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Re-Making Teacher Professional Development

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Abstract. With the introduction of the new two-year Bachelor of Education program across Ontario, our Faculty of Education has introduced a twenty-hour internship. This internship is meant to provide real-world teaching experience for teacher candidates, who are nearing the end of their formal education. By maker pedagogies, we refer to the inquiry-based, student-directed, constructionist approaches to learning typically used in makerspaces. Makerspaces have gained traction in Ontario classrooms, particularly in the last two years. These spaces and their pedagogies facilitate the development of students' global competencies (Hughes, 2017; Somanath et al., 2016). We welcomed eleven teacher candidates (TCs) into our STEAM 3D Maker Lab as part of their internship course for professional development (PD) to provide them with pedagogical experience in a makerspace environment. Our research focused on exploring how the TCs developed a better understanding of maker pedagogies and the associated tools through this PD. As the internship was created and facilitated by an education graduate student in the lab, we extended the research to also investigate this student's development in identifying and understanding some of the best practices associated with making as learning. Through analysis of the TCs' and graduate student's experiences, we identify some best practices in maker-focused professional development for beginning teachers.

Keywords. Making, Makerspace; Inquiry; Constructionism; Professional Development; Pre-service Teachers

1. Introduction

In recent years, the number of individuals participating in Do-It-Yourself (DIY) projects has increased significantly [5][8][17]. This idea of making individualized, tangible, real-world objects has prompted a new culture, known as the maker culture. The maker culture is one that promotes creativity, innovation and solving real world problems, while also sharing, 'hacking' and providing feedback to other, like-minded innovators (Halverston & Sheridan, 2014; van Holm, 2017). Often, makerspaces are equipped with tools that help individuals conceptualize their ideas through the creation of both digital and tangible artefacts.

Recently, makerspaces have become relevant in the lives of students as they are being given the opportunity to participate in making in the classroom [5], during after school programs and at libraries and universities within their communities [3]. Makerspaces are being introduced in schools as areas for students to make, innovate and learn. Often, makerspaces are associated with STEAM subject areas: Science,

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Technology, Engineering, Art and Math. These subject areas (with the exception of Engineering) are part of the Ontario Curriculum and teachers are required to report on each of them for every student. In addition, teachers often use these subject areas as vehicles for incorporating global competencies such as collaboration, communication, critical thinking, metacognition, perseverance and problem solving (Ontario Ministry of Education, 2015).

Wohlwend, Peppler, Keune and Thompson (2017) [16] explain that "*Making* encompasses a range of activities that blend design and technology, including textile crafts, robotics, electronics, digital fabrication, mechanical repair or creation, tinkering with everyday appliances, digital storytelling, arts and crafts—in short, fabricating with new technologies to create almost anything" (p. 445). The various ways that teachers approach the implementation of makerspaces in their classroom determine the culture that develops as a result of the making. With this in mind, it is critical that teachers are incorporating makerspaces in ways that promote STEAM education, as well as the global competencies that are so important in our society. The importance of these skills was stressed by the National Science Teachers Association (2011), which stated that, "One could argue that 21st-century skills have always been important. There is now a need, however, for these skills to be possessed by the majority of the population" (1).

Teacher professional development is essential for making change in the classroom when it comes to innovation. Regardless of the focus of the professional development, Avalos (2010) outlines that it is centered around three aspects: teachers learning, teachers learning to learn and teachers developing the ability to take that knowledge and educate their students. With these three factors in mind, it is important to also consider the constant professional development (whether it be personal, or meta-professional development or school initiated), that needs to occur to keep up with today's ever-changing technologies. Teachers participating in professional development have varying levels of comfort, knowledge and skills when it comes to makerspaces and the tools and pedagogical approaches that can be implemented in them.

While taking this idea of multiple entry points into consideration, Papert (1980) [12] proposed the concept of computer programs that provide learners with "low floors and high ceilings" so learners can easily engage with the technology and have room to grow. In this scenario, more experienced coders could also participate, while still being challenged (hence, 'high ceilings'). Resnick et al. (2009) [13] then expanded Papert's original concept to include "wide walls", which drew on the concept that different individuals have different interests and passions. The wide walls make room for those interests and passions to be incorporated into the learning, so that learners are even further engaged on a variety of levels. The concept of low floor/high ceiling/wide walls) poses a unique dilemma for educators with regards to how to implement this concept in their classrooms.

Although makerspaces, and the resultant maker culture, are becoming more common within schools, the identification of best practices for both implementation of teacher professional development as well as implementation of the maker pedagogies need further exploration. There is a dearth of literature with a focus on the importance of how teachers implement makerspaces in the classroom and in turn, the benefits that different approaches have on student learning. Our research aims to answer some of these questions. By inviting participation of both TCs and an education graduate student, we have several perspectives to draw from to help us address how an understanding of makerspace pedagogies and tools is developed, as well as idenitification of some best practices for professional development in this area.

2. Research Design and Process

Our investigation used a qualitative ethnographic, case study approach. We adhere to Markham's (2018) [7] definition of ethnography as "an approach that seeks to find meanings of cultural phenomena by getting close to the experience of these phenomena [and it is the study of] the details of localized cultural experience, through a range of techniques intended to get close and detailed understandings" (p. 653). We also adhere to Schwandt and Gates' (2018) [14] definition of case study, which is "the study of a social phenomenon carried out within the boundaries of one social system..." [14]. Our participant pool included eleven TCs who applied for positions as interns and the education graduate student who facilitated the sessions. There were six PD sessions in total, which were divided into lab-based sessions in the first half of the internship and classroom-based sessions in the second half. Of the lab-based sessions, these included a mixture of inquiry and constructionist-based learning and facilitator directed learning. The remaining PD sessions took place in classrooms, where the TCs were mentored as they worked with K-8 students. Interns completed a pre-study survey about their comfort level with regards to makerspaces and their knowledge of makerspace pedagogies. Throughout the process, interns were asked to provide observations of their experiences, as well as complete a lesson plan that incorporated the technology. The graduate student also took field notes of her observations and kept journal reflections of her own experiences. Following the internship, participants completed an exit interview to identify what they felt were the benefits and challenges of the maker pedagogies and tools, and to reflect on their learning.

3. Findings

In examining the data, we drew on content analysis [2], which required several layers of coding. We first looked for themes across all data sources and developed these into codes. The codes were then applied to the data in our second wave of analysis. In our third wave, we looked at cross-case comparisons to determine whether the data we analyzed demonstrated true trends, representative of all participants, or of just a select few.

Below we report on the findings from the data and then discuss the educational significance. For clarity, the findings have been divided into the two main research foci: 1) How does an understanding of maker pedagogies and tools develop for teacher candidates, and, 2) What are some best practices to consider in maker professional development? These main headings are then sub-divided thematically. For the purpose of scope, we report on two of the case studies — one of the TCs and the education graduate student who facilitated the sessions.

3.1 How does an understanding of maker pedagogies and tools develop for teachers?

3.1.1. Employing interest-driven learning for engagement with the tools.

Intern. At the beginning of the research, many of the interns had some idea of what is a makerspace; however, they had limited experience with many of the tools that are used in this space. With this in mind, they were given the opportunity to choose the technology they wanted to learn in order to increase the likelihood of engagement. When asked what drove the intern to a particular technology, she explained:

> I really like the circuits and I see a lot of connections with science curriculum, my teachable...I've also learned Arduino. I want to use that on my placement. There's so much you can do with it and it really shows the applicability of understanding circuitry, so it's one of the techs that I've been learning...I've been learning it in the lab, but I've also been doing some self directed learning.

It was important for us to recognize the motivations that drove each participant to learn a specific technology. By allowing the intern to gravitate toward a tool of her own choosing, Arduino for example, this increased buy-in. The tool appealed to her background in science, as she could see the direct application in the classroom and connections to curriculum. In addition, this participant explained that the technologies she focused on were technologies that she had either "previously seen or used". This indicated to us that when learners are introduced to the tools in a makerspace, they may gravitate to the familiar in order to ground or orient themselves in the new environment.

Graduate student. In addition to the interns participating in interest-driven learning while engaging with the tools, the same was true for the graduate student. The role of the graduate student was to facilitate the professional development sessions. Included in her responsibilities was to help the interns problem solve when necessary. When questions arose, the graduate student was much better equipped to answer questions about the technologies that she took an interest in -- mainly Arduino. When she reflected on her experience, she stated that: "Many of the interns would come to me with questions about technologies that I was not so familiar with. In those cases, I would ask one of the other research assistants in the lab to help the intern navigate the problem. When interns who were using the Arduino ran into problems, I worked alongside them, problem solving and collaborating to try to find a solution." For the graduate student, there were many technologies that she could have chosen to become an 'expert' in; however, she was drawn to the Arduino because of her connection to it as a certified science and math teacher. In this sense, her learning was interest-driven, just as much as the interns' learning.

3.1.2. Employing inquiry-based and constructionist learning for experience with the pedagogies.

Intern. It was important to employ inquiry-based and constructionist learning in the professional development sessions in order to develop the intern's understanding of maker tools and pedagogies. The intern was never explicitly taught how to use the maker tools. Instead, she was given resources, minimal guidance and just-in-time support from the instructors and her peers. The emphasis was on inquiry and trial and error. By experiencing these teaching and learning practices in a controlled and safe environment and in reflecting on what and how she learned, the intern developed an understanding not only of the maker tools but the accompanying pedagogies. Through reflecting on the internship, she shared that:

> The internship taught me a lot about inquiry based learning and I'm very thankful for that because that's one of the things I really wanted to pull away from this -- I want to use inquiry based learning opportunities in my future practice. So it's very important that I understand how I go about that and what is involved in setting that up and preparing for that and making it effective and what's the role of the teacher and what does student learning look like?

Not only did she recognize the importance of herself participating in the inquiry-based learning approach, she also quoted the following passage from the Capacity Building Series (2013, p. 2) "Inquiry-based learning concerns itself with the creative approach of combining the best approaches to instruction, including explicit instruction and small-group and guided learning, in an attempt to build on students' interests and ideas, ultimately moving students forward in their paths of intellectual curiosity and understanding." She reflected on this quote saying "I feel like through my internship, I learned so much more about how to do that and how to do it effectively." Because she was given the opportunity to participate in the inquiry-based and constructivist learning, she was able to experience first hand, the benefits of using these pedagogies in a makerspace.

Graduate student. In addition to the interns developing their understanding of maker pedagogies through inquiry-based and constructivist learning, the graduate student also reported a similar experience. In order to facilitate the learning, she needed to be sufficiently prepared to field questions about the technology and help guide the interns in their learning. In her exit interview she shared, "In preparing for the sessions, I had to learn some of the technologies in more depth, specifically the Arduino. No one in the lab knew more than me, so I took my knowledge of circuits and applied this to the new technology (Arduino) as I explored how this tool could be connected to different parts of the science curriculum." When questioned about why this was helpful she shared, "I created my own understanding. The Arduino is a hard tool to understand so by teaching myself I was able to make those deep connections to other parts of science, so the learning was more meaningful. I learned because of my previous experience with science but I wasn't just being told the theory, I was actually applying my knowledge." The hands-on, inquiry-based learning required the graduate student to apply her theoretical knowledge of circuits to the Arduino. Knowing she had to eventually facilitate the sessions encouraged her to go deeper in her understanding.

3.2. Identifying some best practices for professional development in Maker

3.2.1. Positioning teachers in roles of leadership

Intern. At various points in time during the research, the participants were given the opportunity to lead making sessions. By giving the interns this opportunity, they had the chance to practice teaching others with various levels of understanding in a particular area (for example, circuitry). This was done in order to replicate a classroom setting with diverse learners. After analyzing the data, it became apparent that there were multiple benefits that came out of this kind of professional development. One of the most relevant was a shift in perspective on the use of the technology and maker pedagogies, as well as the challenges they pose. When reflecting on the experience of facilitating making with a group of adult learners, the intern stated, "You have to be able to think on your feet, you may be asked about a subject… and you can collaborate and discuss with your other members, but it's also part of the skills that you develop." In one of her written reflections, the intern also stated that, "The classroom setting with students is great to learn further because students will use tools in various ways and encounter issues that you cannot plan for. It is helpful to work in teams though, especially if it is the first time learning a technology." By providing the participants the opportunity to participate in a leadership role, they had the chance to collaborate, communicate and observe the ways that others interacted with the tools and responded to the new pedagogical approaches.

Graduate student. This internship was the first time that the graduate student had led professional development for maker pedagogies and the technologies associated with them. This opportunity was one that required her to demonstrate leadership. Throughout the process, she overcame challenges that she did not anticipate. One such challenge was that the interns learned much faster than she expected, so it did not take long for them to have complex problems with the technologies. An example of this was mentioned in her reflection, when she stated, "There were times when I really was not the expert. I know quite a bit about Arduino, but when the interns were unsure of why their circuit was not working, it took some collaboration between myself and the interns to discern what the problem was. We were able to use all of our knowledge of the technology, as well as the subject area (science) to determine the issue." In this leadership role, the graduate student encountered new issues she may not have otherwise, which stretched her understanding of the technology (Arduino) and prompted her to dig deeper with her learning. It also provided her an opportunity to observe the various types of questions and challenges that could arise in the classroom, especially with students who might reach nearer the technology's ceiling. Being in the position of a leader, she was able to observe the successes and failures of the interns, which differed from her own, to aid in the development of her own understanding of maker pedagogies.

3.2.2. Pairing lab-based PD with supportive classroom-based PD

Intern. The professional development that was offered to the participants took different forms throughout the internship. The interns were first given opportunities to participate in inquiry-based learning in the lab. In these instances, the interns had the freedom to explore whichever tool they were drawn to. The other opportunity was in a classroom setting, with support. When asked about which way she learned best throughout the process, the intern responded, "A combination of both -- personal inquiry and classroom setting with students. I need a bit of preliminary individualized learning time to get acquainted with the technology enough that I can provide some basic instruction or guidance." Through analysis of the data, it was apparent that both types of professional development served a purpose throughout the experience. With that being said, it is important to note that the sequence for delivery of each type was essential for success. As noted above, the intern needed the lab-based inquiry time in order to feel comfortable with the technology before she felt she could succeed in a classroom setting.

Graduate student. The graduate student benefitted from observing the TCs' learning in both the lab and classroom settings. This aided in her own understanding of the affordances of both settings for effective teacher PD. In her journal, the graduate student reflected, "We didn't start with the interns going into a classroom setting, because they had little knowledge about implementing making in meaningful ways, nor were they equipped with the knowledge of how the technology worked. I think that by doing that, we would have been setting them up for failure." The graduate student was able to witness different skills develop in the two distinct environments. Not only did she observe the interns developing these skills, but she was able to pin-point which environment was best for which skill-development, for her own pedagogy. She touched on this in her reflection, stating, "In the inquiry-setting, I noticed myself developing a lot of growth-mindset and critical thinking ideas, however in the classroom setting, there was a lot more effective collaboration and communication." Through the opportunity to facilitate these PD sessions, the graduate student realized that working in these two distinct settings (and bridging the lab and theory work with the practical and in-class work) is important if one is to develop the full range of skills required to successfully implement maker tools and pedagogies in the classroom.

4. Educational Significance

Before maker pedagogies can be successfully implemented in the classroom, teachers need effective professional development. From our research, we have found that effective professional development includes the following:

1. It allows for interest-driven learning of the tools
2. It uses an inquiry-based and constructivist approach to learning the tools
3. It includes opportunities for teachers to take on leadership roles
4. It provides a balance of pre- and in-classroom learning environments for the teachers to develop a deep understanding of the tools and pedagogies.

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