of the new situations influenced their decisions to use particular ICT tools and techniques. • Students use a range of data types, including sound and still and moving images, to record the decisions made and actions taken when developing new understanding and problem solving. They evaluate the strengths and weaknesses of their decisions and actions in the given situations.

- Students independently use the operating system to manage their desktop workspace. They organise their folders logically, appropriately name and locate files for sharing with others and apply techniques to facilitate the easy handling of large files.
- When creating information products, students prepare designs that identify the structure and layout of the products, the evaluation criteria, and the plans for managing collaborative projects. Students independently apply a range of processing skills, functions and equipment to solve problems and create products which contain minimal functional, typographical, formatting and readability errors. During the processing stage of collaborative work, students monitor project plans and record reasons for adjusting them. They apply criteria to evaluate the extent to which the information products meet user needs and comply with intellectual property laws. They use ICT in a safe, efficient and effective manner.
- Students keep their bank of digital evidence up-to-date, and ensure it is easy to navigate, complies with ICT presentation conventions and demonstrates a diversity of ICT skills and knowledge.
- Students select the most appropriate search engines to locate information on websites. They use complex search strategies to refine their searches. They judge the integrity of the located information based on its credibility, accuracy, reliability and comprehensiveness.
- Students share their ideas through their blog, website or other public forums, which are correctly formatted, comply with ICT conventions and demonstrate an awareness of the characteristics that contribute to products meeting their purpose.
- Students organise their email mailbox into a logical structure and maintain it. They evaluate the merits of contemporary communication tools, taking into account their security, ease of use, speed of communication and impact on individuals.

ICT – Progressing towards Level 10 standards

- Students use a range of ICT tools and data types to visualise their thinking strategies when solving problems and developing new understanding. They use visualising thinking tools and apply ICT techniques to support causal reasoning and to model and describe the dynamic relationship between variable and constant data values to test hypotheses.
- Students are efficient and effective in their use of appropriate ICT tools and editing techniques for assisting in visualising thinking. When solving problems, students discriminate between such tools and strategies based on their suitability for problem solving in new situations.
- Students appraise different strategies for organising and managing resources involved in problem solving and creating information products. They use ICT to devise detailed plans that sequence tasks to be done, resources needed, and timelines for completion. They annotate their plans to explain changes made during the project.
- Individually, and as team members, students apply a range of techniques, equipment and procedures that minimise the cost, effort and time of processing ICT solutions and maximise the accuracy, clarity and completeness of the information. They apply strategies that protect their files from being corrupted, stolen or accidentally lost. Their products demonstrate a clear sense of purpose and respect for the audience. Students apply processing practices that take into account their legal obligations and ethical considerations. They compare their own solutions with others and justify suggestions to improve quality.
- Students exchange ideas and considered opinions with others through online forums and websites. Students apply techniques to locate more precise information from websites, including searching general and specialised directories, and applying proximity operators.They use accepted protocols to communicate regularly online with peers, experts, and others, expressing their messages in language appropriate to the selected form of communication, and demonstrating respect for cultural differences.

Mathematics Year Level 7-10

- Identify and investigate issues involving numerical data collected from primary and secondary sources (ACMSP169)
- Explore the practicalities and implications of obtaining data through sampling using a variety of investigative processes (ACMSP206)
- Construct and compare a range of data displays including stem-and-leaf plots and dot plots(ACMSP170)
- Use the language of 'if ….then, 'given', 'of', 'knowing that' to investigate conditional statements and identify common mistakes in interpreting such language (ACMSP247)

Science Year Level 7-10

- Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)
- Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)

- Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166)
- Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate
- Use scientific knowledge and findings from investigations to evaluate claims (ACSIS132)
- Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS133)

Interpersonal Development – Progressing towards Level 8 standards

- Students demonstrate respect for the individuality of others and empathise with others in local, national and global contexts, acknowledging the diversity of individuals. They recognise and describe peer influence on their behaviour. Students select and use appropriate strategies to effectively manage individual conflict and assist others in resolution processes.

Interpersonal Development – Progressing towards Level 10 standards

- Students demonstrate awareness of complex social conventions, behaving appropriately when interacting with others. They describe how local and global values and beliefs determine their own and others' social relationships. They evaluate their own behaviour in relationships, identify potential conflict and employ strategies to avoid and/or resolve it.

Personal Learning – Progressing towards Level 8 standards

- Students monitor and describe their progress as learners, identifying their strengths and weaknesses and taking actions to address their weaknesses. They identify a variety of learning habits and adopt those which assist their learning. They identify, select and use an expanded repertoire of learning strategies appropriate to particular tasks. They seek and respond to feedback from peers, teachers and other adults and explain how their ideas have changed to develop and refine their content knowledge and understanding.

Personal Learning – Progressing towards Level 10 standards

- Students work independently to implement a range of strategies, as appropriate, to maximise their learning. They monitor and reflect on and discuss their progress as autonomous learners, identifying areas for improvement in their learning and implementing actions to address them. Students seek and respond to feedback from peers, teachers and other adults to develop and refine their content knowledge and understanding, identifying areas for further investigation. They evaluate the effectiveness of their learning strategies, study techniques and learning habits, and make appropriate modifications. They identify their interests, strengths and weaknesses and use these to determine future learning needs, especially in relation to the post-compulsory pathways.

Thinking Processes – Progressing towards Level 8 standards

- Students use a range of question types, and locate and select relevant information from varied sources when undertaking investigations. When identifying and synthesising relevant information, they use a range of appropriate strategies of reasoning and analysis to evaluate evidence and consider their own and others' points of view. They use a range of discipline-based methodologies. They complete activities focusing on problem solving and decision making which involve an increasing number of variables and solutions.

Thinking Processes – Progressing towards Level 10 standards

- Students discriminate in the way they use a variety of sources. They generate questions that explore perspectives. They process and synthesise complex information and complete activities focusing on problem solving and decision making which involve a wide range and complexity of variables and solutions. They employ appropriate methodologies for creating and verifying knowledge in different disciplines. They make informed decisions based on their analysis of various perspectives and, sometimes contradictory, information.

Curriculum-Framing Questions	
Essential Question	What will you create?
Unit Questions	• What is STEM? • Why is STEM important? • What are the steps for a successful project?

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Content Questions	**Level 1 – Where do I start? (Refer to Appendix H for the set of level 1 worksheets)** *(each student can select from the following project topics, or create their own in consultation with the teacher –time spent at level 1 will be based on student level and interest)* • littleBits – Making a Morse Code device • MaKey MaKey– Draw a musical keyboard • 3D printing – My first 3D print • Scratch programming– Making a Basic Game • Electronics and bread boarding –Lighting up an LED • Arduino– Blinking an LED • Sphero–My first MacroLab program • Intel Galileo–Blinking an LED • Programming with Microsoft Visual Studio – "Hello World" in 4 different languages • Raspberry Pi - Interacting with sensors • Lego MINDSTORMS–Build the TRACK3R • Digital art with processing.js–Introduction to drawing • Wearable tech–littleBits light up stomping shoes • Blender–Making a coffee cup **Level 2 – What's next?** *(each student can select from the following project topics, or create their own in consultation with the teacher –time spent at level 2 will be based on student level and interest)* • littleBits – Make a catapult • MaKey MaKey – Playing Tetris with your feet • 3D printing – My first 3D project using 123D Design (single component design) • Scratch programming – Make a platform game • Electronics and bread boarding –Measuring voltage • Arduino– LED cube • Sphero–Ocean Research • Intel Galileo - Building a Skill Tester using multiple LEDs • Programming with Microsoft Visual Studio – Programming logic & I/O • Raspberry Pi - Retro gaming console • Lego MINDSTORMS–Program the TRACK3R • Digital art with processing.js–Variables, Logic, Functions • Wearable tech –littleBits sound-activated bowtie • Blender- Creating an animation **Level 3 – Challenge me!** *(each student can select from the following project topics, or create their own in consultation with the teacher –time spent at level 3 will be based on student level and interest)* • littleBits – Analog Pong using the Arduino module • MaKey MaKey – Musical art using MaKey MaKeyand Scratch • 3D printing –3D project using 123D Design (multi-component design) • Scratch programming– Create a story using Scratch • Electronics and bread boarding –Switching • Arduino–Potted plant protector • Sphero –Sphero Hydro-Hypothesis STEM Challenge • Intel Galileo - Building a night light using a photocell and LED • Programming with Microsoft Visual Studio – Text-based hangman game • Raspberry Pi - Mini Raspberry Pi Handheld Notebook • Lego MINDSTORMS–Build & program the MindCub3r • Digital art with processing.js–Animation basics • Wearable tech–littleBits light-up party jacket • Blender–Making a planet explode **Level 4 – Maker Faire** • What is the best way to display and explain my project?

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Please contact corresponding author for the complete unit of work (Student 2 Sample).

Student 4 sample

Unit Overview
Unit Title
Coding with Makey Makey and Scratch
Unit Summary and Rationale
This unit is part of a lunchtime STEM club focusing on ICT and robotics. All students at the school are able to sign up for the program to participate in this inquiry based learning project. During this STEM club students will be introduced to the Makey Makey and Scratch and will be learning how to use and program both of these. Through STEM Clubs, students gain practical, teamwork and leadership skills, their confidence and engagement in STEM increases as well as their motivation to study STEM and enter STEM careers. This project aims to foster student's interest in robotics and coding and lead them to create their own innovative ideas with guidance from the teacher. **Makey Makey** Makey Makey an invention kit for the 21st century. Turn everyday objects into touchpads and combine them with the internet. It's a simple Invention Kit for Beginners and Experts doing art, engineering, and everything in-between. **Scratch:** With Scratch, you can program your own interactive stories, games, and animations — and share your creations with others in the online community. Scratch helps young people learn to think creatively, reason systematically, and work collaboratively — essential skills for life in the 21st century. Over 10 lunchtime sessions, students will learn the basics of robotics and coding in a fun and engaging way. Students are encouraged to try new things and create interesting programs. During these STEM club lessons, students will gradually improve their skills and complete projects that allow them to demonstrate their understanding of the program. Students will lead their own learning and challenge themselves. By the end of this unit, students will have developed the skills to create their own interactive game using both Makey Makey and Scratch.
Curriculum Links
ICT and Science Inquiry

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Year Level
The STEM club invites all students from year 7 to 10 to participate.
Approximate Time Needed
The program will run during lunchtime once a week for a total of 10 weeks. (Can be adapted to suit school)
Unit Foundation
Standards/Syllabus Outcomes
ICT, an interdisciplinary domain, focuses on providing students with the tools to transform their learning and to enrich their learning environment. The knowledge, skills and behaviors identified for this domain enable students to: • Develop new thinking and learning skills that produce creative and innovative insights • Develop more productive ways of working and solving problems individually and collaboratively • Create information products that demonstrate their understanding of concepts, issues, relationships and processes • Express themselves in contemporary and socially relevant ways • Communicate locally and globally to solve problems and to share knowledge • Understand the implications of the use of ICT and their social and ethical responsibilities as users of ICT. Learning in this domain enables students to focus on the task to be accomplished rather than on the technology they are using to do the work. Through the selection and application of appropriate equipment, techniques and procedures. These products effectively demonstrate their knowledge and understanding of the concepts, issues, relationships and processes that are the subject of the task. **Stages of Learning:** Students begin using ICT to create simple information products and to access learning tools. By applying ICT in a range of contexts, students develop knowledge, skills and behaviours for the effective use of ICT for learning in all domains. They become critical users of ICT for learning and communicating, and creating information products. They learn to use ICT tools to visualise their thinking and record their thinking strategies for use in future problem-solving activities. They progress to maintaining a digital record of evidence of their learning in all domains that enables them to reflect on learning how to learn. Electronic communication tools are introduced in students' first years at school and more complex, contemporary communication tools are gradually introduced until students become confident users of the technology for communicating with experts and participating in online forums as both contributors and beneficiaries of knowledge. (AusVELS, 2015)

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Lesson	Activities
1 **Introduction to Makey Makey**	-During this first session students will be introduced to the Makey Makey. Students will be learning through inquiry and experimenting with the two programs. - Lie out all of the pieces for the Makey Makey onto separate tables and ask the students, in groups, to work out what it does and what it is used for. - Students will be leading their learning in this lesson and figuring out through experimentation - Once students have figured out what the Makey Makey is used for explain to them how it works and the unlimited possibilities they have - Show the following video that will hopefully inspire students and get then engaged in creating projects: https://www.youtube.com/watch?v=rfQqh7iCcOU
2 **Using Sketch to program**	- This lesson is to teach the students how to use the Scratch program and how to connect it with the Makey Makey - Instructions for connecting Makey Makey to scratch can be found here: http://wiki.scratch.mit.edu/wiki/How_to_Connect_to_the_Physical_World - This lesson should be to make sure all students a good understanding of how Scratch works as it will be an important component for the STEM activities. - Provide all students with an instruction sheet so they all know how to use Scratch with Makey Makey **(Appendix 1).** - Once students have a good understanding of the program and how to use Makey Makey with it, students may experiment and trial different things.
3 **Controlling Games with Makey Makey**	- During this lesson, students will be experimenting with the Makey Makey using various different fruits and play dough to control an on screen game (Game can be chosen by teacher). - When the students touch a fruit, whatever button that fruit is assigned to will react in the game. - Get students to trial with other objects in the room to see what works and what doesn't • Why do some objects work and some don't? - Students will be working in groups at different tables trialing and learning through experimenting. - Teach the students how to assign the buttons in the game. - Tell students to start thinking about ways they would use the Makey Makey to create their own projects and experiments
4 **Creating Music with Makey**	- During this lesson, students will be looking at various ways music can be created through Makey Makey. Students can work through the following activities:

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Makey	- Creating a musical drawing - Creating a banana piano (http://makezine.com/projects/make-33/the-banana-interface/) -With the musical drawing activity, students draw a picture in grey lead that can be connected up to the Makey Makey. The students will connect the wires to the paper and assign a musical sound to that on the computer. -The Banana piano activity teaches students how to make the Makey Makey turn bananas into piano keys. Students will experiment with connecting it to the computer and making the sounds work. -Students will be using the program Scratch to make all this happen. -At the end the student's will play a song to demonstrate they have successfully connected the banana's to the Makey Makey
5 **Dance Revolution**	- During this lesson students will be making a controller pad to play the game Dance Dance Revolution. -The way that students decide to do this is completely up to them. - Make your own pads so you can play this dancing game with your feet instead of the arrow keys... or invent a totally new way to play. - Link here: http://www.flashflashrevolution.com/FFR_the_Game.php - Students work in teams to come up with an interactive and engaging way to play the game. - Ideas for this are endless, if students get stuck tell them to look online for possible ways to control the game
6 **3D Printed project**	-During this lesson, students will plan and create a 3D printable drum kit, that they can turn into a functioning drum set using the makey makey. - Students will first plan what their drums will look like and design them on the computer to get ready to 3D print. - Teach students how to use the CAD program to create shapes to be printed - The teacher will work with the students to help bring their plans to reality - Students will 3D Print their drum kits in the next lesson.
7 **3D Printing continued**	-During this lesson, students will be able to print their drum kits on the 3D printer. - Once the students have printed their drum kits out students start to connect them to the Makey Makey. • Students connect their drums to the makey makey and then program it on the computer so that when they hit the one of the drums it makes a sound. - (Depending on time, the teacher may need to start printing them before

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	the session). An example of this activity can be found here: https://alexsemmens.wordpress.com/
8 **Planning and coding a game**	- During this lesson, students will be looking deeper into the coding of games and will be planning and creating their own basic computer games. - Watch the following video to give students an idea of the kind of games they could be creating: https://www.youtube.com/watch?v=Un5c_LeC0Pw - Ask the students to continue researching in pairs for ideas on games - Play through some example games using the Makey Makey setup - Students plan their games they wish to create - Using the Scratch Planning Template **(Appendix 2)** - Students may begin the making process and coding of their game once they have submitted their plan to the teacher
9 **Coding and creating games**	- Students will have planned their game in the last lesson so during this lesson students will be coding and creating their games in the program scratch. (Refer to Scratch instructions) - Have a discussion with the students about how to code and model to the students how to create a game on the interactive whiteboard - Students view the following link on their computers that that outlines how to create a game in scratch: https://scratch.mit.edu/projects/10482/ - Students begin creating their games and have them functioning
10 **Playing games and recap**	- During this lesson students will be connecting their games up to the Makey Makey using whatever material they want to. - Students can be creative in connecting their Makey Makey and how to control their games - Encourage studnets to be creative with their Makey Makey controls by having innovative and creative ideas. - All groups set up their games and the groups rotate to get a chance to play everyone's games - Students may use the rest of their time, playing with the Makey Makey and creating their own projects
Assessment: Students will be assessed along the way by the teacher to ensure that all students understand each stage of their STEM learning. This is informal assessment, as students are not required to hand anything in to the teacher, as they are responsible for their own learning. Throughout the unit, the teacher will keep track of individual students and talk to them about their understandings. The game at the end of the unit will be used as a way for the teacher to assess	

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Please contact corresponding author for the complete unit of work (Student 4 Sample).