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Building STEM capabilities at Melbourne Polytechnic: a case study of EAL students

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Abstract:
STEM (Science, Technology, Engineering and Mathematics) is a vital skillset for all citizens in a rapidly changing and information-rich world. The connection between STEM and libraries is gathering momentum, yet the role of academic libraries in supporting STEM is under-represented in the literature. The Melbourne Polytechnic Academic Library & Education Research Team (ALERT) was developed to explore this gap and suggest a framework for STEM literacy support in academic libraries. The methodology for a future case study of STEM activity for EAL (English as an Additional Language) learners will also be outlined.

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Introduction

Libraries foster the skills needed to contribute meaningfully in an information-rich world. STEM (Science, Technology, Engineering and Mathematics) is increasingly seen as an important and critical skillset for all citizens to acquire, both for future success and for economic productivity (Commonwealth of Australia 2015, p. 1). Public libraries have been quick to support STEM, but for academic libraries, the role in supporting STEM remains unclear. The Victorian Government (2016) supports the development of these vital skills to "ensure our higher education and training sectors are creating a STEM-skilled workforce". This need for STEM literacy and the perceived gap in the literature led to the research question: how can dual-sector academic libraries, such as Melbourne Polytechnic (MP), build capacity to support STEM?

To investigate this question, the MP Academic Library & Education Research Team (ALERT) was formed. This paper details part of this project, where an action research approach has been adopted in order to investigate, develop, test, and improve potential avenues in developing MP Library's ability to support STEM. The paper will commence with a brief background of the project team, and then examine current STEM support in academic libraries, before suggesting a potential framework and methodology for future data collection.

ALERT @ MP

MP Library services cater to a diverse population. There are seven campus libraries supporting students in Vocational Education and Higher Education courses over a range of disciplines. Located principally in the northern suburbs of Melbourne, the students and staff have varied cultural and academic backgrounds.

The ALERT project team aims to develop the research capabilities of the library, and to encourage similar research in the wider TAFE sector. Four criteria determined the scope of the research:

(1) Be directly relevant to library professional practice
(2) Add value to the services provided to students and staff
(3) Have potential to feed into other projects
(4) Give the library opportunities to form new partnerships and collaborations

STEM was the focus as it satisfied all the above criteria. STEM is a burgeoning area in education, with increasing demand for libraries to engage in the cause. We also saw STEM as an area that could feed into many other projects, include the wider community, foster dynamic partnerships and open up new funding avenues. This focus also enabled MP Library to utilise the STEM expertise of a staff librarian with a background in science, engineering and education.

STEM & Libraries

STEM is an integrated interdisciplinary educational approach that "covers a wide range of disciplines and skills, which are increasingly in demand in our rapidly changing world" (Victorian Government 2018). The Australian Government (n.d.) also views STEM education as "critically important for our current and future productivity, as well as for informed personal decision making and effective community, national and global citizenship".

Through the provision of resources, services, and space, libraries encourage and support the development of knowledge, skills, and lifelong learning. This includes ongoing support and advocacy for skills across a variety of literacies. The Australian Library Information Association (ALIA) (n.d.) lists these as including "reading, writing, information literacy, STEM and digital literacy."

The Australian Government's (2015) National Science & Innovation Agenda combined STEM with digital literacy, a skillset that is firmly within the field of librarianship. Media outlets have also reported on this educational trend. In the Sydney Morning Herald, education academic Dr Linda Pfeiffer (2017) highlights a variety of skills that STEM cultivates:

> *STEM is important for future generations because future jobs will require problem solving skills, innovative and creative thinking and digital skills. Future generations need to learn how to think critically and flexibly in order to adapt to this rapidly changing world.*

Digital literacy, problem solving, creative thinking, critical thinking, are all within the librarians' toolkit. It is apparent that libraries have a critical role in supporting STEM.

STEM & Academic Libraries

Academic libraries support STEM in many ways, both directly and indirectly through resources, services, and space.

STEM Resources

Academic library resources reflect the courses delivered, many of which fall within STEM or have known STEM connections. For programs and courses not explicitly STEM-based, there is an opportunity for libraries to provide STEM-relevant resources. Just as librarians offer resources supporting course-specific digital literacy, STEM literacy could take on a similar importance and be reflected within institutional policies. One example of a special collection directly supporting STEM is Ohio State University's Archives of Women in Science and Engineering (Palumbo 2016, p.196). More research could be undertaken into special collections directly supporting STEM in Australian academic libraries. For instance, City of Sydney (2018) libraries offer a range of makerspace kits for users to borrow. Offering a similar service within academic libraries could potentially further support STEM, but there is limited research on this topic, and no literature that offers decisive guidance.

Makerspaces

Makerspaces are one area where academic libraries can support STEM. Makerspaces occupy a unique position, directly supporting STEM through resources and space, often leading to specialised STEM services. They are physical spaces, often informal, where users create and explore new projects, often involving a variety of technologies (Blackley et al. 2017, p.23). They encourage self-directed learning, knowledge sharing, and collaboration (Boyle et al. 2016, p.30). In public libraries, this has included emerging and interactive technologies such as 3D printers, laser cutters, virtual reality, robotics, and recording equipment. Many makerspaces have pushed the boundaries of what is considered STEM by including equipment such as sewing machines and craft supplies (see Curtin University 2019), to encourage more people to tinker and experiment. This is also consistent with the movement to incorporate arts and creativity into STEM, i.e. STEAM (Science, Technology, Engineering, *Arts* and Mathematics) (ALIA 2017, p.1). Another way libraries are expanding the makerspace concept is through temporary or mobile exhibitions or activities, usually through the label of a pop-up makerspace (Wong & Partridge 2016, p. 154). Flexibly defined makerspaces, placing the focus on engagement rather than particular types of equipment, are able to reflect the needs of individual libraries and their communities.

Makerspaces have increasingly become a feature of university libraries, but do not appear to have gained the traction they have in public libraries. In the New Media Consortium's (NMC) (Johnson, Adams Becker, Estrada & Freeman 2015, p.40) *Horizon Report*, the authors listed the time-to-adoption for makerspaces within higher education as two to three years. In Wong and Partridge's (2016, p.154) survey of Australian university makerspaces, 12 of the 43 universities surveyed had makerspaces but only two were located in the library. The slow adoption of makerspaces by academic libraries could be attributed to: (1) the focus on supporting coursework with a trend towards specialisation; and (2) the university already owning the equipment traditionally included in a makerspace, though perhaps not housed in the library. This is supported by Wong and Partridge's survey that shows most university makerspaces existing within a specific department. Providing access to these technologies and equipment to the entire student body may not currently be a priority for institutions and libraries, but it is a cause that libraries can champion. Curtin University (2015) is one institution doing exemplary work in this field and is extending access to STEM resources and skills to their entire student body and to the wider community. For example, Curtin University's (2015) *Light Makers @ the Library* event, as part of National Science Week, attracted over 300 participants with over two-thirds from the wider community.

STEM Services

Makerspaces have enabled libraries to develop services that directly support STEM. Public libraries have been progressive in STEM services, as evidenced in ALIA's 2017 report, *The STEM Agenda.* Public libraries, however, have a much broader raison d'être and do not need to be aligned to curriculum. The limited research or documentation of academic library makerspaces makes it difficult to surmise what the most appropriate STEM-related services might be (Wong & Partridge 2016, p. 144). The literature is even more sparse for TAFE libraries. Based on the available literature, two trends seem to emerge: (1) STEM support is focused more on outreach; (2) academic libraries may be delivering services that are STEM-related but are not labelled as such.

(1) STEM support as outreach

For academic institutions, STEM-specific support appears to have taken the role of outreach, as evidenced through the Victorian Government's (2019) *Connecting Victoria's STEM Ecosystem* map. What academic libraries are doing, or can do, to support STEM for their users is unclear. Makerspaces are slowly being adopted as one way to engage students with STEM, in an informal, extra-curricular setting. Course specific or curriculum-based STEM support by academic libraries has not been explored in depth in the literature and is an area of research that requires further investigation. An exception is Barry's 2015 *ALIA Information Online Conference* paper, which states that the Curtin University makerspace allows for activities that are directly relevant to course curriculum, primarily through community engagement and citizen science opportunities. This is an area for academic libraries to explore further.

(2) STEM as a label for existing library services

Academic libraries offer many services that are relevant to STEM. These include the extensive support librarians' offer in digital literacy, critical thinking, and information literacy, both in terms of general skills development and within the context of coursework. It is possible that some current academic library services could be identified as STEM.

To explore this idea, the way in which different institutions created services was compared around Jupyter Notebooks, an "open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text" (Project Jupyter 2019). The table below lists a selection of special events or content open to all students and staff. These events were listed online as of August 2019. Specific courses in Python or programming are not included.

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EVENT			
Institute	**Event name**	**Location**	**Link**
Curtin University	Introduction to Jupyter Notebooks Date: 19 August 2019	Makerspace	https://makerspace.library.curtin.edu.au/event/introduction-to-jupyter-notebooks/?instance_id=3598
University of Melbourne	GLAM workbench: Possibilities of collection data for research, experimentation, and collaboration Date: 15 August 2019	The Lab, Digital Studio	https://arts.unimelb.edu.au/research/digital-studio/events/archive-events/glam-workbench
UNSW	Data Manipulation and Visualisation in Python Date: 16 August 2019	Computer Lab	https://research.unsw.edu.au/events/data-manipulation-and-visualisation-python-0
CONTENT			
Institute	**Content Title**	**Location**	**Link**
University of Sydney	Data Analysis and Visualisation: Analysis Tools Date: Last Updated: Jul 15, 2019	Libguide/Library website	https://libguides.library.usyd.edu.au/c.php?g=508301&p=3477510
Deakin University	Setting up Apache (Py)Spark with Jupyter Notebook in Arch Linux Date: 14 September 2016	Blog post/General website	https://a2i2.deakin.edu.au/2016/09/14/setting-up-apache-py-spark-with-jupyter-notebook-in-arch-linux/
Monash University	Python4Maths Date: Last updated 2019	Publicly available/Creative Commons tutorial through *Monash eResearch Centre version of GitLab*	https://gitlab.erc.monash.edu.au/andrease/Python4Maths
UNSW	Jupyter notebooks Date: n.d.	Research Infrastructure guide	https://research.unsw.edu.au/jupyter-notebooks

Table 1. Comparison of services on Jupyter Notebooks by universities. List compiled August 2019.

The Curtin University event is the only instance where a direct relationship has been created between STEM and the library, because the makerspace hosted the event. The University of Melbourne also made a direct link with the library, although has not labelled it as a STEM event. The UNSW event and the majority of university content mentioning Jupyter Notebooks have been communicated by separate research departments or units. It appears for academic institutions that this kind of activity is tied either to specific departments or to research units, rather than the library. Why this is the case, and whether this is indicative of the potential for other STEM activities, is beyond the scope of this project.

Building a framework of STEM support in academic libraries

As an academic library serving both vocational and higher education, STEM literacy at MP Library needs to be adapted from current academic and public library practice. STEM literacy in VET libraries is yet to be represented in the literature. In the case of VET libraries, examples of similar STEM activities were non-existent.

Based on the *NMC Horizon Report* (Johnson, Adams Becker, Estrada & Freeman 2015), an examination of the literature, and an informal survey of Victorian libraries, it appeared that libraries engaging in STEM tended to have makerspaces. To establish a makerspace at MP Library, ALERT applied for the internal *Research & Scholarship Seeding Grant* and the application was successful.

An investigation into the types of resources included in makerspaces was performed whereupon the Wong and Partridge (2016) survey was a useful resource in comparing what other libraries have included. The most common items included 3D printers, laser cutters, electronics, and robotics. Upon further reflection and discussion, the idea of purchasing such items as resources was abandoned for the following reasons:

(1) Ongoing resourcing costs
(2) Staff expertise required to run and maintain specialised equipment
(3) Level of student knowledge required to engage with these tools
(4) Not inclusive, if located in only one of seven campuses
(5) Not the most collaborative for projects of limited scope

ALERT realised the need to redefine the purpose and types of activity that would be feasible, sustainable, and of most value to MP students. Building the capacity of MP students and staff and fostering relationships with departments were the main priorities. This is consistent with two of the major themes from successful makerspaces in US academic libraries: develop the space around need and have a vision and purpose for the space (Benjes-Small et al. 2017, p. 432).

The ultimate goal for the MP makerspace is to increase STEM awareness and engagement, with a view to empowering students and staff. To maximise engagement in a multi-campus setting, the makerspace should not be restricted to a particular space, just as information literacy is not restricted to being in the library. The resources then become a tool for delivering services at all campuses, a concept consistent with the concept of pop-up makerspaces.

Accordingly, the matrix below was created to map the range of STEM support services offered against the breadth of information and digital literacy services provided:

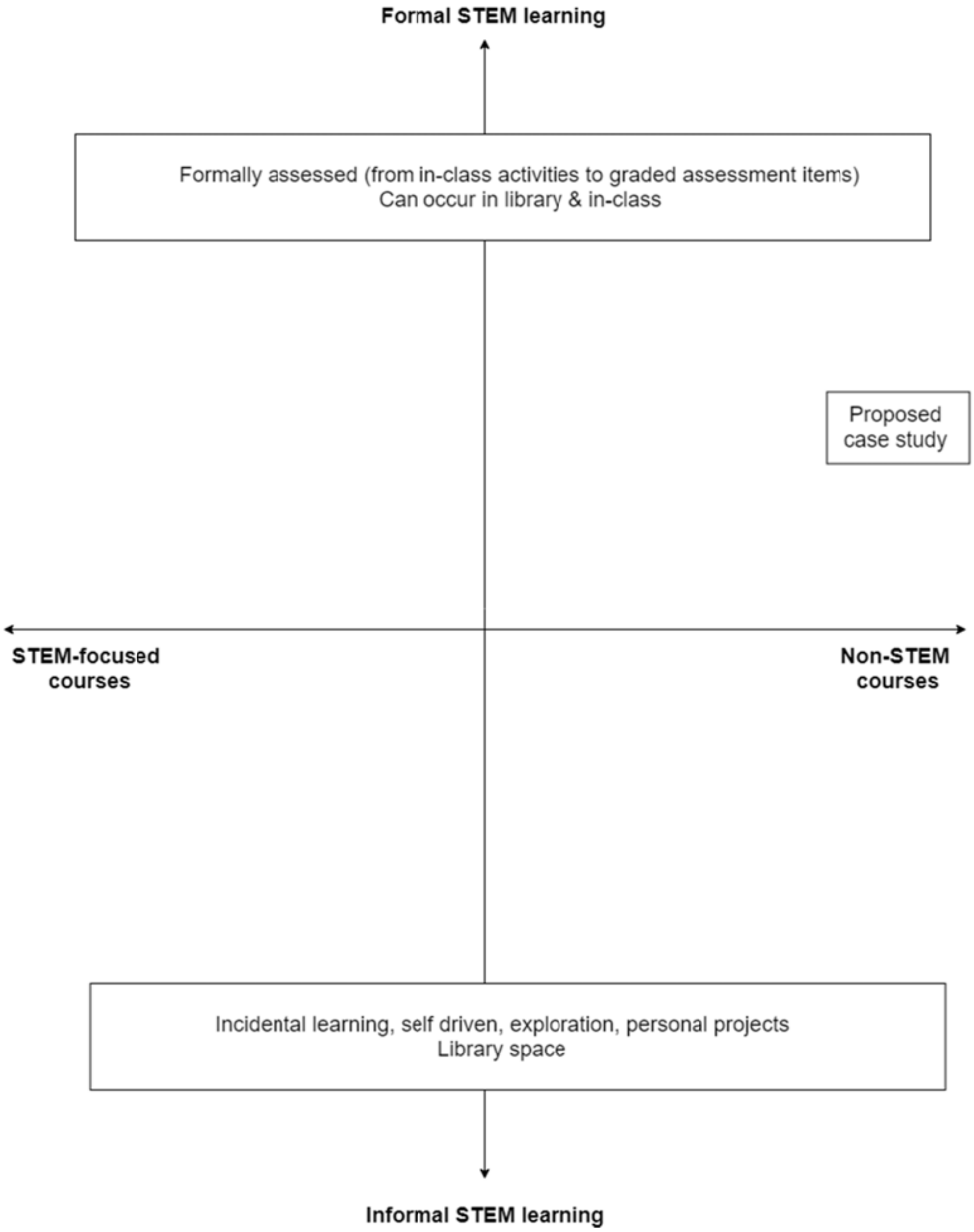

Figure 1 STEM literacy for academic libraries matrix

The matrix encompasses STEM activities: across all vocational and higher education courses (represented by the x-axis) and the range of learning approaches, from the informal to the formal (y-axis). Working in all these areas is desirable to facilitate STEM in a holistic way.

Libraries of all types provide suitable spaces for informal education. Public libraries, however, have been more active in this space. Informal education is not assessed, part of formal accredited course, or tied to a specific curriculum. STEM learning thrives in this informal, participatory and collaborative learning space. Bransford

(2007, p.2) argues that students who study in informal settings may find greater opportunities to be innovative, thereby discovering their vocational calling.

In addition, facilitating activities that connect STEM to curriculum would build deeper connections and engagement, a unique opportunity for academic libraries. This is also consistent with Wong and Partridge's (2016, p. 156) survey of Australian university makerspaces, which found that individual makerspaces covered a range of activities, including coursework, research and personal projects.

In connecting STEM activities to curriculum, academic librarians need to rely on their relationships with teachers and lecturers and to build these partnerships. In Benjes-Small et al.'s (2017, p. 434) article, they attributed faculty partnerships as being one of the primary success factors of makerspaces in academic libraries. Additionally, they indicated that "the level of faculty participation ran the gamut" of what the makerspace could offer (Benjes-Small et al. 2017, p. 434). It is essential that librarians (particularly liaison, academic, faculty librarians) discover and create new ways to connect STEM to coursework and assessment tasks, as well as create buy-in opportunities for faculty staff. The relationships librarians build with faculty can also help to cross discipline boundaries and increase communication between offices and departments (Palumbo 2016, p. 198).

Case study: STEM & EAL Learners

In order to develop the library's capability in developing curriculum-based STEM activities, a targeted activity to collect data on attitudes to STEM was needed. The resources required for this activity will start the MP STEM collection; the pool of resources owned by the library to create pop-up makerspaces and other STEM activities.

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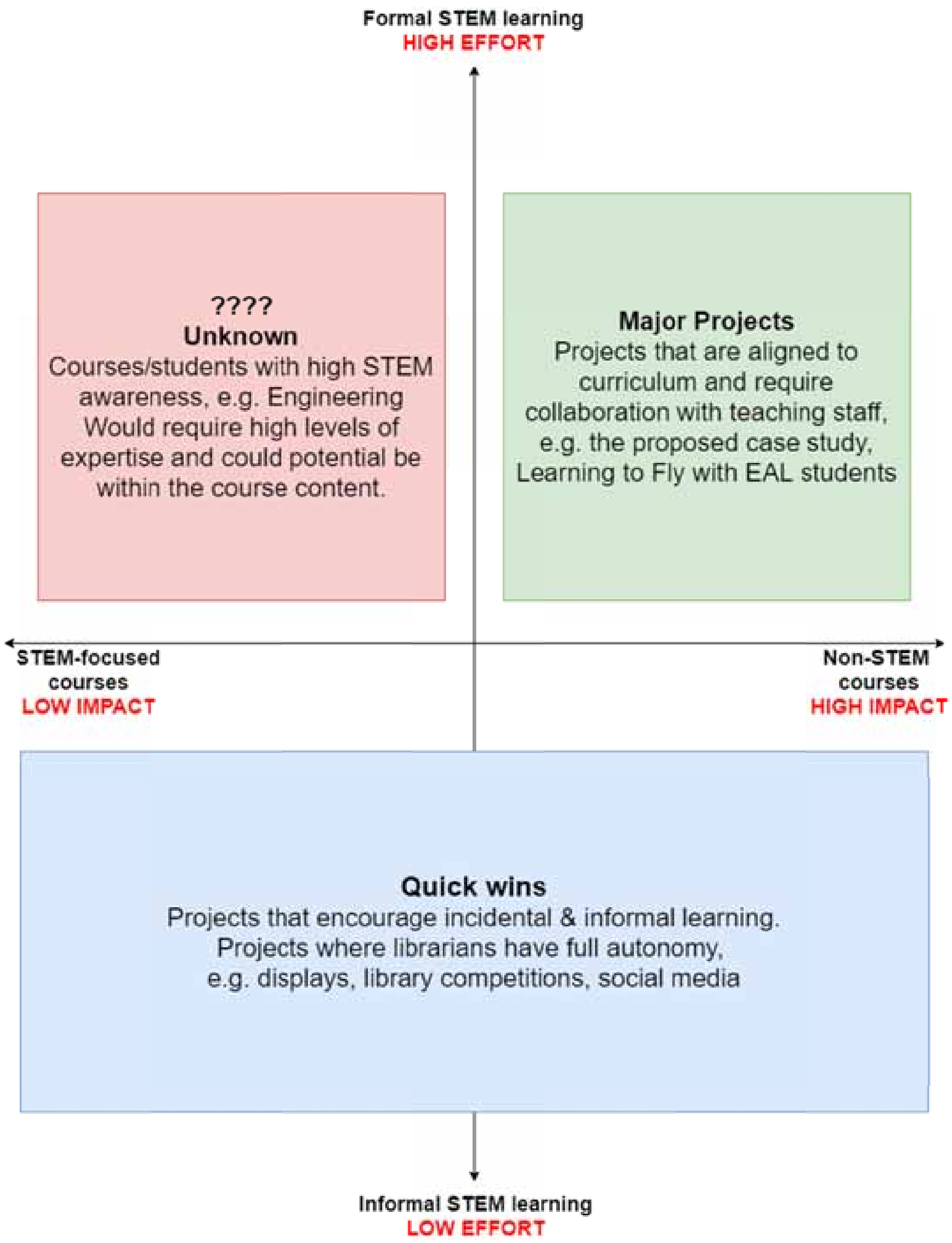

Figure 2 STEM literacy prioritisation matrix

Participants

ALERT mapped Figure 1 to an adapted effort-impact matrix to create the *STEM literacy prioritisation matrix* (Figure 2). This was used to identify where a STEM project could have most impact in an academic library context. It appeared logical to focus on a course that is not traditionally connected to STEM, as this is an area of high impact. The matrix also illustrated that low-effort/high-impact projects, or ‘quick wins’, are within the informal learning space, an area where public libraries thrive. A high-effort/high-impact project was chosen, as connecting STEM to formal learning is a unique area for academic libraries and is a gap in the literature. A focus on a VET-level course was elected, as the literature for library STEM literacy or makerspaces is very sparse.

Since English as Additional Language (EAL) students represent a significant proportion both of the student body and of the library’s active clientele, the focus was on them in developing an activity. Students will be selected for the research project through their EAL teachers, primarily through email invitation. STEM activities will be completed during class time and the level of involvement will be open for the student to decide.

Another reason this cohort of students was chosen is that it intersects with social inclusion and empowerment. A recent report from the United States by the National Academies of Sciences, Engineering, and Medicine (2018) illustrates that English learners are under-represented in STEM, both at the college level and in the workforce. The report also identifies EAL learners as assets who bring with them diverse cultural knowledge along with multi-competence to a STEM classroom. Their emergent bilingual development can be enhanced and broadened via an engaging and meaningful STEM activity. In Australia, there is some indication that access and participation in STEM is not equal amongst all students. Under-represented groups include girls and women, and those of low socio-economic background (Marginson et al. 2013, p.27).

This project may contribute towards other research areas, though potentially outside the scope of this project. For instance, the effectiveness of using STEM activities as a tool for teaching English is an area open for further research and exploration.

Activity

The chosen STEM activity is entitled Learning To Fly (LTF). Designed at the University of Melbourne, LTF is an experiential learning lesson created for EAL students to explore aerodynamics. Initially, students construct their first paper aeroplane from scratch without any guidance. They launch the paper aeroplane. They reflect upon which paper aeroplane travelled the longest distance. Students are given the opportunity to discuss, collaborate and communicate about their paper aeroplanes, thus developing “more expansive ways of speaking, listening, and interpreting the discourse of science” (Lederman & Abell 2014, p.323).

The second phase enables students to use their experience with their first paper aeroplane to design and launch a second paper aeroplane. They reflect upon the distance it travelled and compare paper aeroplane two with paper aeroplane one.

Students improve upon their first paper aeroplane. A class discussion will involve comparing the aeroplanes that travelled the longest distances and the paper aeroplanes that travelled the shortest distances.

In the third phase, students are given templates (thus a prototype to investigate), in order to construct a third paper aeroplane and launch it. Then they reflect upon how this paper aeroplane differs from their first and second prototypes. Students experience the iterative design process that engineers use to solve real-world problems, and thus students are not only immersed in scientific methodology but are also given the opportunity to become novice scientists and engineers.

This activity has been modelled on a Royal Academy of Engineering STEM resource, “Aircraft Design” (Royal Academy of Engineering 2018). A member of ALERT specialising in science and mathematics education used their knowledge and skills to evaluate and redesign the Royal Academy of Engineering’s resource to cater for Melbourne Polytechnic students and EAL learners in particular. The program features an approach to STEM learning in which interactions between learners and the real world enable “intellectual restructuring and transformation” as adult learners are empowered to transform and develop their individuality and STEM identity (Harrell 2010, pp.146-147).

The benefits of having a science educator redesign this program means that it is highly adaptable to the learning needs of the dual-sector education provider’s students. LTF activities can be differently paced and timed, and in this case, the library has chosen a one-hour session to deliver the LTF activity. This flexibility also allows for a variety of technologies to be incorporated for students to enhance the flight characteristics of their aeroplanes. For example, Arduinos (electronic technology) can be used to create sensors to monitor the flightpath or microscopes to examine the effects of micro-structure on aerodynamics. LTF has been designed using a blended and interdisciplinary approach allowing the STEM elements to remain identifiable (Lederman & Abell, 2014, p.399). Furthermore, the LTF lesson design has the potential to be mapped back to vocational education training packages (refer to Figure 2).

Data collection

To measure the impact of the STEM activity by understanding the attitudes of students before and after they complete the activity, data will be collected through surveys, which require human research ethics approval. The survey will be carefully constructed to ensure meaningful data is collected while making it accessible and easily understood by EAL students. The team’s interactions with students as they complete the survey will need to be investigated to ensure the results are not affected. Observations from the research team may also be included.

Conclusion

STEM encompasses a mindset and skillset universally recognised as vital for all citizens to participate meaningfully in the workforce and society in general. Libraries are uniquely positioned to support this need.

We explored the literature on makerspaces and STEM literacy and examined how this manifests in academic libraries. Three major themes in developing STEM literacy geared towards academic libraries emerged:

(1) Develop a diverse range of STEM activities

Public libraries have been early supporters in STEM development, but academic libraries should offer different support to reach the unique and diverse needs of their users. This includes incidental and informal learning opportunities as well as formal STEM learning opportunities linked to curriculum.

(2) Foster relationships & connections

STEM capacity should be built by developing relationships with faculty staff. As there is likely to be specialist STEM equipment and knowledge within an academic institution, start the STEM conversation to see what collaborations could be viable. The ALERT case study is only possible because of the specialist knowledge and relationships that already exist at MP.

(3) Apply for funding

It can be difficult to establish new ventures within limited budgets. Funding can give libraries freedom to try new ideas and establish new connections. The MP internal grant allowed the team to apply their diverse skills and also to develop their professional capacity.

The concepts and ideas discussed in this paper invite further research, especially on how libraries can provide STEM literacy to formal courses that are already STEM-focused, as this may prove a particularly difficult area to penetrate without specialist knowledge. How academic libraries can add value or have impact in this area remains ambiguous (see Figure 2). Negotiating the boundaries of course content and STEM literacy may be part of the reason academic libraries have been slower to adopt makerspaces and address STEM literacy. Through partnerships with faculty, academic librarians can provide a unique perspective on STEM while situating it within the existing range of literacies. This will ensure that students develop the critical skills necessary to function as active, informed and STEM-inspired citizens.

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