Makerspace in STEM (MIS) for girls: An Exploratory Study

PROPOSAL SUMMARY

PURPOSE AND OBJECTIVES
Research has shown that over the 15 years since its inception, Science, Technology, Engineering, and Mathematics disciplines continue to be taught separately in subject silos in schools (Blackley & Howell, 2015), and there is little or no integration or connections between the silos to emulate how professionals in the field actually work. The desire and perceived need for increased numbers of students opting for STEM subjects in senior secondary and tertiary STEM-related courses have been a challenge for educators globally (Chubb, 2015). Authentically integrated STEM education would see the immersion of students in “rich tasks” drawing on a number of STEM subject areas as a preferred way of learning; however in this instance we propose an approach that sits outside of the traditional classroom. This approach incorporates the utilisation of the Makerspace phenomenon to provide opportunities for students to apply their subject knowledge to undertake a design process resulting in the creation of STEM-related artefacts. The Makerspace in STEM (MIS) Project that will be reported on in this session, describes the engagement of female pre-service teachers (PSTs) and female engineering students (ESs) on STEM Makerspace projects hosted in Year 5 and 6 classrooms at a Catholic girls’ school in Australia, and describes a new model of pre-service teacher learning: the Reflective Identity Formation Model (Sheffield & Blackley, 2015).

Objectives
The project seeks to:

- create a dynamic and integrated approach to STEM education through Makerspace;
- enable PSTs to authentically engage with students in school settings to increase their work-readiness;
- facilitate cross-faculty collaboration in the Education and Engineering communities by targeting PTSs and ESs; and
- highlight and develop the 21st century learning skills of: collaboration, communication, creativity, and problem solving.

Specifically, in this paper we focus on these key questions:

1. How did pre-service teachers engage with and participate in the MIS project?
2. How did the Reflective Identity Formation Model support PSTs’ confidence and ability to mentor the school girls in the MIS project?

PERSPECTIVE

Makerspace: STEM for the Future
The turn of the 21st century has signalled a shift in the types of skillsets that have real, applicable value in a rapidly advancing world. In this landscape, creativity, design, and engineering are making their way to the forefront of educational considerations, as tools such as robotics, 3D printers, and web-based 3D modelling applications become readily accessible and less expensive. Makerspaces are increasingly being heralded as a catalyst for engaging learners in creative, higher-order problem solving through hands-on design, construction, and iteration (European Union, 2015). Makerspaces are physical spaces that have been designed or set aside to support the maker in the creation,
design, and building of new projects and technologies. Smith, Hielscher, Dickel, Soderberg, and Oost (2013) posit that *Makerspaces* are really about the community and connections that develop whilst the individuals are creating in the space, and libraries, having been traditional centres of community, are adopting the *Makerspace* phenomenon. *Makerspace* in schools is an interesting and engaging “tinkering” of ideas but can it be anything more?

*Makerspace* in STEM is the deliberate positioning of student learning in contexts that require the drawing together of skills and knowledge from the areas of science, technology, engineering, and mathematics to create, construct, and critique a product. *Makerspaces* in STEM use hands-on, creative ways to inspire students to plan, research, build, and create as they participate in projects (Cooper, 2013). Products are usually selected by the participant and are often unique in nature. The “maker approach” can cater for a range of learning styles, especially kinaesthetic, as it is a hands-on approach that value-adds more traditional forms of classroom practice.

This paper argues that *Makerspaces* can be more than tinkering if there is a strengthening of the *explicit connections* between the curricula of mathematics, science, and technology and the end product or artefact. Researchers of informal settings and the science of this space (such as Krishnamurthi & Rennie, 2013) identify *Makerspace* opportunities as informal science programs and define these as “engaging, hands-on learning approaches in less formal environments that aim to feel different from school” (Krishnamurthi & Rennie, 2013). They assert that this type of learning should be student-centred and presented in a way so as to provide choices to the learner, enabling them to explore as their interest prevails (Krishnamurthi & Rennie, 2014).

**Professional Learning**

With pre-service teachers’ reluctance to engage with science and mathematics during their teaching degree, and often reporting a lack of confidence in personally doing mathematics and science, there is a need to provide additional opportunities for them to develop skills and positive dispositions in the STEM space (Appleton, 2003; Hackling, Murcia, West, & Anderson, 2014). Although research indicates that pre-service teachers and some elementary school teachers lack knowledge in STEM, there is additional evidence to suggest that girls and women do not engage in STEM activities in the same numbers as their male counterparts (National Research Council, 2012; US Department of Commerce, 2013). This is particularly concerning when over 85% of the students in elementary school teacher education courses are women (Blackley & Sheffield, 2015).

In this project, the focus is on scaffolding girls and women to work together in STEM education which has been proven to be a powerful and productive collaboration (Cooper, 2013; Holmes, Redmond, Thomas, & High, 2012). Stage 1, which prepares the PSTs for the *Makerspace* project, is designed so that female PSTs work alongside female engineering students in a training workshop. This initial workshop is specifically designed to help PSTs to develop their confidence and skills in STEM. The three components of this workshop are:

- creating the product that they will be mentoring the elementary school students to complete; tinkering with the base equipment; and exploring modifications that can be made by extending the base materials;
- understanding the related STEM concepts, supported by the ESs; and
- designing key questions to scaffold elementary school students to apply and reflect on the science and technology knowledge and skills learned in the classroom; and determining the pedagogical practices that would support the students to develop an increased understanding of STEM concepts and what it means to work in the STEM space.
Stage 2, sees the PSTs mentoring groups of 4 – 6 elementary school girls in making the *Makerspace* product using their knowledge from Stage 1, and the questions they prepared to scaffold and prompt the children. A new model of professional learning underpins these two stages: the *Reflective Identity Formation Model* (Figure 1) that we believe will enhance pre-service teachers’ confidence and competence in STEM education.

![Reflective Identity Formation Model](image)

**Figure 1:** Reflective Identity Formation Model (Sheffield & Blackley, 2015).

### RESEARCH METHODS

The methodology for this project is interpretivist qualitative research, based on an exploratory case study to examine participant engagement with and reflections on a single, re-iterated *Makerspace* STEM project. Data were generated and processed to determine the viability of the model that framed the study. The research was carried out at two sites: one independent Australian independent Catholic girls’ school and on the Curtin University campus.

**Participants**

Group 1: Nine volunteers from the Primary Bachelor of Education degree (2nd year, female students, on-campus at Curtin University) and one student from the School of Engineering (2nd year, female, on-campus at Curtin University).

Group 2: All Year 5 and 6 girls (n = 62) from an Australian independent Catholic girls’ school.

**Method**

There were two stages in this study:

**Stage 1: Learn by Doing:** Preparation of the STEM Makerspace projects and PST training,

**Stage 2: Makerspace Project:** Operationalising the STEM Makerspace at project the school site.
### Project Overview

<table>
<thead>
<tr>
<th>When &amp; Where</th>
<th>Participants</th>
<th>Tasks/Activities</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2015 University 60 min</td>
<td><strong>Stage 1</strong> Pre-service teachers (PSTs) &amp; Engineering students (ESs)</td>
<td><strong>Learn by Doing (45 min)</strong> - Make the origami flowers - Create design brief questions - Discuss science and technology</td>
<td>• Focus Group Interview • Individual Reflective Survey • Audio-recording of interactions • Researcher field notes</td>
</tr>
<tr>
<td>October School 90 min sessions</td>
<td><strong>Stage 2</strong> Year 5 and 6 Students (groups of 4 - 6)</td>
<td><strong>Makerspace Project (90 min)</strong> <strong>Basic Design Brief</strong> – make a basic flower in a cup that can light up <strong>What Else</strong> Extension – use materials to expand functionality/design.</td>
<td>• School Student Survey • Audio-recording of discussion • Audio-recording of project • PST Observation sheet</td>
</tr>
<tr>
<td>October School</td>
<td><strong>Stage 2</strong> PSTs</td>
<td><strong>Reflection (45 min)</strong> Examination of the teaching and learning.</td>
<td>Focus Group Interview: PSTs</td>
</tr>
</tbody>
</table>

### Stage 1: Learn by Doing Training Workshop

The PSTs and the ES were provided with materials and instructions to create an origami flower, and then to assemble a simple light circuit so that the flower could be illuminated. The members of the research team facilitated the session by grouping pre-service teachers (PSTs) and the Engineering Student (ES) to enable them to:

1. Become familiar with the project as it would be presented to the school students;
2. Identify the science, technology, and engineering concepts and terminology of both the base project and potential extensions;
3. Develop and record a series of questions that the PSTs would refer to when they are mentoring school students on site to prompt and probe; and
4. Develop the PSTs’ confidence and competence to extend the base project.

### Stage 2: Makerspace Project

This stage took place at the school site. The team (9 PSTs and 1 ES) were assigned in pairs to small groups of girls (4 - 6); one PST took on a mentoring role for the female school students (rather than instructional), and the other PST observed the session, and annotated a specially designed chart to record the children’s ways of working as well as social interactions and elements of the affective domain. The school girls were supported to make the base design product, describe how they managed to complete the product, and were encouraged to use additional available materials to extend their basic product (such as incorporating a switch into the circuit).

### Data instruments and collection
Data were collected from both stages of the project. In Stage 1, the interactions between the team were audio-recorded, and at the conclusion of the training session, the group undertook a focus group interview to reflect on the session (also recorded). The team also completed individual email reflective surveys.

In stage 2, multiple data sets were collected: at each group table an audio recording device was placed to collect random dialogue (both girls and PSTs); the annotated notes written by the observing PST at each table were collected; upon completion of their base project, a digital photo of each product was taken and the children were asked to explain what the experience what like; at the end of the session, children were asked to complete a short Likert-scale survey; and at the end of the day, the PSTs took part in a final focus group reflection (audio recorded). The Facebook communications of the dedicated Makerspace group (Makerspace virtual space), during the course of the project, were also captured, with PSTs’ permission, and analysed.

RESULTS

The vast amount of data collected from Stages 1 and 2 has made it clear that there are multiple narratives to tell. There is the narrative around the PST and ES collaboration, the unintended formation of a Community of Practice, and the concerns, hopes and expectations that the tertiary students expressed and how these changed over the course of the project. There is also a narrative that focuses on the Makerspace and the experiences of the Year 5 and 6 students, and the differences between these cohorts in their approach to the problem with which they were presented and their classroom experiences.

The focus of this paper will be on the Reflective Identity Formation Model support of team (PSTs’ and ES) confidence and their ability to facilitate the MIS project in the classroom context.

Stage 1 Learning by Doing.

Not all members of the team were able to attend the training, however those who did reported on the value of session in improving their science knowledge and their pedagogical knowledge. Some students were confident in both science and pedagogy:

I feel that I am ready to complete the mentoring with a much expanded knowledge of the nature of electrical circuits than I had previously. (Henrietta)

And

After the training day and additional practice, I feel confident that I would be able to mentor a small group of girls to complete this project. (Mikala)

There were others who were more confident in science yet there were other aspects that concerned them.

After the training I was fairly confident of making the circuit, and fairly sure I could lead the girls to following this. Yet I was unsure of how to prompt some girls into critical thinking and problem solving with my questions and no direct teaching. I was also concerned about making the flower origami as I found that really difficult. (Catrina)

Some PSTs also reported on the importance of practice after the technical session to improve their confidence.
To an extent yes, I feel prepared knowing what questions to ask the students to guide them through the thinking process, and I practised the origami at home so I feel all right doing that, but I am very nervous to demonstrate or make the circuit. (Leonie)

And

I didn’t complete the training but after reading through the instruction sheet and setting up my own circuit, I felt quite confident in mentoring the students as I had completed the circuit myself and understood the steps. (Alice)

Researchers’ Reflection

There was a problem with the origami flower at the training session; it was soon apparent that the instructions were complex and difficult to follow. At the session this led to a high level of frustration that was not completely resolved by the end of the session. This prompted some PSTs to reflect:

With additional practice outside of the allocated training day, I now feel confident. (Mikala)

And

.....once I rewired my circuit and practised the origami at home, felt a lot more confident. (Sarah)

As a consequence, several students continued to use the Makerspace (Training Workshop) by moving from the physical space at the University to a virtual space (Facebook). This produced a new narrative that grew organically as a result of the team members posting videos and photos of other origami flowers, and members reporting on their trial and error approach to creating a flower that could be used in the project (Facebook photo 4, 5 and 6).

The team continued to move in and out of the virtual Makerspace, helping each other to prepare for the Makerspace Project in the school context. Mikala was chosen to post for the group due to her high level of technical knowledge, and posted details on where to park and how to get to the school. The ES posted on the Facebook site what she intended to wear on the day:

Hey guys 😊 what do we wear tomorrow? Is it OK to wear leggings? (Ellie 2306)

The response was from another member of the team minutes later:

No, don’t wear leggings. Ahaha I’m either wearing ¾ work pants that are tight with a nice plain (sic) top and cardy (sic)....... (Sarah 2309)

Stage 2: Makerspace Project.

The team were asked to reflect on their experiences in the classrooms, and how they were able to engage with the students and successfully facilitate the Makerspace project. In the classroom there were the classroom teachers and the researchers, all of whom were participating in the project. Members of the team collected observational data about the girls in their small groups and then the girls were asked to complete a survey, administered by the team, examining their science understanding, engagement, and enjoyment. These data will be presented in a paper that will be a collaboration of both the academics and tertiary students. The tertiary students were aware that they were collecting research data about the girls, and would again reflect on the learning and other aspects of the Makerspace experience.
In the focus group interview, members of the team were able to articulate several differences between the Year 5 and 6 students related to their ability to demonstrate perseverance, resilience, and collaboration. They enjoyed sharing their observations and becoming aware of the girls’ behaviour as not being directly related to their teaching, and then to reflect on why the girls acted in this way.

- Some just wanted us to feed them the answers
- One of them like just moved her hands just to pretend like they were doing it
- Learned helplessness
- Yeah

*(Group Focus Interview at Makerspace Project School)*

**Researchers’ Reflection**

In the focus group interview several of the PSTs were very insightful about this opportunity to reflect on their own learning in science and pedagogy.

- The project really made me adapt to a teaching style I am not used to seeing where the teacher takes a step back from the learning and the students discover it for themselves. Although I read about it a lot in units, I haven’t really seen it done in classrooms that much; teachers tend to be so time poor that they end up giving the students the answers. It also gives an opportunity to really engage with science and engineering particularly with girls who are so under-represented in the field(s). *(Dawn)*

It provided a unique opportunity to engage with a different approach to science education.

- ......engaging with the project consolidated the half-formed theories in my mind and made them complete, so in terms of my own learning it was invaluable. I feel the interaction with students in a hands-on activity is also quite different to the ‘usual’ classroom activities I have experienced and so far taught, therefore experiencing how to coordinate these activities will be a huge advantage for my future approach to teaching science and technology! *(Henrietta)*

It was also helpful to increase PSTs confidence in science and teaching.

- Practising my confidence, patience and resilience to work through problems by myself. I hope to gain the ability to guide students in their thinking about circuits, as I worked through many of the problems too which will help my questioning abilities during the session. I think this whole project is good in gaining self-confidence through achieving first the creation of the actual flower and circuit and then through being able to teach/guide the students to do the same. *(Leonie)*

**DISCUSSION**

**PSTs’ engagement and participation in the MIS project**

Whilst it must be acknowledged that a limitation of this project is the small number of PSTs involved, and data from a larger participant group may prove to be contrary, the PSTs indicated that they had concerns about the activity and were worried that the girls would ask questions that they could not answer. They had expressed a range of concerns: some were anxious about the science content knowledge and skills, whilst others were worrying about the pedagogical issues of working with the Year 5 and 6 girls. All of the PSTs in the study reported that they found the project to be valuable and enjoyed participating in the project. The PSTs reported that their concerns had been addressed, and their STEM and pedagogical knowledge improved.
Reflective Identity Formation Model Future

The model was created to frame the project with the goal of scaffolding the PSTs to develop a STEM identity. It used an activity-based, learning-by-doing approach that the PSTs reported as an effective way to improve their STEM knowledge and skills. It also incorporated a series of reflections to encourage PSTs to consider how the activities have improved their STEM and pedagogical skills and knowledge.

"I feel the interaction with students in a hands-on activity is also quite different to the 'usual' classroom activities I have experienced and so far taught, therefore experiencing how to coordinate these activities will be a huge advantage for my future approach to teaching science and technology!" (Henrietta)

Future

This study was a pilot to develop the model and to investigate how the PSTs and ES engaged in the Makerspace Project. The model incorporates key components including learning-by-doing (where the PSTs and ES complete the activities themselves) then a reflective component (PSTs and ES consider the science and the pedagogy including the questions that they might ask the student), then the mentoring of the students in the classroom, and finally further reflection around their experiences. The model will continue to be validated in 2016 in a Curtin University funded project that, over the course of the school year, will see three iterations of the cycle.

EDUCATIONAL IMPORTANCE

This project seeks to promote female students’ (elementary and tertiary) engagement with and skills in STEM through the Makerspace concept. This is significant as girls even more so than boys, opt out of STEM subjects in secondary school, and also the predominant gender of elementary school teachers is female.

Further, whilst elementary school teachers generally find it difficult to wrestle curriculum contact time away from focussed mathematics and literacy teaching, often the reluctance to engage with STEM education lies in a lack of confidence in technology, science and engineering, - let alone providing opportunities for integration. We believe that the Makerspace in STEM approach supports the classroom teacher, and provides engaging opportunities for children to engage with authentic STEM education.

The characteristic of positioning the pre-service teachers as mentors is also significant as they tend to face the same attitudinal hurdles as the classroom teachers, and this approach enables them to develop their confidence and competence in STEM education. The new model of professional learning (Reflective Identity Formation Model) is significant in that it supports the development of personal and professional identity of the PSTs, and is highly reflective in nature, both of which we posit are key to generative learning.

REFERENCES


