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Makerspaces: Building Confidence in STEM for Primary Preservice Teachers

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Abstract
'Design and Technology' has been propelled into the spotlight with the popularity of the idea of 'STEM'. So much so that it is now common for primary schools to have 'STEM classrooms' or makerspaces. Whilst there has been an increasing exploration of the use of makerspaces, there has been limited research on the impacts, particularly with pre-service teachers (PST), who are known to lack confidence in STEM-related subjects. Therefore, in this research, we explore how different aspects of makerspaces may influence PST confidence. Participating PST worked in small groups in the Uni Makerspace to design a product as part of a formal university assessment in a primary education Science subject. The case study design includes four groups of PST and data from interviews, observations and artefacts. Results outline confidence development amongst PST with several key Makerspace influences identified, including the importance of learning to use sophisticated equipment and the key role played by the Makerspace facilitators. Implications for Makerspaces and STEM education are discussed, including the potential to leverage the 'novelty effect' of Makerspaces, and the need to offer extensive support, particularly in the early stages of engagement.

Keywords STEM · Primary preservice teachers · Makerspaces

Introduction

Makerspaces have flourished in education, promising to enrich students with integrated knowledge in science and technologies and to help develop twenty-first century skills such as creativity and collaboration. Amongst science educators and science education researchers, makerspaces enable a range of pedagogies such as inquiry-based learning, problem or project-based learning and STEM pedagogy. This paper is part of a program

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of research aiming to explore how pre-service teachers' (PST) knowledge and confidence developed when working in a makerspace. In this paper, we focus on PST confidence.

Confidence is important for PST because increased confidence is associated with a range of positive outcomes, such as student engagement, aspiration and achievement, as well as teacher efficacy and wellbeing (Caprara et al., 2006; Harlen & Holroyd, 1997; Jones et al., 2019; Kelley et al., 2020; Nadelson et al., 2012). Traditionally, pre-service and in-service teachers at the primary level (K-6) exhibit lower confidence and more negative attitudes towards STEM compared to other key learning areas (Buss, 2010; Education Council, 2015; Kurup et al., 2019; Trygstad, 2012). A recent study, for instance, found that only 30% of Australian primary school teachers felt confident to teach engineering skills and processes (Department of Industry Science & Resources, 2022). Importantly, however, primary school is often the time where student interest in STEM is either focused or stifled (Ainley et al., 2008). At a time of increasing demand for STEM-literate citizens, improving teacher confidence in STEM could be an important step in helping to lift declining levels of student interest and participation (Kennedy et al., 2014; Thomson et al., 2019, 2020). Whilst some research demonstrates potential benefits for both pre-service and in-service teachers engaging with makerspaces (e.g., Blackley et al., 2017; Falloon et al., 2020a), we aim to explore potential links between experiences in a makerspace and PST confidence.

Makerspaces

Makerspaces are generic spaces that allow open exploration and creative use of tools and technology, whilst also allowing participants to engage in knowledge sharing and collaboration (Vuorikari et al., 2019). Makerspaces are associated with the 'maker movement' or the activity of 'making' which encompasses, but goes beyond Design and Technology or STEM learning (Brahms & Crowley, 2016). Described as an activity characterized by 'high ceilings, low floors, and wide walls' (Bevan, 2017, p. 76), making has been associated with increased accessibility due to the open-ended nature of the project-based work and appears free from stereotypes commonly associated with engineering practices and identities (Bevan, 2017). Makerspaces can appear and operate differently according to the intended purpose and who created the space; nevertheless, they do exhibit some core features. Mersand (2020), for example, classifies these features into six categories: participants, tools, objectives, division of labour, community and rules, whilst Vuorikari et al. (2019) identify tools, people and the maker mindset as common features. An interesting commonality is that 'learning' in makerspaces is deeply embedded in the making experience: "These spaces value the process involved in making—in tinkering, in figuring things out, in playing with materials and tools" (Sheridan et al., 2014, p. 528). Makerspaces began to flourish in Australian schools after the 2015 National STEM School Education Strategy was implemented (Education Council, 2015), reflecting a broader and earlier wave across the globe (Sharma, 2021). In the educational context, makerspaces are strongly linked to STEM instruction (Sheridan et al., 2014) and, more generally, encourage the development of 'incidental' competencies such as entrepreneurship, teamwork and problem solving (e.g., Becker & Jacobsen, 2019).

As research on makerspaces has advanced, more detail about impacts on everything from intentional content learning to participant perceptions has been revealed (e.g., Bevan, 2017; Blackley et al., 2018; Hsu et al., 2017). Whilst the research on educators and PST is less substantial (Cohen, 2017), there are also some reports on positive outcomes. Cohen et al. (2017), for example, reported enhanced teacher knowledge of maker pedagogies and improved confidence. In a similar study, primary teachers improved their understanding and implementation of maker pedagogies and felt more confident to use inquiry-based pedagogies and student-centred practices in their day-to-day classroom teaching following makerspace professional learning (PL) (Stevenson et al., 2019). Blackley et al. (2017), one of the few studies that focused specifically on PST, reported that participants felt that working in the makerspace offered them opportunities to learn and teach in ways that were otherwise unavailable during initial teacher education. Discussion of the 'community' aspect illustrated the PST' feelings of belonging as they engaged with peers, the students they were teaching and the corresponding online community through a virtual makerspace. However, as research notes, makerspaces and the maker movement are relatively new ideas, and there remains limited empirical evidence supporting maker-based educational practices. Furthermore, the field is characterized only by its heterogeneity; there are no agreed upon definitions, activities, designs or overall approaches to incorporating makerspaces in education, with several calls for additional research (e.g. Blackley et al., 2017; Falloon et al., 2020a, b; Mersand, 2020; Stevenson et al., 2019).

STEM

STEM is mentioned extensively in makerspace research. Rising in prevalence in the 1990s (Blackley & Howell, 2015), 'STEM' represents Science, Technology, Engineering and Mathematics, though is interpreted in various ways in different contexts. STEM can refer to a set of subjects, a distinct pedagogy or even a unique teaching philosophy, which possibly explains why it is often misunderstood and/or misinterpreted (Bagiati & Evangelou, 2015; Kelley & Knowles, 2016). In education contexts, STEM often refers to a curriculum or individual learning activity which is problem- or project-based and intended to develop skills for designing and making a product. This can also involve elements of the scientific method (Falloon et al., 2020a, b).

In the current paper, STEM refers to PST knowledge and skills of 'Technology' (or 'Technologies'). Technology, as it refers to the subject of Design and Technology, is also poorly defined and may variously refer to Information Technologies; Design or Technology within different contexts (such as woodwork or textiles); Design; or even STEM (Gibson, 2008). In our context, Technology refers to the knowledge and skills represented in the 'Technology' and 'Design and Production' sections of the Science and Technology NSW syllabus, respectively (NESA, 2017). Technology-coded knowledge includes, for example, knowledge about how agricultural processes work or how to build circuits or write algorithms. The Design and Production skills include identifying and defining; researching and planning; producing and implementing; and testing and evaluating. The Technology knowledge and skills co-exist with science and are taught in the context of science in an integrated K-6 curriculum in NSW; thus, teacher education programs must address the necessary content and skills in Technology *embedded* in various science contexts (Tytler, 2007). STEM is also used in this paper to refer to the product the students were tasked to make (a 'STEM kit').

Confidence

Confidence, as with many other psychological constructs, is famously difficult to define (e.g., Lee, 2009). In a broad sense, confidence refers to a "perceived capability to deal effectively with various situations" (Shrauger & Schohn, 1995, p. 256). Confidence is often described as a 'non-cognitive' skill in psychological studies and accounts for the largest variance in educational achievement (compared to other non-cognitive constructs) (Stankov et al., 2015). Confidence is related to a range of other factors such as self-construct or self-efficacy (Bandura, 1993, 1997), though such constructs tend to exhibit high correlations (Lee, 2009; Stankov et al., 2015). In general, 'confidence' typically describes a broad characteristic, whilst 'self-efficacy' tends to describe confidence more particularly as a skill (Stankov et al., 2015). For STEM pre-service teachers, there are two relevant contexts for confidence: the STEM 'knowledge' context and the 'teaching' context (Sadler, 2013). As noted earlier, primary PST need knowledge of STEM content for teaching key areas of the Science and Technology syllabus (NESA, 2017). 'Teaching self-efficacy' refers to teachers' perceived ability on how well they can support student learning and engagement (Tschannen-Moran & Hoy, 2001) and is often measured according to specific discipline-based teaching self-efficacy (e.g., Bleicher, 2004). Thus, PST confidence in STEM may be consequential for their perceived self-efficacy and confidence to teach STEM.

Further research has sought to identify the factors that influence teacher confidence. According to Ramey-Gassert et al. (1996), the most common and influential factors are: previous experience, attitudes and anxieties, teacher preparation and professional development. Palmer et al. (2015) added teacher enthusiasm and subject interest as important for influencing and supporting teachers to develop confidence. Finally, and pointing to the complexity of the construct of confidence, Hahl and Mikulec (2018) found that strong professional identity is inextricably linked to a teacher's confidence and, as such, is a key influence on professional identity developing over time through experience, feedback and support.

In general, interventions aiming to improve teachers' and pre-service teachers' confidence and self-efficacy in STEM are effective (e.g., Baysal & Mutlu, 2021; Dökme & Koyunlu Ünlü, 2023; Gardner et al., 2019; Jaipal-Jamani & Angeli, 2017). However, research is more plentiful on professional development interventions for in-service teachers. For instance, Baysal and Mutlu (2021) in their meta-analysis that included 14 experiments related to professional development programs aimed to improve teacher confidence, returned a 'moderate' average effect size of 0.652. The researchers report a high level of heterogeneity in their results, implicating a range of moderators, including topic, stage of teaching and year of publication. Research in pre-service teacher education is similarly varied, with approaches ranging from a six-hour intervention focus on robotics (Jaipal-Jamani & Angeli, 2017) to a 14-week intervention focused on implementing an Inquiry framework to develop STEM confidence (Dökme & Koyunlu Ünlü, 2023). Research on interventions involving Makerspaces is limited. Blackley et al. (2017) noted the potential for improvements in confidence, but also a risk: the PST population generally has limited experience of and interest in STEM, thus not all experiences may end up being positive since the underlying lack of confidence or challenge of the unfamiliar environment can be barriers to learning. PST also remained unsure of whether (or how) their experience would translate into their preparation for classroom work. Primary teachers also report a lack of preparedness to teach STEM, in particular, the technologies or engineering components (Trygstad, 2013), and STEM-specific professional development competes with the range of other subject-level initiatives or school-level objectives for teacher development.

The present study thus acknowledges makerspace (and associated) pedagogies as having potential to influence PST confidence within initial teacher education. The limited research on PST and Makerspaces and the huge diversity of these experiences mean it is difficult to understand if and how confidence develops. In this research, we ask: how do makerspaces influence the confidence of pre-service teachers in STEM?

Method

When conducting research into confidence and self-efficacy, quantitative methods are common (e.g. Riggs and Enochs, 1990, Sharma et al., 2011; Tschannen-Moran et al., 1998; Unfried et al., 2022). In addition to existing scales (which may include multiple factors or constructs), confidence can be interpreted through individual items or questions related to 'attitudes' or 'perspectives' (Hackman et al., 2021; Kah Wei & Mistima Maat, 2020) on questionnaires or interviews (Kim et al., 2015; Tao, 2019). In the current study, we relied on case study methods, primarily interviews, to investigate influences on PST confidence through their participation in a makerspace experience.

Data for the study include observations of PST working in groups in the university makerspace (called "Uni Makerspace" herein) on a STEM-focused assignment, interviews with participating PST, and a design portfolio that was part of the assignment in their science method subject. As a result of the research protocols and the ethical approvals for the research (HREC 2020/311), each participant had the option to allow researcher access to any or all of the data points (observations, interview, and design portfolio). Thus, four case groups were included in the study on the basis that all members consented to the observations and collection of the design portfolio and at least one member consented to an interview. Observations were carried out by a research assistant who observed each group working in the Uni Makerspace at least three times using an observation pro-forma recording details such as group members present; the nature of participants' interactions with the space and each other, how the facilitators supported the participants, and any quotes from the participants that the observer deemed important. The first observation occurred during a common one-hour introductory session in the space, with further observations occurring over the subsequent 7-week period until the assignment was due. Of the 12 participants in the four cases, six agreed to individual interviews that took place after the assignment was submitted. Interview questions were semi-structured and explored participants' perceptions of themselves in relation to STEM, including their confidence levels, how they engaged in the space, and their overall experiences in the space (see Appendix 1 for interview questions). Appendix 2 includes the task description and design portfolio template that all groups used.

The Uni Makerspace has a range of tools available including 3D printers, laser cutters, a water-pressure cutter (Wazer), sewing machines, and general hand and power tools (Fig. 1). The Uni Makerspace was built with support from the University's internal grant program with the aim of positively impacting the local economy. University staff from business, IT, Engineering, the Arts and Humanities engaged in projects in the Uni Makerspace as part of the grant. Engaging PST in STEM was one such project. In addition, the Uni Makerspace at the time was open to the public and staffed primarily by student facilitators from Engineering and Education.

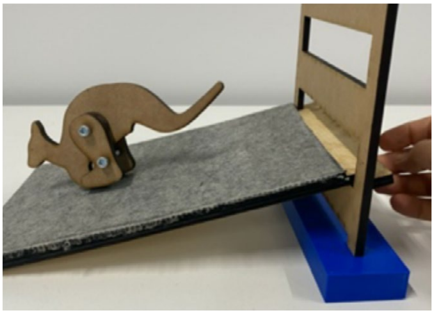
Fig. 1 Bench containing 3D printers at the Uni Makerspace

Participants

The participants were K-6 PST enrolled in a core first-year subject focused on developing their content knowledge related to 'Science and Technology' (NESA, 2017). As part of the subject, PST ($N = 240$) completed an assignment in groups of three where they designed and created a "STEM kit" that could be used within primary schools. All PST had an introductory 1-h session in the Makerspace and had the option of working in the space to complete the assignment; 24 PST selected this option. Participants in groups also decided when and for how long they would visit the space.

Data Analysis

A thematic analysis (Braun & Clarke, 2022) was conducted using Nvivo software across all data sources, including the design portfolio. However, the vast majority of the coding references (92%) were drawn from the interviews. Thus, the in-person observations and design portfolio were mainly used to contextualize data and interpretations (see Table 2 and Fig. 2). Data were initially coded under two a priori codes: 'Confidence' and 'Makerspace Influences'. Confidence was further divided into 'STEM-related Confidence' and 'Confidence to Teach' reflecting the two main aspects of teacher self-confidence and our desire to take a broad view of PST confidence. Subsequent open-coding (Maquire & Delahunt, 2017) resulted in two additional sub-codes being



a. Group 1 “STEM Kangaroo”

b. Group 2 “Solar Powered Car”

c. Group 3 “Mathematics Board Game”

d. Group 4 “Multiplication Grid”

Fig. 2 Group products

associated with ‘Confidence’ (subcodes: Previous Experience and New Perceptions) and five for ‘Makerspace Influences’ (subcodes: Facilitator, Tools and Materials, Collaboration, Hands-on, Open-ended Enquiry).

These subcodes reflect common features and characteristics of makerspaces that were identified as impacting or influencing confidence. For instance, the following quote illustrates the relationship between confidence (STEM-related Confidence) and the makerspace influence ‘Tools and Materials’:

I just keep thinking back to the laser cutter because I’ve never seen one in my life. So when we had that initial rundown, oh okay, we can do this and I didn’t know how to do that. And the more and more we used it, the more we can achieve really. (Interview with Riana).

Some comments were not as explicit in terms of the relationship between the makerspace influences and confidence and required some inference. For instance, the following quote illustrates the same coding categories as the one from Riana: “I have worked a lot with the laser cutting of our board. And yeah, like me last night, a lot of programmes and stuff that I didn’t know about. And even for the 3D printer, like looking up, like you can look up prints that other people have made” (Interview with Hailey). The final coding structure is presented in Table 1.

Table 1 Themes and coding structure

Confidence	Excerpts were coded to confidence when any aspect of confidence (see below) was discussed. This coding took a broad view of confidence, including prior experience and also new understandings
Previous Experience	Discussion of a participants' experience in relation to the identified topics (in Science and Technology), piece of equipment or the Makerspace or specific Design and Production skills
STEM-related Confidence	Confidence related to STEM knowledge
New Perceptions	A new idea that the participant discussed, related to the identified topics (in Science and Technology)
Confidence to Teach	Confidence to teach STEM
Makerspace influences	The makerspace characteristics that were identified as important or associated with changes in confidence
Facilitator	An expert working in the space with greater knowledge regarding equipment, concepts, etc
Tools and Materials	The available resources in the Makerspace: machinery, technology, software or devices and discussions related to the use of raw material resources (fabrics, plastic, etc.)
Collaboration	The interactions between group members within groups or across groups
Hands-on	Working with tools personally and physically
Open-ended Inquiry	Working in the Makerspace without a set outcome and being involved in conversations where there wasn't one correct approach/answer

In a form of interrater checking, Authors 2 and 3 used the coding structure developed by Author 1 to code roughly 20% of the interview data. Using Geisler and Swarts' (2019) simple agreement formula, coding agreement was 85.7% which meets the acceptable level of 80%. Discussion amongst the researchers resolved any discrepancies.

Results

We begin with an overview of the observational and interview data as summarized in Table 2. Images of the products made by each of the case groups are shown in Fig. 2. Following this, we organize influences thematically, integrating makerspace influences in the area of confidence consistent with how they appeared as overlaps in the data set. For instance, the themes of 'Facilitator' and 'Tools and Materials' are presented along with 'STEM-related confidence' because this is where the overlap was greatest. Similarly, 'Open-ended Inquiry' and 'Hands-on' co-occurred with 'Confidence to Teach'. Collaboration is a distinct influence in the Uni Makerspace and is discussed separately. Pseudonyms are used throughout.

Confidence: Prior Experiences

Initial confidence in STEM and prior experience with makerspaces and STEM varied amongst the participants. In Group 1, both Jayde and Mia (see Table 2) stated that they had very low STEM-related confidence at the beginning of the study due to their lack of prior experience. During the interview, Mia described herself as "technology challenged", consistent with observation notes that described her as hesitant, often avoiding

Table 2 Summary of data set

Grp	Product	STEM concept	Visits (attend/total)	Equipment used	Confidence
1	"STEM kangaroo" from medium-density fibreboard (MDF); assembly kit to create a kangaroo that "hops"	Forces	Jayde (3/3)	3D printer Laser cutter Experimented with heat pres	Initial lack of confidence. Solid improvement with eagerness to return to the space for personal use. Mention of intention to use strategies learned in makerspace in future teaching
			Mia (3/3)	3D printer Laser cutter	Initial lack of confidence. Small improvement but wishes to gain further experiences to strengthen
2	Solar powered car from MDF: kit to build car that is solar-powered	Energy	Connor (7/7)	Laser cutter 3D printer Hot glue gun	Very confident initially. Significant confidence at the end of the study. Not as confident with STEM-teaching, but is not concerned about this
3	Mathematics game with a wooden board and plastic pieces: game set for students to play	Addition and subtraction	Thalia (4/6)	Laser cutter 3D printer Drill	Had some experience with technologies, but not especially confident. Increase in confidence, but still requires support
			Hailey (6/6)	Laser cutter 3D printer Apps/software	Had some experience with technologies, but not especially confident. Increase in confidence, but would like further opportunities to work with tools/STEM concepts
4	Multiplication grid from recycled plastic and acrylic	Multiplication	Riana (3/3)	Heat press Wazer cutter Laser cutter	Considerable experience initially (had studied technologies in high school). Had previous experience with equipment in makerspace. Significant increase in confidence, particularly in relation to STEM teaching

opportunities to work with the equipment. Similarly, Jayde stated in the interview that STEM “for me was … not something I’m very good at” and that “coming into it, I didn’t know very much”. Both Mia and Jayde were mature-aged students who indicated that the last time they encountered STEM/technologies material was a “long time” ago in high school. Connor (Group 2) stated that he had substantial experience and confidence with music-related technologies and a general interest in technology before beginning the study but expressed limited confidence regarding his ability to teach STEM content. Both Tahlia and Hailey (Group 3) stated that they had some experience with technology in high school, but neither felt confident in their ability to work with the equipment in the Uni Makerspace initially. Riana (Group 4) also had high school technologies experience and said she felt confident at the outset of the project.

Confidence: STEM-Related Confidence

For every participant, language shifts clearly indicate improvements to STEM-related confidence. Participants discussed changes in confidence both generally and also specifically. For instance, when discussing STEM generally, Hailey explained that “learning and making the assignment in the Makerspace helped so much” and in relation to the product: “you know, making that quality product… it’s not that hard. Like, it seems hard, but it’s not that hard once you get to it”. Jayde also explained that she felt “more confident now than when I first started”, making the following comment about the project and referring to the third group member (who was not interviewed):

> You [referring to the research team] allowed us to think; you allowed us to take our own time with our project really gave all of us that boost of confidence. And I think especially Liette, I think it gave her a big boost of confidence as well. Because she was fantastic in the design aspect of it….I felt like that was her element.

Many participants also expressed increased confidence working in the space and an eagerness to return, including Riana (Group 4), who stated that she felt “very confident” to return to the space and use the facility again. This was despite her initial wariness when approaching new equipment in the Uni Makerspace.

Other participants, in discussing improvements in their STEM-related confidence, admitted feeling initially “hesitant” (Connor) or “overwhelmed” (Hailey). And whilst Mia felt that she was “more confident than before”, she experienced the most marginal improvements. Group 1 observations, for example, show that all group members spent several sessions in the ‘planning room’ before using any equipment, with Mia explaining in the interview that she “didn’t want to go in there and ruin everything”. During the fourth observation, when Group 1 was preparing to use the laser cutter, Mia remarked that she was “not a person who should be touching software”. Observation notes also report that Mia was often not engaging with the group: “[group members] engaged with model but Mia still passive”. In the interview, Mia admitted that she wanted to learn more and would welcome future opportunities to work in the Uni Makerspace.

We identified ‘Tools and Materials’ as a key makerspace influence on PST confidence due to a large number of overlapping coding references. The ‘Tools and Materials’ category was associated most with ‘STEM-related Confidence’ due to this high degree of overlap. Jayde, for example, explained that “we were hands-on with the equipment, doing it ourselves rather than watching it done. So I feel confident to be able to go in there”. Observations showed that Group 2 (Connor) began using the equipment and materials quickly with support from the facilitator, and as the observation notes report, Connor was able to independently operate the selected equipment in the final few sessions. Connor explains how by the end of the project, he felt “pretty confident… I know how to use all the equipment now, I’m a lot more comfortable to just go in there with, I guess, for lack of a better term, with guns blazing and just give things a go”. As shown in both the observations and design portfolio, Group 4 experimented with every piece of equipment when deciding on a design for their product, ultimately using the Wazer, heat press and laser cutter for their final product. A Group 4 observation comment notes: “none of the group members had used the laser cutter before but they were all enthusiastic about using it and each completed an element”. In a reflective comment to conclude the group’s portfolio, they explained:

> Since we have started to use the makerspace, we have been able to attain many new skills. We were able to learn how to use the laser cutter, many power tools, a heat press, the Wazer and the computer technology to enable these processes to work. (Group 4)

The novelty of the equipment seemed to encourage engagement in STEM processes and practices:

> like the computers and how that sends the stuff to make to the 3D printer and all that we used, the laser cutter and stuff, was really cool….I gained some good skills in using technology and understanding how it works. (Hailey)

Hailey’s comment is consistent with those of other participants too, like Jayde: “I learned new skills, which I never had before, which was the laser cutter and the 3D printer. I learned how to sit down and sort of design a project”.

However, some of the materials and tools at the Uni Makerspace were challenging to use and thus could potentially act to inhibit confidence development. For instance, designs sometimes melted or snapped and in one instance, the observation notes record that one participant (Connor) got frustrated and left the space early. Additionally, Mia, who had limited prior experience, was intimidated by the “high tech” and “expensive” equipment and was slow to engage in the space.

The link between ‘Confidence’ and ‘Makerspace Influences’ was most pronounced when considering the ‘Facilitators’. Again, the specific sub-category of ‘STEM-related Confidence’ was implicated. Hailey (Group 3) indicatively states that her group “wouldn’t have been able to do any of that [use the tools within the space] without them” and Group 4 explained in their design portfolio: “the makerspace staff and volunteers showed us how to use the design software … and helped us on our journey to successfully design and create our STEM activity kit”.

Observation notes reveal that whilst facilitators provided explicit instructions on how to use equipment, they always encouraged participants to undertake all steps on their own and encouraged participants to find solutions to their problems. Most participants recognised this “way” of teaching as supportive, for example:

> They were able to teach us to a point where I could go back and use [the equipment] without having to ask them every time or it was more than just them sitting down and taking over the project. The way that they taught was really helpful and hands-on. (Riana)

In addition to the supportive scaffolding provided by facilitators, most participants stated that they valued the relationships built with the facilitators. Connor explained: “the fact that it can be conversational and personable has helped me again, be more excited about it". Most participants felt supported to ask questions if needed: "even the way they [the facilitators] helped us and approached us. It wasn't like we were dumb and didn't know what we were doing. It was very supportive" (Riana). Jayde, however, did note that the facilitators were often not immediately available when other users were in the space (there were usually one to two facilitators present at each session with other users present in the space).

Confidence: New Perceptions

'New Perceptions' refers to changes in participants' ways of thinking, which often involved a new realization about their own confidence or knowledge and what the technology could be used for.Connor, for example, explains how.

> just the idea of opening my mind to these new things that I didn't think were possible, or I didn't think were possible in such a short amount of time, or to somebody who was not in that world yet…. I can think of ways that, whether I'm using technology to make processes more productive, or even just being able to make something in general….[working in the Uni Makerspace] opened my eyes in terms of what else I can be using technology for.

Participants also changed their perceptions about what counts in STEM education. For example: "it got me to learn more about science and think of science in a different way. Rather than just think of it as, yeah, the periodic table" (Jayde). During interviews, participants were asked if they found any aspect of learning about STEM interesting or surprising. The question led to multiple accounts of participants stating their renewed perceptions of themselves in relation to STEM. Thalia provides an example. Originally, she did not think coding was something she could or would want to do but after engaging in the Uni Makerspace, felt that coding was "pretty cool". Mia's changed perceptions were less effusive, but were evident in her interview when she was asked what she had gained from working in the Uni Makerspace: "I guess that 3D printing is probably not as hard as you think, or laser cutting".

Confidence: Confidence to Teach STEM

All participants felt their confidence to teach STEM had improved after working in the Uni Makerspace but it was clear that this improvement was less notable when compared to their confidence in STEM skills and STEM knowledge more generally. For instance, Hailey explained that she didn't feel confident, but was ready to "give [STEM teaching] a go". Hesitancy towards teaching STEM was often expressed as limited knowledge of pedagogical strategies, such as in this comment from Connor: "In terms of the actual information, I think I've been well-equipped to be able to teach someone about the technology that's available. But yeah, I guess teaching techniques would be more, [I] need more help with". Participants also attributed their STEM-teaching hesitancy to limited understanding of educational policies and documents: "I haven't looked at the syllabus yet … it would be better to know what technology content and skills we will actually need when we're teaching" (Tahlia). This hesitancy is unsurprising given the subject focus on content knowledge and skills rather than curriculum and pedagogy, but also their status as first-year university students. Nevertheless, improvements in STEM-related confidence did seem to influence participants' STEM-teaching-related confidence. Connor explained how knowledge about STEM will be useful in the classroom:

> I have gained this unique experience where when I go into a school and have to teach this content, I can take the things that I've made in this subject … and say, 'well, this is something that I had to make', and walk them through the steps that I had to take … And again, having the excitement of being able to know how it works, and … being able to have the practical experience of it myself.

When asked "how ready do you feel for teaching technology now?" Riana stated:

> [I am] much more ready than I was before this subject. I can say that. I have such a greater understanding now than what I had or thought I would have ever had before.

Also responding to the question about readiness to teach technology, Jayde explained that there was 'vicarious' learning through the pedagogies modelled in the Uni Makerspace that were a "whole new way of teaching". Connor similarly added: "I think I've just learned that in terms of getting people involved in technology, and teaching people about technology, the importance of being hands-on with it". For this reason, we note the key Makerspace influences of 'Hands-on' and 'Open-ended Inquiry' as important and most associated with 'Confidence to Teach'.

In the context of this study, 'Hands-on' refers to the practical and active nature of the space, which was both enjoyable and beneficial for participants. Hailey explains that she "decided to go to the Makerspace because it was like that hands-on thing". The opportunity to physically manipulate materials and work with equipment was also important to Connor:

> If I wasn't in this space…hands-on, I wouldn't have been able to think of how to make a product that was, again, a physical 3D product that people want to be able to touch and use without seeing it myself like how to touch and use this product.

The 'hands-on' element was particularly important when considering future teaching experiences. Riana explained that "when I become a teacher I can … take the knowledge from this assessment and employ it in the classroom". Further, she would like to "take students on an excursion there … because it's such a fun, hands-on space for people to learn". Similarly, Connor stated "I would love to be able to bring classes in [to the Uni Makerspace] to be able to get a hands-on idea of what the technology we have available to us can do".

The Uni Makerspace also provided a place for open-ended inquiry that participants valued for developing their confidence. Two groups explicitly discussed how the opportunity to experiment in the space supported them in designing and creating their product. Analysis from observations and the assessment task for Group 1 showed that the open-ended design of the space allowed them to work through problems that arose in order to find a solution, with Jayde noting that this was a "vital engineering process". Similarly, Group 4 deliberately trialled every piece of equipment when prototyping and problem solving:

> Initially we were only going to use two or three of the machines, but it ended up being seven or something that we ended up using so I was really happy with how our final product was and how it allowed us to trial everything. Even in the end we used the Wazer cutter…I mean it didn't work to plan but we tried it. (Riana)

Riana also discussed that the opportunity for open-ended experimentation supported her confidence to work in the Uni Makerspace because it allowed her to develop a wide repertoire of skills that expanded beyond the immediate needs of her project: "we got to learn how to use [equipment] like how it worked to learn a little bit about it, and if that machine didn't work for what we needed that was okay we got to try it". Similarly, when discussing her experience with the "investigation process", Tahlia stated that she had developed ideas on how to teach STEM-related content, suggesting she would organize a similar project for children so that they could work with similar processes.

Collaboration

Collaboration was a key expectation for the assignment and the participants' experience in the Uni Makerspace; importantly, this led to improved confidence. Collaboration was evident across all data sources and was discussed by all participants. Most participants stated that they valued the nature of the space as they were able to gain new ideas and perspectives, as exemplified when Jayde discussed a key collaborative process: "feeding off the ideas of other people to get what you might have missed". Group members also helped each other with equipment use, as noted by Thalia:

> Well, I found it sort of challenging when I was first trying to use, like the 3D printer, and the laser cutter, because there's just so many different programs and you've got to remember the process of how to do it right … but what helped was having the group members who were good at it.

Riana also explained that "the opportunity to be able to use the technology and connect with other students to explore it was key".

However, collaboration was not always a positive experience. Connor noted the lack of confidence amongst his group members as a problem for the group's collaborative work: "I think there would be a tendency to withdraw from the project. Because they may be nervous about using the technology available to them". Observations of Group 2 showed Connor frequently working on his own in the Uni Makerspace and compiling the creation of the group's product mostly on his own, which may explain why he views collaboration as potentially problematic.

Discussion

This research aimed to examine how the Uni Makerspace influenced pre-service teachers' confidence in STEM, which included both STEM-related Confidence and perceptions of Confidence to Teach. Consistent with the extant literature, the results show that makerspaces have the potential to meaningfully improve PST' confidence in STEM (e.g. Blackley et al., 2017). Participants with varied initial levels of reported confidence all expressed positive improvements. Unlike other interventions related to pre-service and in-service teacher confidence improvement (e.g., Baysal & Mutlu, 2021; Kim et al., 2015; Nadelson et al., 2012; Stevenson et al., 2019), this project did not involve a specific course or overall design, but rather, consistent with 'maker' culture, allowed for independent project-based work that was unique to each group/student. This approach authentically represents the design process and is a feasible way to help PST develop knowledge, skills and confidence in STEM-related topics within pre-service teacher education subjects. This is particularly important given the constraints in initial teacher education, with many primary education degrees having limited time available for explicit attention to STEM in a crowded curriculum (McDonald et al., 2019). However, the open-endedness of this kind of intervention makes it difficult to plan or account for any specific outcome, a challenge associated more generally with the teaching of technologies (Albion et al., 2022). The particulars of why or how confidence improved, and which aspects of the Makerspace experience were associated with the positive changes is therefore important.

As in the wider pre-service teacher population, study participants included individuals with varying initial levels of confidence, allowing a broad exploration of aspects of the Makerspace and relative influences across the range of interests and confidence levels. Whilst it was unsurprising that participants with intermediate and higher confidence levels at the outset reported their confidence had improved, we note that a large portion of this discussion centred on the use and mastery of equipment in the Uni Makerspace. We hypothesize the presence of a 'novelty effect' (Jeno et al., 2019), which results in a higher-than-normal engagement with the task due to the presence of novel equipment or materials. The novelty effect can be leveraged to engage users and result in positive affective and achievement measures, however, is not sufficient in and of itself.

In our research, two female-presenting participants acknowledged that they were extremely hesitant and had low confidence at the outset, consistent with research regarding PST confidence in STEM (Buss, 2010; Department of Industry Science & Resources, 2022; Kurup et al., 2019). These participants did not experience the same trajectory in terms of their confidence development; they took longer to interact with the equipment and generally felt more frustrated. Research shows that PST with minimal teaching confidence will often avoid STEM teaching and learning opportunities (Gerde et al., 2017; Harlen & Holroyd, 1997), so the choice to initially engage, and reports of a positive outcome, are noteworthy. In a demographic characterized by hesitancy towards STEM learning and teaching, the significance lies in the makerspace potentially fostering accessibility for individuals who typically refrain from or do not identify with STEM-related activities (Bevan, 2017).

There were five main elements associated with changes in confidence amongst participants in the current study: Facilitators, Tools and Materials, Collaboration, Hands-on nature of the experiences and Open-ended Inquiry. These elements, or influences, whilst not exclusive to makerspaces, can inform the effective use of makerspaces and other STEM-related activities in the primary classroom as well as primary pre-service teacher education, and our exploration in this paper elaborates these as contributions to the wider literature.

Participating PST consistently identified the Uni Makerspace facilitators as being the strongest influence on their developing confidence, with frequent mention of a range of positive qualities and interactions, from direct support with software and equipment, to the interpersonal relationships that were developed. Research identifies experienced practitioners as essential for learning in a makerspace (e.g., Hoople et al., 2020; Robnett et al., 2018). Whilst this seems intuitive, Hoople et al., (2020) explain that there may be an additional advantage in the makerspace context, as the expert practitioners tend to be a part of the maker community, and are more accessible to learners, compared to university lecturers or tutors. Robnett et al. (2018) describe this support as 'mentorship', explaining that these mentors offer "instrumental" and "skills-based, task focused guidance" (p.10). The researchers offer a link between this support and changes in attitudes, explaining that: "undergraduates who reported receiving more instrumental and socioemotional mentoring had higher levels of scientist identity" (p.10). One possibility and implication then is to grow and draw expert support from within the maker community in order to help learners transition into working in the space and to help improve their confidence.

In our case, the Makerspace had resources available to offer this support but PST generally don't have access to sophisticated equipment (Andrews et al., 2021).

Similarly, in the primary classroom, support from those with expertise in STEM is not common, and primary schools often rely on rudimentary equipment for science learning (SCORE, 2008). However, as previously mentioned, expertise in makerspace is more effective when the facilitator is a mentor, or more expert peer, and as such, this kind of support is more accessible in both initial teacher education and in the classroom, as both can draw from more expert peers or those in the maker community. Similarly, with respect to equipment, the nascent status of both PST and their future students means that there are opportunities to engage with novel equipment that is accessible and/or inexpensive, particularly when paired with free software. As Jeno et al. (2019) noted, novelty is a relative concept.

The hands-on and open-ended nature of experiences in the Makerspace were generally positive influences for PST confidence. The facilitators modelled relevant pedagogies in the Makerspace which gave the PST the chance to see the pedagogies in action, which contributed to their understanding of and confidence in STEM education. Open-endedness and being 'hands-on' are core elements of technologies pedagogy, so this is consistent with what we already know about best practice (Albion et al., 2022).

Whilst overall the study demonstrated positive outcomes and details for influences on PST confidence, understandably, some participants still expressed hesitancy, particularly in their perceptions of *teaching* STEM. This is not surprising given that the subject and assignment did not explicitly include STEM curriculum and pedagogy. Consistent with Hahl and Mikulec (2018), our participants had not had any instruction in pedagogy or professional experience and thus had limited opportunity to come to view themselves as teachers. We should also not be surprised that confidence to teach STEM showed limited development. Notably, at this early stage of the initial teacher education program and their developing teacher identities, we ought not expect too much from a short-term experience. We assert that confidence to engage in STEM is a necessary but not sufficient condition for developing confidence to teach STEM; PST also need to develop confidence to teach STEM by learning appropriate and effective pedagogical strategies to help them feel fully prepared (Sadler, 2013). Due to limitations in our own initial teacher education program, such connections to professional learning are not possible. It does, however, point to the import of an integrated focus on content and pedagogical knowledge both for pre-service and in-service teachers.

Conclusion

Makerspaces offer a unique opportunity to engage primary PST with authentic learning opportunities in STEM disciplinary practices. These professional development opportunities have the potential to significantly improve STEM teaching confidence, but must include a scaffolding focus that supports engagement especially if working with novel equipment. Future research should explore the influence of explicit instruction on pedagogical practices for teaching STEM and developing teacher knowledge and confidence to teach STEM.

Appendix 1

The following are the semi-structured interview questions:

1. Can I begin by asking what you knew of this topic before XXXX102 and what your past experiences, feelings or attitudes were?
2. Did you find any aspect of learning about Technology as part of XXXX102 interesting or surprising?
3. Did you find any aspect of learning about Technology as part of XXXX102 difficult or challenging?
4. What did you find most challenging about the Technology aspect of XXXX102?
5. What resources were most helpful in developing your Technology knowledge?
6. Did your view on Technology, both what it was and your general feelings or attitude about it change after completing the course?
7. How do you feel about teaching Technology now?
8. In completing Assessment 2, did you attend any of the physical spaces on offer?
9. Why did you choose to work in the Makerspace?

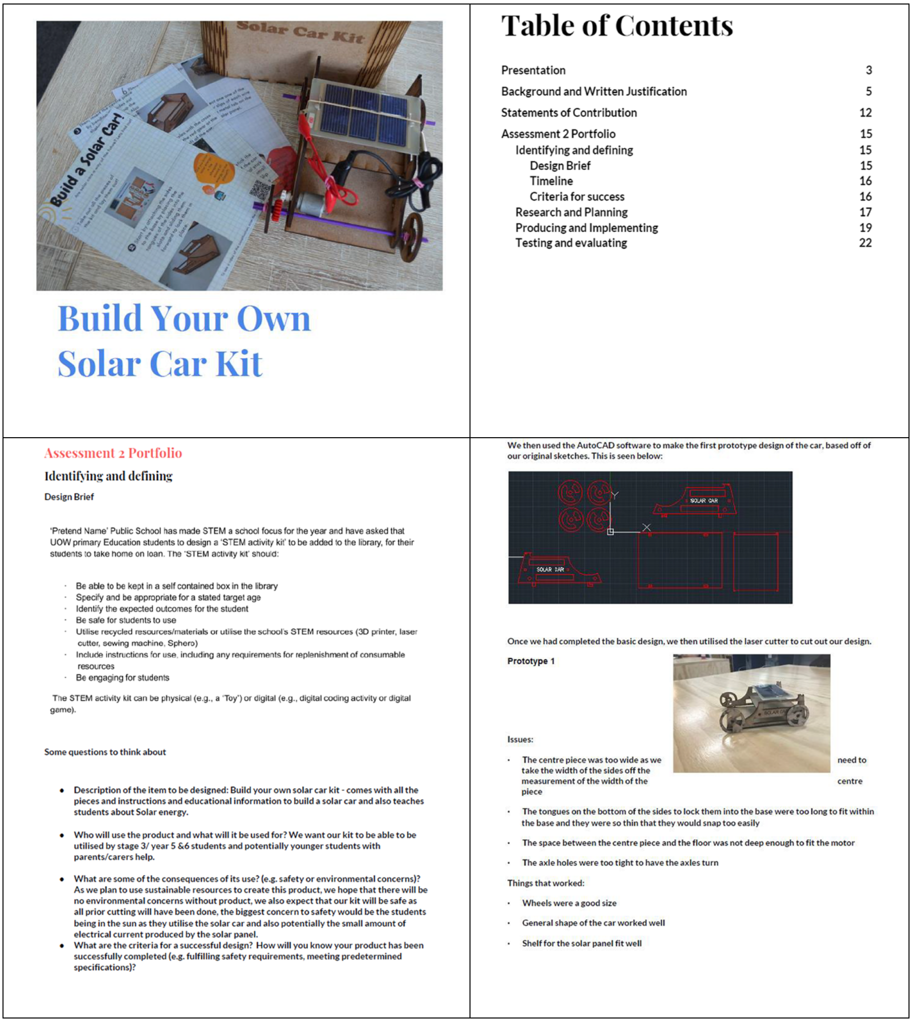
- Which equipment or resources did you use?
- How did you decide this?
- What were the resources that helped you work in the Makerspace?
- What resources do you think you needed to provide you with more support in the space?
- What do you think you gained from working in the space?
- How likely do you think you'll use the Makerspace as a teacher?

10. Do you have anything else you'd like to share about your experiences this semester, in terms of your Technology knowledge?

Appendix 2

Design project task description and design portfolio template are shown as follows:

Assessment 2	Design project (35% task)
Description	Students will design a product that addresses the following design brief and will report their design process in a written justification, supported by a design portfolio Design Brief 'Pretend Name' Public School has made STEM a school focus for the year and have asked that UOW primary Education students to design a 'STEM activity kit' to be added to the library, for their students to take home on loan. The 'STEM activity kit' should: • Be able to be kept in a self contained box in the library • Specify and be appropriate for a stated target age • Identify the expected outcomes for the student • Be safe for students to use • Utilise recycled resources/materials or utilise the school's STEM resources (3D printer, laser cutter, sewing machine, Sphero) • Include instructions for use, including any requirements for replenishment of consumable resources • Be engaging for students The STEM activity kit can be physical (e.g., a 'Toy') or digital (e.g., digital coding activity or digital game) Templates and resources for structuring the design project will be available on Moodle



Build Your Own Solar Car Kit

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Assessment 2 Portfolio

Identifying and defining

Design Brief

'Pretend Name' Public School has made STEM a school focus for the year and have asked that UOW primary Education students to design a 'STEM activity kit' to be added to the library, for their students to take home on loan. The 'STEM activity kit' should:

- Be able to be kept in a self contained box in the library
- Specify and be appropriate for a stated target age
- Identify the expected outcomes for the student
- Be safe for students to use
- Utilise recycled resources/materials or utilise the school's STEM resources (3D printer, laser cutter, sewing machine, Sphero)
- Include instructions for use, including any requirements for replenishment of consumable resources
- Be engaging for students

The STEM activity kit can be physical (e.g., a 'Toy') or digital (e.g., digital coding activity or digital game).

Some questions to think about

- Description of the item to be designed: Build your own solar car kit - comes with all the pieces and instructions and educational information to build a solar car and also teaches students about Solar energy.
- Who will use the product and what will it be used for? We want our kit to be able to be utilised by stage 3/ year 5 &6 students and potentially younger students with parents/carers help.
- What are some of the consequences of its use? (e.g. safety or environmental concerns)? As we plan to use sustainable resources to create this product, we hope that there will be no environmental concerns without product, we also expect that our kit will be safe as all prior cutting will have been done, the biggest concern to safety would be the students being in the sun as they utilise the solar car and also potentially the small amount of electrical current produced by the solar panel.
- What are the criteria for a successful design? How will you know your product has been successfully completed (e.g. fulfilling safety requirements, meeting predetermined specifications)?

We then used the AutoCAD software to make the first prototype design of the car, based off of our original sketches. This is seen below:

Once we had completed the basic design, we then utilised the laser cutter to cut out our design.

Prototype 1

Issues:

- The centre piece was too wide as we need to take the width of the sides off the measurement of the width of the centre piece
- The tongues on the bottom of the sides to lock them into the base were too long to fit within the base and they were so thin that they would snap too easily
- The space between the centre piece and the floor was not deep enough to fit the motor
- The axle holes were too tight to have the axles turn

Things that worked:

- Wheels were a good size
- General shape of the car worked well
- Shelf for the solar panel fit well

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Declarations

Competing interests The authors declare no competing interests.

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