Guiding Pre-service Teachers to Making

by

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ABSTRACT

As our society becomes further driven by technology, schools need to consider adopting student-centered maker pedagogies that harness the capabilities of technology while disrupting traditional teacher-centered learning. This research aimed to understand how a progressive guided to self-praxis approach learning maker pedagogies can impact pre-service teachers' confidence and competencies and influence their teaching practices. Using a qualitative, interpretive case study, a small cohort of pre-service teachers participated in a three-phased, 20-hour Maker Lab internship. A four-tiered conceptual framework guided this study which used an iterative abduction analysis process to interpret the findings.

The results of this study highlight that these guided approaches with a community of learners supported pre-service teachers' competency and confidence growth with maker pedagogical approaches. These approaches also positively influenced the mindsets and agentic perspectives of pre-service teachers. However, there were unique barriers in secondary schools that adversely impacted Intermediate/Senior pre-service teachers' views on adopting maker pedagogies.

Keywords: pre-service teachers; maker pedagogies; agency; self-efficacy; situated learning

AUTHOR'S DECLARATION

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MARGIE S. LAM

STATEMENT OF CONTRIBUTIONS

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

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LIST OF ABBREVIATIONS AND SYMBOLS

AI	Artificial intelligence
AT	Associate Teacher
B.Ed.	Bachelor of Education
CoP	Community of Practice
I/S	Intermediate/Senior
IoT	Internet of Things
ML	Machine Learning
MKO	More Knowledgeable Other
OTU	Ontario Tech University
P/J	Primary/Junior
RA	Research Assistant
STEAM	Science Technology Engineering Arts and Mathematics
STEM	Science Technology Engineering and Mathematics
ZPD	Zone of Proximal Development

Chapter 1. Introduction

1.1 Technology-influenced Society

Over the last decade, we have embarked on the Fourth Industrial Revolution, led by ground-breaking technologies that continue to augment and strengthen our global systems and societies. These technologies have been integrated into almost all aspects of everyday life from the explosion of connected smart objects, to the growth of enabling technologies like Artificial Intelligence (AI), Machine Learning (ML) and Robotics, to the rise of virtual worlds and online platforms changing the way we communicate and interact (World Economic Forum, 2020). The growth of the Internet of Things (IoT) smart devices by late 2019, connected through the near-instant 5G wireless networks, expanded by 329%, interconnecting over 17.7 million everyday objects worldwide (Bechtel, Buscaino, Erb, Golem, & Hickin, 2021). The current models for data expansion from these technologies concern many industries, governments and citizens. There is a sense of urgency to design data storage, organization, management, security and trust as cyber-attacks are growing, driving the need for adaptable solutions, advanced cryptography and a move to more open-sourced software and technology approaches (Bechtel et al., 2021). This urgency will only grow with more data accumulating daily and projections of exponential growth to the pace of technology adoption in the near future (Bechtel et al., 2021). The World Economic Forum Technology Futures Report 2021, analyzed and consolidated by leading industry specialists using quantitative and algorithmic analysis, has predicted significant technological transformations in our future society (Bechtel et al., 2021). The report projects energy economies prioritizing cleaner, renewable, low-carbon sources with further advances in battery technology to power driverless electric vehicles travelling at synchronized speeds on traffic-free roads. A transformation of Web 2.0 is predicted to merge the physical and the digital realms forming an always-on Web 3.0 or spatial web where global citizens will share 3D digital experiences in a virtual world (Bechtel et al., 2021). The report also forecasts how technology is reimagining future careers by nullifying the “one career, one company” principle to a more “liquid workforce,” encouraging society to think about why we work and for how long (p.31).

1.2 Technology and Future Careers

Many future careers will require a working knowledge of technology and its capabilities. The World Economic Forum (2020) Future of Jobs Report has estimated a shift of 85 million jobs to machines by 2025, while technological advancements in industries and corporations will result in 97 million new jobs requiring machine and algorithmic competencies. Many new careers in the green economy or data and AI economy have never existed; other vocations in engineering, product development, and cloud computing have been modified and require computational and technical knowledge (World Economic Forum, 2020). Yet the future of rapid technological innovations has come much more rapidly than expected with the Coronavirus outbreak. Rapid technological developments enabled our world health, economies and global workforce to survive the first devastating ways of the COVID-19 pandemic forcing citizens to change how they interacted, worked and learned (Reimers, 2021). Medical industries quickly modified how they diagnosed and treated patients by integrating automation to limit human contact (Dorn, 2020) and manufacturing revolutionary vaccines and life-saving treatments enabled by emerging technologies (Klobucista, 2022). Online work, communication and education stress-tested our wireless networks while demanding people to rapidly adapt to new software, online communication platforms and learning systems. Much of the global workforce had to shift to working from home during the height of the pandemic. As we near the seventh wave of COVID-19, many corporations and employees have acknowledged the benefits of this arrangement advocating for a new model of flexible and remote work options enabled through technology (Bechtel et al., 2021). As we have learned to adapt to a global pandemic and prepare for our future society, it is clear that technology is significant to our lives and will continuously change the way we work, how we innovate and the career options available for our global workforce.

The immediate disruption from COVID-19 to our world and ways of working and the rapid and ever-growing technological advancements in businesses have highlighted the need for adaptability and increased the demand for new job skill sets and competencies. Since the advent of the Fourth Industrial Revolution and the explosion of technological change in society and industries, job skill gaps have grown, and projections highlight a continued expansion in the immediate future (World Economic Forum, 2020). The World Economic Forum (2020) Future of Jobs Report summarizes the leading skills grouped by employers, which include: skills in self-management such as active learning, resilience, stress tolerance and flexibility, critical thinking, analysis, and problem-solving. The report further emphasizes that many employees and new graduates lack these skills and as a result companies are required to upskill their workforce (World Economic Forum, 2020). Our 21st-century knowledge society demands adaptive skills, flexibility and a workforce that can collaborate dynamically and critically to problem-solve, innovate and navigate an ever-changing, uncertain world (Lee & Hannafin, 2016). These global competencies will only be achieved by adopting a new way of evaluating unfamiliar and ambiguous issues or challenges and inventing cooperative, empathetic solutions that require risk and persistence (Davidson & Price, 2017). We can no longer do the things we have done precisely the way we have done before; our society demands education reform to meet these emerging needs.

1.3 Technology and Education

Many educational organizations worldwide have recognized the need to reform learning and prepare students for a dynamic and technology-enabled future society. It is common to view new policy documents and revised curricula spear-headed by Ministries of Education with the popular catchphrase "21st-century learning or skills" (Blikstein, 2018, p.422). The challenge is that most of these top-level transformation initiatives are superficial (Resnick, 2002) lacking a comprehensive and collaborative vision (Christou, 2016; Ertmer, 1999; Ontario Public School Boards Association, 2015), implementation strategies (Finley & Hartman, 2004), resources (Winter, Costello, O'Brien, & Hickey, 2021) and funding (Reimers, 2021). Along with the slogan 21st-century learning, educational institutions have made considerable investments in educational technology, hoping it will quickly transform many traditional-based school systems where change is notoriously slow (Blikstein & Cavallo, 2002; Rudd, 2013).

Although technology has supported the survival of education through online learning during the pandemic and aids many physically challenged students through assisted technologies, the widespread revolution in student experiences and teaching methods has not been achieved (Hughes, 2017; Martin, 2015). The fact that technology can be so disruptive to society yet lacks an equally powerful impact on schools seems perplexing, particularly knowing that today's children have always been immersed in technology. Scratch coding platform co-developer and progressive researcher Mitch Resnick (2002) has suggested that many children have an inherent capacity to consume and play with technology but lack significant scholarly aptitudes for designing, programming and creating with technology. He has described this notion as being “digitally fluent,” where learning with technology involves discovering how it works, harnessing its capabilities and using it to design innovative products (p.33). Digitally fluent educators understand that technology alone does not deliver significant learning (Serdyukov, 2017). Instead, pedagogical practices that leverage technology as an enabling instrument can support better learning outcomes (United Nations, 2020).

1.4 Maker Pedagogies and Agentic Potential

Student-centered approaches that integrate hands-on, active and collaborative learning processes like maker pedagogies are one effective method for adopting technology in meaningful ways in schools while fostering global competencies. Maker pedagogies promote the principles of hands-on tinkering and designing innovative products in collaborative and supportive spaces fostering unique philosophies related to risk-taking, failure-positive learning, problem-solving, critical thinking, and sharing (Hughes, 2017). The leading advocate of the maker movement Dale Doughtery (2013), has argued that maker pedagogies could revolutionize teaching and learning, disrupting current educational practices. Researchers have supported this view by demonstrating many of the benefits of makerspaces in education, including the fostering of computational competencies (Martin, 2015), technical knowledge (Davidson & Price, 2017), and global skills such as collaboration (Vossoughi & Bevan, 2014), resilience (Hughes, Fridman, & Morrison, 2016a), problem-solving (Blikstein, 2013), creativity (Tan, 2019) and design-based thinking (Sheridan, Halverson, Brahms, Litts, Jacobs-Priebe, & Owens, 2014). Despite the research supporting educational making benefits, Hira and associates (2014) describe some significant challenges to implementation in schools related to technology and resource management, accountability to standardized testing and curriculum, and ensuring equitable practices and teacher preparation.

Researchers Ertmer (1999) and Datnow (2020) suggest that teachers are the key to any educational reform, including making in schools, as they are the direct conduit to students and their learning experiences and hold the ultimate responsibility of implementing change. Teachers face many barriers to maker pedagogies, and as such, they require flexible, ongoing, and collaborative teacher professional maker education that is continuously supported through mentoring, coaching and agentive capacities so they can build momentum to address school culture and instructional practice challenges (Hughes, Morrison, & Robb, 2021). Enabled by school directives, supportive administration and vision alignment from school districts, these maker teachers could have the potential to influence educational reform from the bottom-up. Pre-service teachers could further support this momentum as waves of new teachers with agentic drive in making or through unique pre-service teacher maker education program practicum experiences of mutual mentoring with in-service teachers (Winter et al., 2021). While there is emerging research on the effective practices for in-service teachers with maker pedagogies, there is a distinct lack of literature supporting the educational methods for pre-service teachers on making in education (Jones, 2021). This study evaluated a guided inquiry approach to learning maker pedagogies with emerging technologies in a Faculty of Education Maker Lab with pre-service teachers and how to influence the development of competencies, confidence and their mindsets towards teaching and learning.

Chapter 2. Literature Review and Research Problem

2.1 Literature Review

The ultimate goal of this thesis is to contribute to the growing body of literature on pre-service teacher maker education and effective practices to support this innovative and novel approach to teaching and learning in education. While educational library makerspaces are dominant in schools, making in classrooms is more elusive (Rouse & Rouse, 2022). Adopting maker pedagogies is challenging for in-service and new teachers as there are various barriers embedded in our traditional education system (Sang & Simpson, 2019). New teachers have unique challenges and will require the competencies, confidence, and maker mindset to navigate and overcome these barriers. A new way of thinking, learning and teaching could help drive organic educational reform from the bottom of the organization upwards and create the learning experiences and skill sets demanded in our ever-changing and challenging world.

To develop the research parameters driving this study, it was necessary to evaluate the existing literature related to the maker movement and educational makerspaces, barriers to educational reform, and the analysis of pre-service teacher maker education. The following section offers a view of the literature highlighting practical challenges and considerations of each theme and was used to identify the gaps and support the development of the research questions and study approach.

2.1.1 Maker Movement

The maker movement has become an international phenomenon involving an ever-growing population of citizens who embarked on the innovative design and creation of artifacts shared with a community of learners in makerspaces and a wider online collective (Halverson & Sheridan, 2014; Sung, 2018). In 2006, the maker movement was popularized in the United States through companies like Make Media, and its publication MAKE magazine (Blikstein, 2018; Halverson & Sheridan, 2014; Hira, Joslyn, & Hynes, 2014; Sang & Simpson, 2019). A year later, this social movement was promoted further through the inaugural Maker Faire hosted by Dale Doughtery, who owns Make Media and coined the maker movement phrase (Bullock & Sator, 2015; Sung, 2018). Do-It-Yourself (DIY) enthusiasts, hobbyists, engineers, inventors, and educators have attended these Faires and lauded the maker movement for bringing people together to share, discover, and collaborate on making activities and the artifacts created through these hands-on processes. These Maker Faires have continued to expand both in the U.S. and internationally where in 2016 more than 1.44 million people in 28 countries were in attendance, including in 2014, a White House Maker Faire which ignited educational program research and developments (Sung, 2018).

The maker movement was strengthened by several key developments during the last several decades including DIY citizenship, ubiquitous communication networks, and the democratization of technology. The DIY culture has slowly built up since the 1960’s finding a launch pad in the maker movement (Stornaiuolo & Nichols, 2018). The DIY approach is one where people shift from only consuming mass-produced goods to creating personal products (Resnick & Rosenbaum, 2013; Taylor, 2016). These citizens are often driven by pride in creating their own products (Resnick & Rosenbaum, 2013), a desire to change the world (Litts, 2015) or influenced by corporate and government incentives (Litts, 2015; Sang & Simpson, 2019; Sheridan et al., 2014) such as President Obama's Educate to Innovate Campaign which encouraged "...young people to create and build and invent - to be makers of things, not just consumers of things." (The White House, 2009, para.69). In making, DIY philosophy has influenced makers to consider the challenges of a consumer society and to consciously develop meaningful products, not to revert back to a time when everything was handmade (Sang & Simpson, 2019). This emphasis on social consciousness and liberatory features has associated the maker movement with an aspect known as critical making where people challenge why they make a product, who will be impacted and how it can help society (Bullock & Sator, 2015; Hughes, 2017).

One of the most significant drivers of the maker movement has been the exponential advances in technology over the past few decades. In the last several years, our communication infrastructures and networks have been embedded in all aspects of society (Bechtel et al., 2021). The speed and size of these invisible networks have grown enormously along with the interconnection of smart objects making access to global data and information seamless, precise, and lightning-fast (Bechtel et al., 2021). Communication online through social media, websites and hosting platforms, and an ever-growing list of apps has enhanced making ideas, provided opportunities to share making insights, and assisted problem-solving and learning (Martin, 2015; Martinez & Stager, 2013). In terms of digital fabrication, the last decade has experienced a democratization of both hardware and software technological tools due to the dramatic reduction in price and increase in ease of use and accessibility (Blikstein, 2018; Bullock & Sator, 2015; Cohen, Jones, Smith, & Calandra, 2017; Halverson & Sheridan, 2014; Resnick & Rosenbaum, 2013; Valente & Blikstein, 2019). Researcher Sung (2018) highlighted this phenomenon by explaining how in just over a decade 3D printers have shifted from being too expensive and complicated for everyone but a few engineers or technicians to become part of the making process for untrained elementary students. The culminating technological shift to open-source software and hardware, along with investments and developments from technology corporations and higher-ed institutes have provided free and easy-to-use coding platforms like Scratch, Alice, NetLogo, Arduino and Makecode making it much easier to integrate programming logic and smart functionality in technological artifacts produced through making (Blikstein, 2018; Blikstein & Krannich, 2013; Martinez & Stager, 2013).

The DIY philosophy has motivated and inspired makers around the globe, while technological advancements have elevated making to an international phenomenon. Yet, the act of making is not a new activity. Citizens have been creating and innovating for centuries through activities such as crafting, baking, sewing, and woodworking. The uniqueness of the making activities is the interconnections and interdependencies to the making community, helping foster the maker mindset (Godhe, Lilja, & Selwyn, 2019; Litts, 2015). Halverson and Sheridan (2014) described making as a more comprehensive activity than just producing artifacts where there is a critical aspect of collaborative learning and sharing processes and products with a community of makers that share in the same philosophies of playful experimentation, innovation and risk-taking, failure-positive learning, willingness to support others, and acceptance that anyone can ask, learn, teach and grow. The three key elements: making activities, making community and maker mindset, mix together in a makerspace creating a trifecta of innovation, support, sharing, learning and fun.

At the nucleus of this triad are the making activities that Litts (2015) described as having evolved from constructivist discovery learning, constructionist epistemologies of learning-by-making, and engineering principles. Driven by interests and passions, makers delve through unique making processes to create, learn, invent, fix or solve a need with a new or remixed product or design. These making processes can involve a blend of self-directed or collaborative hands-on tinkering, ethical hacking, and informal design-based practices (Davidson & Price, 2017; Gilbert, 2017; Resnick & Rosenbaum, 2013; Stager, 2013). Not to be confused with the nefarious act of criminal 'hackers,' ethical hacking is often observed in public makerspaces as members disassemble and reassemble machinery or technologies to discover and learn the inner mysteries (Bullock & Sator, 2015). Resnick and Rosenbaum (2013), constructionist and making advocates, have described tinkering as an essential inquiry-based learning practice that encourages discovering and learning about products, technologies, machinery and processes. The researchers characterized tinkering as hard fun through iterative, playful experimentation and, in some makerspaces, can traverse design phases of ideation, prototyping, iteration and reflection but in a much less structured way (Resnick & Rosenbaum, 2013). These inquiry-based making practices are self-directed by makers using tools, materials and ingenuity to not only produce meaningful and shareable artifacts but also to learn interesting concepts, strategies and competencies in the process (Davidson & Price, 2017; Litts, 2015; Martin, 2015; Sheridan et al., 2014; Stager, 2013).

Supporting and encouraging these hands-on activities is an ever-growing community of makers who share a common mentality. The community of makers typically begins in makerspaces but can extend globally and offers a culture of support, sharing, observing, teaching, collaborating, providing insights, and having fun. Some researchers equate the making community to Lave and Wenger's (1991) concept of Communities of Practice (CoP), while other researchers liken this culture of making to Scardamalia and Bereiter's (2006) knowledge building community (Berman, Garcia, Nam, Chu, & Quek, 2016; Martin, 2015). Regardless of the comparisons, there are key aspects identified as characterizing features of making communities, including mutual trust and support, a sharing practice with resources, knowledge, experiences and feedback, inclusive and welcoming to all, and a common work ethic based on trial and error, risk-taking, and intellectual stimulation (Vuorikari, Ferrari, & Punie, 2019). This collective of like-minded tinkerers and creators thrives in welcoming makerspaces that encourage roaming, observing, testing prototypes, asking questions, learning, providing insights or feedback, teaching, or even just laughter and play (Vossoughi & Bevan, 2014). In these environments, it is common to hear novice makers helping experts, loud declarations of discoveries and other forms of "collaboration through the air" (Kafai & Harel, 1991, p. 88). Being a part of this kind of community helps promote a sense of identity as a member of like-minded innovators and creators who support collaborative learning, productive struggle, and iterative cycles of failure and improvement (Sheridan et al., 2014). These makers are not afraid to fail and deal with some frustration because they recognize the importance of productive struggle and learning from mistakes in the process of improving prototypes. Dale Doughtery (2013) labelled this philosophy the maker mindset with several attributes, including having a growth-oriented disposition, a risk-taking and fail-positive orientation, and a desire to collaborate and have fun (Martin, 2015). While Chu, Quek, Bhangaonkar, Ging, and Sridharamurthy (2015) proposed three specific attributes of the maker mindset that are based on social psychology: "self-efficacy (I can make), motivation (I want to make), and interest (I like to make)" (p. 11).

Born out of the needs of the making community, makerspaces have grown internationally, becoming the most recognized aspect of the maker movement. According to notable making researchers Halverson and Sheridan (2014), makerspaces have elevated the maker movement from a mere conceptual idea to the physical manifestation of making that can be observed, experienced and enjoyed. Embodying the community of makers, makerspaces are typically described as publicly accessible, creative and physical spaces filled with culturally relevant tools, expertise and materials for making activities and an ethos of active participation, collaboration and exploration (Litts, 2015; Schad & Jones, 2020). Embedded in and reflective of the communities they are situated in, no two makerspaces are alike. The uniqueness of each makerspace is built organically from the needs and wants of the local members and is evidenced in the various tools, materials, spaces, themes, and community projects (Davidson & Price, 2017; Hughes, 2017; Litts, 2015). A common misconception is that makerspaces require expensive and highly complex machinery and tools like modern fleet manufacturing tools, high-end laser cutters and industrial 3D printers (McKibben, 2014). Experts contradict this belief, highlighting how makerspaces have evolved from technically-focused hackerspaces and structured fab labs to offer a range of analog and/or digital tools that serve their local areas and may include arts & crafts materials, cardboard & recyclable options, sewing and textiles, woodworking & carpentry equipment, multi-media stations, or technology hubs with microprocessors, robotics, circuitry, 2D/3D tools and AR/VR equipment (Blikstein, 2018; Gilbert, 2017; McKibben, 2014; Vuorikari et al., 2019).

In makerspaces, more significance is placed on the relevance and variety of tools versus the specific types of tools. These tools and materials should be visible to promote ideation and experimentation (Davidson & Price, 2017) and offer a range of accessibility (Vuorikari et al., 2019). Seymour Papert, the father of constructionism and influencer of the maker movement, proposed that the range of maker tool options should include those that are easy to use for novices (low-floor capabilities) and expand to include tools that offer greater complexity and challenge to their projects (high-ceiling capabilities) (Resnick et al., 2009). Former student of Papert and advocate for constructionist learning Mitch Resnick further suggested that tools should support a wide walls aspect by encouraging the imagination of learners in creating anything they desire (Resnick et al., 2009). An advocate of educational computing and co-creator of the block-based, easy-to-program Scratch coding platform, Resnick has advanced the idea of integrating more technology and coding in educational makerspaces as they provide enabling options for low floor, high ceiling and wide wall capabilities (Resnick & Silverman, 2005).

2.1.2 Educational Makerspaces

A massive shift from commercial, membership-funded makerspaces to public, government-funded makerspaces in museums, libraries and now educational makerspace libraries have become the norm encouraging informal learning practices and creative spaces for all types of learners (Cohen et al., 2017; Gilbert, 2017). Benjes-Small and associates (2017) research on the impact of the maker movement on academic libraries highlights how makerspaces have reformed the perception of many libraries from warehouses of information to innovative and active school community learning spaces. Many of these educational makerspace libraries have been relabelled as “hubs of 21st-century creativity” and re-designed into more open, collaborative locales with increasing supplies of educational technologies to promote hands-on, making practices (Mestre, 2020, p.273). Promoted by making advocates as transformative, educational makerspaces build on the constructivist and constructionist principles of active discovery and empowering learning experiences (Litts, 2015; Martin, 2015). Contrasting to traditional passive teacher-centered learning, researchers highlight how these educational makerspaces engage students in the hands-on discovery of new processes and concepts while they collaboratively build artifacts and then share insights, ideas and learnings in their school making community (Tan, 2019; Valente & Blikstein, 2019).

In support of these potentially transformative learning environments, there is a growing body of research devoted to exploring the capacities, capabilities and challenges related to educational makerspaces. Valente and Blikstein (2019), leading makerspace researchers, conducted a significant and unique case study that demonstrated how knowledge was constructed through making activities and emphasized some of the important implications for student learning. This research is crucial in demonstrating to educators that students can build knowledge through making, however, the researchers stipulate teachers need to use rich activities and continuously challenge, guide, and promote students to interact with their designs and peers to help them assimilate concepts and strategies used (Valente & Blikstein, 2019). These findings tie closely to the theoretical propositions advanced by Piaget, where teachers are encouraged to support student discoveries and Vygotsky's concept of the More Knowledgeable Other (MKO), where instructors can guide the conceptual learning process for students (Lee & Hannafin, 2016; Valente & Blikstein, 2019).

Much of the research related to making in education is focused on exploring the development and fostering of global competencies. Vastly based on qualitative analysis, several studies highlighted the development of numerous skill sets, including collaboration (Berman et al., 2016; Braga & Guttmann, 2019), creativity (Caballero-Garcia & Grau-Fernandez, 2018; Saorín et al., 2017; Tillman & Smith, 2018), risk-taking (Gruen, 2018; Hughes, Laffier, Mamolo, Morrison, & Petrarca, 2016b*)*, problem-solving (Doorman, Bos, de Haan, Jonker, Mol, & Wijers, 2019; Tishman & Clapp, 2017); critical thinking (Gruen, 2018), failure-positive approaches (Brahms, 2014; Gruen, 2018), and self-efficacy (Girvan & Savage, 2019; Hilton, Tomko, Newstetter, Nagel, & Linsey, 2018; Martin & Klein, 2017). This body of literature supports the idea that the process of making is more comprehensive than just building an artifact and involves a community of learners who share and support and teachers who engage and challenge, fostering the development of global competencies that help form the students' maker mindset (Halverson & Sheridan, 2014). And as educational makerspaces have developed, further insights and investigations have emerged. The research from Braga and Guttman (2019) and Doorman and colleagues (2019) highlighted specific characteristics of mutual engagement, knowledge sharing and creative support that help build CoPs during making activities. In the study from Sinha, Rieger, Knochel and Meisel (2017), student engagement was a significant finding which emerged from an informal mobile makerspace activity with 3D design and printing. As many educational makerspaces today involve making with emerging technologies, it is not surprising to discover studies demonstrating students’ computational learning (Atmatzidou & Demetriadis, 2017; Chou, 2018; Hughes, Gadanidis, & Yiu, 2017). The detailed case study from Richard and Giri (2019) evaluated the practices of grade nine students engaged in integrated making activities and published key findings on collaborative skills and unique patterns of computational thinking. Chamrat (2018) published one of the few quantitative studies on educational makerspaces. The academic performance of middle-school students in a maker camp was evaluated through this experiment, with statistical results demonstrating a significant increase in students' electrical concept knowledge (Chamrat, 2018). These results are unique, however, and are not generalizable considering contradictory findings from Blikstein, Gomes, Akiba, and Schneider (2017), who evaluated students’ academic performance and did not find any significant improvement.

The literature on educational makerspaces has overwhelmingly highlighted positive outcomes from various studies; however, there have been several criticisms of these results and the lack of alignment with publicized student learning gaps (Government of Ontario, 2019; Reimers, 2021). A significant challenge has been reported by researchers Nichols (2020) and Bevan, Gutwill, Petrich, and Wilkinson (2015), who argued that most of the published gains for educational making came from non-teacher, maker specialist-led activities conducted in informal learning contexts. These making situations have ranged from after-school clubs to one-off or unique workshops to mobile maker visits to private or specialized school set-ups, all of which are outside of the typical K-12 curriculum-learning public classrooms. A systematic review of the literature related solely to making in formal, educational contexts by Rouse and Rouse (2022) highlighted a mere 22 published studies, with much of the literature published in the last four years. Although the transition to making in the classroom has not been studied as thoroughly as the school library and informal makerspace learning activities, Rouse and Rouse’s (2022) meta-analysis highlighted some emerging ways teachers are adopting maker pedagogies. For many teachers, the culture of one-size-fits-all curriculum standards has been a deterrent to implementing making activities in their classrooms (Godhe et al., 2019; Lock, Santos, Hollohan, & Becker, 2018; Rodriguez, Smith, & Harron, 2021). Recent global corporate and societal influences on injecting STEM, engineering and programming into education, however, have resulted in some nations reforming their curriculum and policies (Cision PR Newswire, 2022; Davidson, 2022). These top-down educational reform initiatives can provide the impetus for bottom-up alignment when teachers feel empowered and supported in the implementation of innovative pedagogies (Serdyukov, 2017; Twining et al., 2021; Ungar, 2016). A larger, qualitative study on educational making, conducted in Finland by researchers Kajamaa and Kumpulainen (2019), was supported through successful curriculum reforms focused on STEAM (Science, Technology, Engineering, Arts, Mathematics) concepts and student-centered pedagogical practices involving design and digital learning. The research involved 535 students, with 28 teachers facilitating the maker approaches that demonstrated the enhancement of student creativity and transformative agency (Kajamaa & Kumpulainen, 2019). These findings are significant in the length of study and the fact that in-class teachers co-planned and facilitated the making activities which were aligned to the curriculum and assessed.

As curriculum reforms are integrating STEM or STEAM, coding and engineering concepts and more and more technologies are supplied, making opportunities are rising, but the challenges teachers face in most schools remain. Making critics have argued that the traditional school environment of passive learning by failure-adverse students seems highly unlikely to be transitioned to a divergent culture of active, risk-tolerant making experiences (Gilbert, 2017). These making experiences are often personalized (Bullock & Sator, 2015) and involve long durations (Campos, Soster, & Blikstein, 2019), open-ended solutions (Jin, 2021), interdisciplinary learning (Resnick, 1998), multiple cycles of fail and revise (Vossoughi & Bevan, 2014), and no guarantee of uniform, subject-specific learning (Halverson & Sheridan, 2014; Tan, 2019). Compounded with the fact that teachers are driven by packed curricula, subject silos, timed work periods, standardized testing, and accountability (Berman et al., 2016; Godhe et al., 2019), maker pedagogies present significant challenges related to assessment, meeting learning outcomes, supporting students needs, and time (Fasso & Knight, 2020; Lock et al., 2018; Tan, 2019).

To overcome these barriers, many teachers have assimilated making activities into their traditional, teacher-centered pedagogies (Fields, Kafai, Nakajima, Goode, & Margolis, 2018). Making advocates warn about appropriated projects that can be described as prescriptive recipe-style labs or trivial cookie-cutter tasks that lack student creativity, agency, and meaningful learning experiences (Resnick & Rosenbaum, 2013; Vuorikari et al., 2019). Electronic or kit-building activities have been included in some classes as making activities, however, Davidson and Price (2017) have described the inefficiencies with these tasks as offering limited or short-term experiences that are robbed of risk and personalization. Blikstein (2013), a regularly cited makerspace researcher, described the “keychain” syndrome in some schools' attempts at making (p.8). This syndrome refers to teachers leading quick remix-style modelling methods where all students develop similar 3D printed keychains, but the experience lacks meaning and context and focuses more on the product than the process (Blikstein, 2013). In these scenarios, untrained or unprepared teachers focus on technology instead of pedagogy to engage students, lacking substance and contextual learning (Davidson & Price, 2017; Vossoughi, Hooper, & Escudé, 2016). Making activities in the class requires careful consideration of curriculum ideals (Iwata, Pitkänen, Ylioja, Milara, & Laru, 2019; Vuorikari et al., 2019), scaffolded and authentic activities (Fasso & Knight, 2020; Hughes, 2017), the current class culture (Hughes & Morrison, 2020), student passions and learning needs (Somanath, Morrison, Hughes, Sharlin, & Sousa, 2016; Stergiopoulou, Karatrantou, & Panagiotakopoulos, 2017), equitable learning practices (Vossoughi et al., 2016), assessment strategies (Litts, 2015), design and setup of the classroom (Nichols, 2020), materials, tools and their usage considerations (Stager, 2010), and methods to foster, challenge and enhance student learning and mindsets (Valente & Blikstein, 2019).

Integrating robust maker pedagogies requires planning time, risk-taking, resources, testing, flexibility and most importantly ongoing, professional development and supportive environments (Hughes et al., 2021; Lock, Gill, Kennedy, Piper, & Powell, 2020; Stevenson, Bower, Falloon, Forbes, & Hatzigianni, 2019). Many teachers lack confidence and competencies with technologies and student-centered pedagogies like making (Finley & Hartman, 2004; Lock et al., 2020; Stevenson et al., 2019). Partnerships with maker specialists or researchers can support school improvement efforts including integrating emerging technologies and implementing maker pedagogical approaches (Datnow, 2020). Researchers Becker and Jacobsen (2019) conducted a design-based research project working collaboratively with a sixth-grade teacher to implement a sky science makerspace project. The research findings focused on both the student and teacher developments highlighting engagement and deeper science learning and a change to their pedagogical approach, respectively (Becker & Jacobsen, 2019). A larger study in the United Kingdom by Marsh et al. (2019) involved four different schools and 223 students with teachers partnered with maker specialists to provide the making interventions. The project aimed to understand student maker agency and findings support key aspects of the development of student agency and the importance of sharing knowledge in the making community. As a result of this study, several teachers not only participated in maker training but co-planned, tested and co-facilitated making activities with their students providing an essential element of supported professional development (Hughes et al., 2021; Jones, 2021; Marsh et al., 2019).

In Ontario Canada, a massive and unique partnership between lead researcher Hughes, Morrison, and Thompson (2018a) and twenty different school board districts in Ontario resulted in a progressive two-year qualitative, action-oriented participatory study investigating the impact of using maker pedagogies in the teacher and learning process. Sixty teachers from twenty schools representing the school districts were involved in the study which discovered four main themes: challenges with maker pedagogical practices; supports necessary for shifting teachers to maker pedagogical practices; promising practices associated with maker pedagogies; and benefits of maker pedagogical practices (Hughes, Morrison, & Thompson, 2018a). The teacher professional development and support during the two years of this study was significant involving a two-day off-site maker pedagogy and technology learning workshop, funds to purchase maker technologies and tools for their school makerspaces, continuous communication, school visits for observation and consultation, and a final off-site targeted professional development session focused on making, subject-integration and collaborative learning with other teachers in different boards (Hughes et al., 2018a). These types of researcher-teacher partnerships provide an important opportunity for helping teachers integrate maker pedagogies in their practice and overcome environmental barriers (Datnow, 2020). Researcher Winter and colleagues (2021) highlight another potential strategy for ongoing professional development for in-service teachers through a partnership with pre-service teachers who have been trained and equipped with maker pedagogical approaches and technologies. This setup supports maker pedagogical peer-learning for in-service teachers and practical facilitation experience for pre-service teachers helping them bridge theory to practice (Winter et al., 2021).

Although educational makerspaces are dominant in school libraries, making in the classroom is evolving more slowly. There is promise through research partnerships, support of the administration and actions of risk-taking educators. Yet, the barriers to effective maker pedagogical integrations are significant and highlight a broader issue of how to effectively manage educational reform. The maker movement in education reflects innovative learning and progressive student-centered pedagogies and cannot be envisioned as a mere add-on to our current, first industrial-age-based, traditional system (Cohen et al., 2017; Morrison, Hughes, & Fridman, 2018). Research that examined tensions in a school-based makerspace by Campos, Soster and Blikstein (2019) concluded that educators and administrators need to recognize, confront, and debate school culture challenges before implementing making practices while a similar study from Tan (2019) suggested a fundamental shift in school culture was required. These are important considerations as only through the removal of barriers can educational makerspaces realize their transformative potential (Godhe et al., 2019).

2.1.3 Barriers to Educational Reform

Education systems are social institutions that serve the needs of society. According to the United Nations Universal Declaration of Human Rights, Article 26, every citizen has the right to an education which should be free and compulsory during elementary stages (United Nations, n.d.a). Universal public education is indispensable for democratic nations to foster just and inclusive societies that will drive our fast-changing and unpredictable world (Serdyukov, 2017; United Nations, 2020). Each new generation will face novel and ever-growing challenges that will need to be navigated and overcome through innovative and collaborative international initiatives. Existing challenges are becoming progressively dangerous to society from climate change to energy demands, to migration and global conflicts, to health crises that are forcing our world to adapt and develop strategic and equitable solutions (United Nations, n.d.b). New patterns of technological adoption are impacting virtually every industry demanding our workforces have flexible ways of working and develop global competencies and skills (World Economic Forum, 2020). Our educational systems need to adapt and innovate to meet the needs of our current and emerging societies' economic, social, and technological impacts (Christou, 2016; Serdyukov, 2017).

Many global education systems remain based on organizational models from the first industrial age, well over a century ago (Christou, 2016; Gilbert, 2017; Papert, 2002; Tan, 2019). The focus of these schools was to prepare students for the known world of work at the time. This led to a factory model of mass schooling where students were grouped by age-related cohorts, rules were strictly enforced, and subjects were siloed with short-duration learning delineated by a ringing bell (Gilbert, 2017; Godhe et al., 2019; Setiawan, 2020). Teachers developed pre-set, standard lessons conducted through teacher-centered pedagogies requiring passive learning devoted to rote memorization and a culture of right versus wrong answers (Gilbert, 2017; Sang & Simpson, 2019; Schad & Jones, 2020). This traditional model of learning has remained foundationally intact despite surrounding societal and industrial modernization. Author and scholar Fernando Reimers (2021) argued that traditionalists' primary concern for education is teaching the basics of literacy and numeracy. Focusing on these fundamentals in uniform and top-down curricula necessitates the learning expectations of students by grade which are measured through standardized testing both locally (Education Quality and Accountability Office, EQAO in Ontario) and internationally (Program for International Student Assessment, PISA) (Allison, 2021; Boyd, 2021; Organisation for Economic Co-operation and Development [OECD], 2010). According to Reimers' (2021) book evaluating various international education reforms, governments that heighten accountability to mathematics and language fundamentals often drive educators to "teach to the test" (p.185). This method typically reinforces continuous traditional teacher-centered instruction with passive student-learning methods while limiting meaningful opportunities to integrate student-centered pedagogies (Allison, 2021; Christou, 2016; Reimers, 2021).

Progressive educators have challenged the ideals of traditional education and advocated for more student-centered, active learning philosophies that can adapt and align to modern advancements (Blikstein, 2018; Christou, 2016; Sung, 2018). The ideology of progressivists has three essential tenets: schools should focus learning experiences on the passions of children rather than upon a traditional curriculum; students should be involved in hands-on, active learning experiences where they construct knowledge through the process of doing and making; and students need to be engaged in relevant, real-world activities that constantly evolve and adapt to contemporary society (Christou, 2016). These ideals were supported over a century ago by renowned scholar John Dewey, a proponent of learning-by-doing, who called for schools to focus on the lived experiences of children versus preparing them for social or occupational needs (Hansen, 2018). Many other progressive advocates and government bodies have aligned with these philosophies and attempted to implement policies and initiatives to transform traditional learning structures. In Ontario, we have witnessed three significant progressive educational waves that started in the 1930s with reforms on curriculum and examination structures, then cresting again in the late 60s focused on student exploration and redesigning classroom spaces and culminating recently with 21st-century learning and emphasis on Discovery math and curriculum revisions (Bennett, 2020; Christou, 2016). Arguably the most successful progressive education reform came during the early stages of this final progressive wave where the liberal government led by Dalton McGuinty partnered with education consultant, and now global education reform influencer, Michael Fullan. This reform focused on a centralized implementation strategy which involved renewed partnerships with teachers, professional development initiatives and significant investment (Boyd, 2021; Fullan, 2012). Although there was some initial success in students' literacy and numeracy scores and graduation rates, and some of the structural changes are still in place to this day, the classroom practices of teachers remained relatively unchanged from traditional methods (Bennett, 2015; Reimers, 2021). In fact, each of these progressive waves have fallen short of transformational promises despite initial, short-duration success (Milton, 2015). Traditional advocates argue that these initiatives are oversized and impulsive, catering to untested societal influences and lacking the necessary disciplinary focus needed for learning basic foundational content (Reimers, 2021). This back-and-forth battle of opposing learning approaches in education has been continuous for over a century.

The common view of education today is that the sector is confrontational to change (Setiawan, 2020) and with the polarizing and ongoing tensions between the rhetoric of traditionalists and progressivists, it is not surprising. The 2019 Ontario provincial government education platform appeared to have attempted to bridge traditional and progressive views with a 'Getting Back to Basics in Education' plan that emphasized modernizing the curriculum and classrooms (Government of Ontario, 2019, p.127). Yet critics maintain that neither of these goals can be achieved as the claim for modernizing lies in mandatory online learning and increasing class sizes. While curriculum changes have made encouraging updates to include technology, design, and programming, they lack classroom implementation strategies and a broader 21st-century learning vision (Bennett, 2020; Boyd, 2021; Christou, 2016). Curriculum reform has been at the heart of each new government's educational initiatives, promising transformation, student improvements and impactful educational change. The challenge with many of these curriculum reforms is how the curriculum was changed, the influences on the new curriculum, and how schools and educators are supported in learning and adopting the changes. Educational reformists argue that curricula are often modified based on political partisan views lacking comprehensive evidence-based content and practitioner input, leaving educators to grudgingly attempt to integrate without training, resources or sufficient adjustment time (Allison, 2021; Boyd, 2021; Ertmer, 1999; Setiawan, 2020).

Educational systems are complex and revising one aspect, such as curriculum, lacks the power to modify all components. According to the C21 and CEO Canada 2015 white paper (Milton, 2015) on 21st-century learning and the urgent need to transform education, superficial changes to the curriculum have often resulted in short-lived improvements that have not led to transformed educational practices and 21st-century learning. Educational reform is a process that involves changing the system in order to improve it. Influences on educational reform can range from student academic deficiencies and low standardized test scores (Reimers, 2021), to falling graduation rates (Boyd, 2021), to gaps in future-ready skills and competencies (Serdyukov, 2017), to political agendas (Allison, 2021) or broader issues of preparing students for an ever-changing modern and technical world (Christou, 2016). Serdyukov (2017), in his analytical review of education innovation in the United States, proposed that in order to meet the demands of the emergent knowledge society, education systems need to focus on innovation initiatives as opposed to facile curriculum reform. Innovation initiatives, the scholar argued, can produce considerable and transformative results that require large-scale implementation intended to increase productivity and improve learning quality (Serdyukov, 2017). Curriculum revisions alone are not innovative unless they fundamentally change the format and content. Student-centered learning focused on active, hands-on practices including maker pedagogies with restructured curriculum would be considered a transformative educational innovation as it would drastically reform traditional education practices and structure.

The majority of educational reforms around the world are not innovative in nature and lack transformative power, originating from the top of the educational institution. Government, top-down education reform policies have often aligned to partisan agendas, and therefore with each new elective body, old policies are uprooted and replaced with new mandates from the incoming administration (Allison, 2021; Reimers, 2021). Researchers Morrison, Hughes, and Fridman (2018) highlighted this constant ebb and flow of educational reforms where we take two steps forward in school improvements and one step back. In Ontario, the top-driven administration approaches are initiated by the central provincial government, through the minister of education, who determines major policies for schools, sets the curriculum and provides most of the funding for schools (OECD, 2010). The operational responsibility for these top-driven approaches lies with the deputy minister who is a civil servant and has the onerous task of negotiating implementation strategies with school districts and locally elected school boards (Milton, 2015; OECD, 2010). Most top-down reforms have taken a central direction approach with their policy frameworks by mandating change quickly, but these initiatives take time to carry out all of the activities progressively to reach the ultimate goals (Milton, 2015; Reimers, 2021; Serdyukov, 2017). Time is an elusive resource for many elected officials who demand change to support their elected platforms and demonstrate immediate results for their constituents. Consequently, top-down educational reforms are rapidly enforced, often lacking sequential and coordinated planning activities, resources and support, fluidity and adaptability to changing conditions, and fundamental stakeholder buy-in, particularly from educators who have the ultimate responsibility of implementing changes (Datnow, 2020; Le Fevre, 2014; Reimers, 2021).

Years of top-down mandated and hastily introduced education reforms have fortified barriers within educational institutions preventing meaningful change. These pushbacks to change can range from competing interests and overloaded workloads (Le Fevre, 2014; Milton, 2015; Priestley, Biesta, & Robinson, 2012), differing translations of initiative objectives (Reimers, 2021), contrasts between new assessment strategies and standardized testing results (Bernard, 2013), teacher skill and competency gaps (Fasso & Knight, 2020; Reimers, 2021) and stagnant school cultures (Datnow, 2020; Serdyukov, 2017). As articulated by scholar and researcher Peg Ertmer (1999) in her academic paper on Barriers to Educational Change, these types of institutional first-order barriers are extrinsic to teachers and often easier to eliminate than second-order barriers. Fundamental and intrinsic, second-order barriers are rooted in the personal beliefs and deeply ingrained doctrine of teachers, and when educators fundamentally oppose initiatives, it can cause significant obstacles to reform (Ertmer, 1999). Teachers hold deeply ingrained doctrine related to teacher-student roles, effective classroom management and practices, planning and organization methods, and ways students learn and their assessments (Ertmer, 1999). Ertmer (1999) suggested that confronting these entrenched philosophies is critical for the attainment of change integration and particularly, for adopting innovative reform. Ultimately, teachers are the key to educational change and innovation, and therefore supporting their transitions through ongoing novel professional learning and development, supportive school infrastructures, professional learning networks, and mentorship programs is essential (Boyd, 2021; Hughes et al., 2021; Stevenson et al., 2019). Teachers who have adopted transformative practices and beliefs have a tremendous opportunity, when supported, to act as agents of change and promote organic, bottom-up educational innovation (Hughes et al., 2021; Milton, 2015; Priestley et al., 2012; Serdyukov, 2017).

Maker movement advocates have argued that the maker culture could revolutionize student learning and school communities (Blikstein & Krannich, 2013; Dougherty, 2013; Martinez & Stager, 2013; Resnick & Rosenbaum, 2013). Resnick (2002) has envisioned this revitalization as fundamentally reorganizing school classrooms to be more entrepreneurial, with teachers guiding students of varying ages through active, hands-on and collaborative learning with a curriculum focused on themes and projects bridging subject disciplines where students' learning is not cut-off by bell-initiated timeframes but allowed to continue through extended periods. Although this utopic vision of making in schools seems extreme compared to existing practices and despite the critics of the liberatory aspects of educational makerspaces (Gilbert, 2017; Stornaiuolo & Nichols, 2018), many advocates are hopeful that organic, teacher-evolved practices can grow progressively to build momentum and influence upper tier educational policymakers to foster a modern, reinterpreted vision and strategies for learning (Milton, 2015; Serdyukov, 2017). This progressive transition to maker pedagogies is emerging with pockets of teachers who have initiated some transformations and often risky cultural shifts in their classrooms (Peterson & Scharber, 2018). Many of these maker educators have highlighted how school conditions are starting to enable the maker movement in the classroom through mobile maker options, funding dedicated to new educational technologies, and curriculum updates that have added engineering, technology learning, coding and design aspects (Davidson, 2022; Peterson & Scharber, 2018). The missing elements for this organic growth in many of these schools are supportive communities with ongoing, creative learning and development structures for teachers (Berman et al., 2016). Bottom-up transformative innovations are led through the agentive actions of teachers and supported by administrators, school communities and local school boards (Bernard, 2013; Milton, 2015; Price & Valli, 2005). According to the qualitative research by Sang and Simpson (2019), it takes a significant risk for teachers to migrate from teacher-centered to student-centered making practices where there is a fundamental shift in the role of the teacher, voice and empowerment of students, scaffolding and design of activities, strategies for assessment, and directions learning can take. Developing teachers' competencies in making processes, adopting a maker mindset, and establishing a school making community is necessary for agentic teachers to lead the maker movement and inspire institutional change from the bottom-up (Hughes et al., 2021; Vossoughi & Bevan, 2014). While research is growing on professional development and learning best practices for teachers and making in the class (Stevenson et al., 2019), there is still much to learn about shifting mindsets, building school maker communities and the impacts of teacher maker agency. Pre-service teachers may also have the capacity to foster innovative agentic change through establishing university partnerships and novel practicum experiences (Datnow, 2020; Hughes et al., 2016b). Further research needs to explore and understand the elements of any teacher maker education, the role of in-service and pre-service teachers in driving change, and how to foster a maker mindset while building competencies and confidence with maker pedagogical practices and emerging technologies.

2.1.4 Pre-service Teacher Maker Education

The teaching profession is complex, requiring the methodical practices of facilitating student learning and skill development, managing classroom activities and behaviours while supporting students' maturation, passions, special needs, and mental, physical and social well-being (Laurillard et al., 2013; Ontario College of Teachers [OCT], 2017). Cohen, Hoz, and Kaplan (2013), in their review of empirical studies on pre-service teacher practicums, summarized key aspects for new teachers to develop and learn, including the need to foster dynamic and differentiated learning experiences, be adaptive to student needs, behaviours and challenges, and flexible to ever-changing policy initiatives, board directives, school priorities, and significant societal changes. Recently, educators around the globe have demonstrated their skills and capacity for rapid reaction and adaptation as the global pandemic caused the largest disruption of education ever known to humankind (United Nations, 2020). Statistics from the United Nations (2020) brief on education during COVID-19 and beyond reported that 1.6 billion learners in 200 countries were impacted as schools worldwide were closed. Immediately, teachers were charged with effectuating remote learning modalities, often without sufficient training, resources, and guidance (United Nations, 2020). It is abundantly clear that teachers have the collective capacity for adaptation, innovation, and change, and even though online learning, broadly speaking, has not been entirely successful, leading to gaps in student learning, the capabilities and resourcefulness of teachers are evidenced and can be harnessed for new ways of learning and teaching (Reimers, 2021). Educational researcher Reimers (2021) authored a book on 21st-century education reforms that evaluated aspects of attempted and successful transformation initiatives around the globe and consolidated key insights, including learnings from the global pandemic. In the chapter devoted to leveraging lessons learned from COVID-19 and ways to build innovative momentum, Reimers (2021) postulated that as we navigate forward from the pandemic and with our ever-changing world of technological advancements, now is not the time to move back to the same traditional learning structures. Now is the time to reimagine what students should learn and why and how best to support these learning experiences. Leveraging support and insights from varying industry specialists and analyzing key findings from academic research can support the evaluation and integration of novel pedagogical approaches and innovative strategies for new and continuous teacher development and education.

Leading the charge for research in innovative pedagogical approaches, 21st-century learning, and novel ways of thinking and understanding are higher-ed institutions, typically through pre-service teacher education or initial teacher education programs. These post-secondary departments are also responsible for the development and preparation of pre-service teachers through Bachelor and Graduate level programs in Ontario (Ontario College of Teachers [OCT], n.d.). To be certified to teach in Ontario, as stipulated in the requirements policy brief by the Ontario College of Teachers (OCT, n.d.), one must successfully complete a pre-service teacher education program which requires completion of four semesters that consists of 10% educational foundations, 20% teaching methods, 20% practice teaching (400 hours), and 50% in other areas to support various needs and methodologies in education. Within these boundaries, Ontario pre-service teacher education programs could deliver a program that fosters the professional development of innovative pedagogical approaches by leveraging epistemological learning theories and then bridging to practice through hands-on, active discovery and practicum teaching opportunities. Furthermore, as leaders in educational research, these university programs can establish innovative locales, strategies, and partnerships to facilitate and support novel teacher development initiatives (Batane & Ngwako, 2017; Datnow, 2020; Hughes et al., 2016b). Adopting courses to teach making approaches involving inquiry-, design-, problem-, and project-based learning is a method for these pre-service teacher education programs to integrate innovative pedagogies that can foster global competencies while using technology in meaningful and creative ways (Bullock & Sator, 2015; Lock et al., 2020). These courses would also be in line with the Ontario

Provincial Government Regulation 347/02, Schedule 1, which was revised in 2013 to stipulate that any "Accreditation of Teacher Education Programs, requires that a program of professional education includes how to use technology as a teaching tool" (OCT, 2017, p.13).

Yet, makerspaces for learning, maker movement courses and making in ed research or practicum partnerships have emerged in only a small number of pre-service teacher education programs (Cohen, 2017; Hughes et al., 2016b; Jones, Smith, & Cohen, 2017). The quantitative survey study by Cohen (2017) analyzed how extensively U.S. pre-service teacher education programs integrated maker principles and technologies. Results of the 14-question survey were analyzed statistically, leading to findings that suggested maker-focused full courses are rare, but interest is growing, and any maker unit during a course lacks significant impact on teachers' self-efficacy with maker technologies (Cohen, 2017). Additional findings summarized by Cohen (2017) suggested that the adoption of courses on maker pedagogies is driven by faculty interest, dependent on funding, and related to faculty members' capacity and interest in related research. Although similar studies have not been conducted in Ontario, there have been reports highlighting the same approach where there is the inclusion of makerspaces or maker pedagogical units in technology courses for pre-service teachers at Trent University, Brock University, University of Ottawa and our OTU university Faculty of Education (Kitchen & Petrarca, 2022). These results suggest that learning about makerspaces and maker pedagogical approaches for pre-service teachers in Ontario is emerging in some capacity to help support the need for meaningful integration of technology in future classes.

Maker courses for pre-service teachers are growing in interest but distinctly lacking is the amount of research related to best practices for how to educate pre-service teachers in maker principles and pedagogies (Hansen, 2018; Jones, 2021). According to the systematic literature review by Schad and Jones (2020), there is a need for research related to pre-service teachers' understanding of the maker movement philosophies and how this can influence their pedagogical practices as they transition to becoming new in-service teachers. Maker education for any teacher should mirror the process of making for students and needs to encompass the philosophies of the maker mindset while learning and practicing the making processes in a community of makers (Hughes et al., 2021; Jones, 2021; Le Fevre, 2014; Peterson & Scharber, 2018). The detailed best practice approaches to achieving this setup are a work in progress, and as the programs are limited but emerging, we need to build on what was learned through research studies. Searches for journal articles related to pre-service teacher education with a focus on making confirmed one mixed methods dissertation and six qualitative studies. Two of these studies were Canadian papers focused on the practical and experiential aspects of making with students in informal contexts (Hughes et al., 2016b; Hughes, Morrison, & Dobos, 2018b). Hughes was the lead researcher in both articles which involved ethnographic approaches and volunteer pre-service teacher participants (Hughes et al., 2016b; Hughes et al., 2018b). In terms of maker pedagogical approaches, Hughes and colleagues (2016b) evaluated what the pre-service teachers learned about the experiences of facilitating making activities, while Hughes, Morrison, and Dobos (2018b) assessed how pre-service teachers developed maker pedagogical understanding. Both studies highlighted the need for practical teaching with students because these experiences involved being flexible and adaptable to unforeseen challenges (Hughes et al., 2016b) and enabled pre-service teachers to practice strategies for just-in-time support (Hughes et al., 2018b). Furthermore, the authors stressed the significance of pre-service teachers starting with discovery sessions and then progressing to facilitation to ensure teachers are prepared and comfortable.

Two exploratory studies from the U.S., conducted by the same group of researchers, involved assessing the experiences of pre-service teachers during informal, half-day maker workshops. Jones, Smith, and Cohen (2017) evaluated the participants' beliefs related to making in schools using group interviews, while Cohen, Jones, and Smith (2018) analyzed reflective journals of participants to evaluate their preconceptions and misconceptions of maker pedagogies. Both studies suggested teachers believed in the benefits of making but perceived significant barriers, including lack of time and tool complexity in makerspaces and lack of support from administrators and mentor teachers (Cohen, Jones, & Smith, 2018; Jones et al., 2017). Additionally, the researchers suggested that misinterpretations of short, subject-specific making activities were most likely due to the overview workshops that focused more on technology discovery (Cohen et al., 2018).

The dissertation of Hansen (2018) also discovered challenges from pre-service teachers with making activities related to their innate need for structure and what constitutes a student-centered project. The researcher's mixed method case study compared the design and facilitation of two distinct making activities during a Maker Faire and discovered that even after a semester-long making course, there were misinterpretations of authentic making activities, often resulting in closed-ended, simplified tasks (Hansen, 2018). The same maker course and Maker Faire originated in the design-based study by O'Brien, Hansen, and Harlow (2016) but involved different year cohorts. These scholars evaluated the experiences of four pre-service teachers during their final Maker Faire and highlighted their concerns with effective assessment methods and perceived notions of being the expert and needing to answer all questions asked. Another unique micro-credential program called "UTeach Maker," which is part of a larger pre-service teacher education program, was analyzed in a case study report by Rodriguez, Smith and Harron (2021). Similar to the previous two studies, Rodriguez and colleagues (2021) methods involved analyzing pre-service teachers who participated in a full-term course learning maker principles and practices and then assessed their facilitated making activity from their practicum. The research evaluated the participants' philosophies and compared what they believed with what they implemented with students. Findings showed there was motivation and interest in using maker pedagogies; however, there were practical disconnects in their actual making activities, highlighting a need for more guidance and potential tensions with formal school environments (Rodriguez et al., 2021).

The structures of the maker programs from these studies ranged from free inquiry and self-directed learning primarily with maker technologies to short overviews of maker philosophies with tool discovery to semester-long courses facilitated around STEM or design concepts. The small number of studies made it challenging to compare strategies on maker pedagogical learning; however, the results do indicate that while pre-service teachers appreciated the autonomy of discovery learning and planning, there were challenges related to the authenticity of their designed and facilitated making activities.

Several step-by-step, heavily structured, and short, concept-driven activities were incorrectly designed as making activities (Cohen et al., 2018; Hansen, 2018; O'Brien, Hansen & Harlow, 2016; Rodriguez et al., 2021). Understanding the role of guided inquiry and co-ideation with a maker specialist can provide new insights on potential ways to address the genuineness of making activities in a pre-service teacher maker education program.

Practical facilitation or teaching experience with making activities was described by many pre-service teachers in these studies as a significant aspect of their learning experience. Research by Jones (2021) with in-service professional development echoed these findings and added that teachers were able to overcome pre-implementation concerns, build greater confidence and support their maker mindset. Key insights on practice teaching setups from the pre-service teacher studies emphasized the necessity of bridging theory to practice (Hughes et al., 2016b; Rodriguez et al., 2021), the need for continuous learning on just-in-time support and adaptive teaching (Hughes et al., 2018b), and the importance of acknowledging perceived barriers and providing practical strategies to navigate them (Cohen et al., 2018; Jones et al., 2017; O'Brien et al., 2016). Many of these studies used co-facilitation strategies, but what was not analyzed was the benefits of a progressive approach from co-facilitation to opportunities for self-facilitation in their own practicums, indicating a potential gap in the literature. It is important to consider that pre-service teachers will have unique practical teaching experiences with making as they are both new to teaching, new to making and lack established pedagogical practices. Guiding, preparing and supporting their journey is essential to helping them establish these innovative and transformative approaches right at the beginning of their professional practice (Batane & Ngwako, 2017).

The study by Rodriguez et al. (2021) indicated that the practicum making lessons were manifestations of the maker philosophies of teachers. Implementing these lessons during class is not an easy decision, particularly when there are potential barriers in schools (Stevenson et al., 2019). It takes a willingness to try and fail and being a risk-taker, both important aspects of a maker mindset and an essential element of any maker education program (Hughes et al., 2021; Lock et al., 2018). While Rodriguez et al. (2021) discussed the necessity of aligning making philosophies with practical making activities, there was little mention of how pre-service teachers adopt a maker mindset and what factors can contribute. Furthermore, these studies enforced the practicum activities for pre-service teachers, yet it is important to provide them with choices and evaluate why they are willing to take the risk or not. When we consider the importance of risk-taking to help drive agentic change for making in the classroom from the bottom-up, we need to consider how we help foster a maker mindset through these pre-service teacher maker education programs.

Through this review of the literature, distinct gaps have been identified related to the impacts of guided inquiry for making courses, the potential benefits of progressive co-facilitation to self-praxis, and the factors that impact the development of the maker mindset and ways to assess it. The approach for this study endeavours to evaluate these gaps and situate this research project in the growing body of literature on pre-service teacher maker education best practices.

2.2 Research Problem

2.2.1 Background

Five years ago, I graduated with a B.Ed. degree at the OTU pre-service teacher education program, where I received an introduction to some educational technologies and novel pedagogical approaches. Intrigued and desiring deeper understanding, I pursued a Research Assistant (RA) role in a STEAM-3D Maker Lab at the OTU Faculty of Education while enrolled in the Master of Education program. During my time as a RA, I was involved in numerous research projects across Ontario, learning the theoretical and practical applications of all aspects of the research process and in-depth learning of maker pedagogical philosophies, approaches, and technologies. This experience was eye-opening to see how in one aspect, there was a desire from educators, administrations, and school boards to leverage making to innovate pedagogies but a gap in consistent practice often driven by tensions, fears, resistance, and perceived barriers. In many instances, technology became the focus on how to innovate and reform practice ignoring the underlying pedagogy. Having a previous career as a process specialist in the Information Technologies industry, I recognized this flaw immediately as we had always emphasized the need for processes to drive innovation using technology only as an enabler. This experience has driven me to ask questions about why there are tensions and barriers, what we can do to address them, and how we can better educate both in-service and pre-service teachers on maker principles and meaningful pedagogical practices and the effective use of technologies.

2.2.2 Interpretive Framework

My passion drives my research study to transform education and learning experiences for students, and my ontological stance reflects my professional and personal philosophies and innately impacts my academic pursuits. As such, it is vital to be transparent and identify my interpretive framework for this study. I identify primarily as a social constructivist, and this paradigm shaped the development of my research problem, questions, and methodology. Social constructivists believe that participant learning is *"constructed through…lived experiences and interactions with others"*, and their views are complex and impacted by the specific contexts of their environment (Creswell, 2013, p.36). Aspects of postpositivism and pragmatism have also been ingrained in my methodological approaches based on years of learning and practicing mathematics and life sciences with the scientific method. The postpositivist practices have influenced my research in that I used logical and empirical processes with some basis on a priori theories and rigorous inductive methods of data collection and analysis. At the same time, my pragmatism affected the research data analysis, as I believe that interpretations flow from the researchers' background and experiences (Creswell, 2013).

2.2.3 Research Question

This study evaluated a guided inquiry approach to learning maker pedagogies with emerging technologies in a Faculty of Education Maker Lab with pre-service teachers and how to foster the development of competencies, confidence, and influence their mindsets towards innovative learning and teaching. To guide the study, the following research question and sub-question were developed:

To what extent does guided inquiry, coupled with hands-on facilitation, promote pre-service teachers' confidence and competence with maker pedagogical approaches and influence their mindset and teaching practices?

- *What challenges do pre-service teachers face, and what risks do they take to implement maker activities in their own practicum placements?*

Chapter 3. Theoretical and Conceptual Frameworks

3.1 Theoretical Framework

To guide this research and support the analysis, I leveraged a theoretical framework encompassing four distinct theories. Theories are meant to support our understanding of how things work, guide how we can behave, and predict outcomes that may result (Herrington & Oliver, 2000; LeCompte & Preissle, 1993). In addition, theories contain "assumptions and assertions used to interpret and sometimes explain psychological, social, cultural, and historical processes" (Dimitriadis & Kamberelis, 2006, p. vii). The function of these particular four theories was to inform the research problem, questions, approach, and analysis. Each theory is described below in four distinct sections, followed by the conceptual framework, which explains how these theories co-relate and interconnects in a logical structure to guide this study.

3.1.1 Constructivism

In this study, constructivism was the basis for the hands-on, active practices used by the participants as they initially learned and discovered new maker technologies and experienced making principles. In addition, the guided inquiry approach is of particular significance, as it is a type of inquiry-based learning often used to support various learners in makerspaces or Maker Labs. In this investigation, I strategically leveraged the guided inquiry approach to support the participants based on their needs and readiness as they learned maker technologies and maker pedagogical approaches. The following sections describe the basic tenets of the constructivism theory, the application of this theory to develop effective learning contexts, and the relationship to inquiry-based learning and guided inquiry facilitation practices in Maker Labs.

3.1.1.1 Jean Piaget.

Constructivism is an epistemological perspective on the nature and development of knowledge and how learning happens (Lee & Hannafin, 2016). Pioneering Swiss psychologist Jean Piaget (1896-1980) developed his theories based on his research working with children and observing their experiences (Alanazi, 2016; Sung, 2018). Piaget postulated that learners actively construct knowledge and meaning through interactions with their environment and develop mental representations called schemata (Piaget, 1936). As learners explore and encounter more complex objects or new experiences, they cognitively enter a process of accommodation and assimilation that requires them to adapt, change or create new schemata and ultimately reach a state of mental equilibrium (Piaget, 1957). This cycling of disequilibrium and equilibrium of mental schemata through an adaptation process is Piaget's concept of how children learn and build knowledge and has been described as cognitive constructivism. Analyzing this progressive learning process with children, Piaget developed the stage theory, which highlights four distinct stages of development and provides an understanding of how children's learning evolves and what they are capable of at each age group (Ackermann, 1991; Piaget, 1936; Piaget, 1957).

3.1.1.2 Cognitive Constructivism.

Although Piaget did not explicitly describe how his theory can support educative practices, in his 1972 article 'Some aspects of operations' Piaget explained his thoughts on the importance of active learning and students being creative discoverers. "Children should be able to do their own experimenting and their own research…Every time we teach a child something, we keep him from inventing it himself. On the other hand that which we allow him to discover by himself will remain with him visibly." (Piaget, 1972, p.27). These philosophies resonated with progressive educators who leveraged Piaget's cognitive constructivism as a foundational learning theory for progressive education, driving the support for active discovery and experiential learning based on students' interests and passions. Progressive advocates encourage hands-on educational experiences, where children build knowledge through open exploration activities that are spontaneous and not prescribed (Christou, 2016; Hansen, 2018; Jones, 2021). Seymour Papert (1980), progressive education advocate and protégé of Piaget, suggested that a true constructivist educator facilitates without curriculum or deliberate instruction. Although some schools have incorporated these discovery learning experiences, particularly in kindergarten and early elementary grades, most schools still emphasize direct instruction and passive learning (Gilbert, 2017; Sang & Simpson, 2019; Schad & Jones, 2020). Critics of progressive learning have argued that the lack of direct teacher instruction can make students "lost and frustrated" (Alanazi, 2016; Kirschner, Sweller, & Clark, 2006, p.6). Other arguments on constructivism have highlighted the lack of situational contexts and individualization to Piaget's stage theory (Ackermann, 1991). Despite the criticisms, Piaget has left an indelible mark on progressive enthusiasts and maker movement advocates who have lauded the benefits of active, hands-on, passion-based learning and the positive impacts of tinkering and discovery.

3.1.1.3 Social Constructivism.

Some of the most significant challenges to Piaget's cognitive constructivist theories on learning were from a fellow cognitivist, Russian psychologist Lev Vygotsky. Born in Russia, psychologist Vygotsky thought of development as a continuous process not discrete stages (Vygotsky, 1978). More significantly, Vygotsky emphasized the critical role of social and cultural influence on learning and knowing. Whereas Piaget believed that development must necessarily precede learning, Vygotsky stated that social learning tends to precede development (Vygotsky, 1978). Vygotsky (1978) further extended his contributions to constructivism by describing the Zone of Proximal Development (ZPD) as an area of optimal learning for a student with the guidance of or scaffolding by an MKO. While important from a cognitive knowledge perspective, Vygotsky's work in the social context of learning and the importance of culture and guidance laid the groundwork for social constructivism.

Social constructivism describes how learning is an active, discovery and social-cultural process where formalizing concepts or understanding can be mediated by an MKO when the learner is ready and in their ZPD, not necessarily at a particular age (Lee & Hannafin, 2016; Vygotsky, 1978). There are important educational applications for social constructivism, including the notion of readiness, the role of the teacher as a guide and the development of a supportive classroom culture. However, critics of social constructivism have argued that too much emphasis on the collective can promote group thinking and ignore individuality (Alanazi, 2016). Despite these views, the adoption of social constructivism philosophies has been accepted in many schools through group work and inquiry-based learning activities as there is greater clarity on the role of the teacher and how to facilitate learning outcomes. In educational makerspaces, social constructivism has been integrated through guided inquiry learning and discovery practices with a collaborative community of learners who the teacher and MKOs scaffold.

3.1.1.4 Guided Inquiry.

Cognitive and social constructivism ideals come together in meaningful ways to support inquiry-based learning. This educational strategy emphasizes active learning and experimental practices that test hypotheses, investigate problems, and help students make discoveries (Pedaste et al., 2015). However, some educators have expressed anxiety related to inquiry-based learning due to misconceptions of chaotic and unstructured free play (Hughes et al., 2021). In makerspaces, however, many different types of inquiry learning are driven by the scaffolding practices of the facilitator or MKOs. Often visualized as a spectrum, these types of inquiry range from free, open-ended exploration to more structured and dependent on the needs of learners, the complexity of tasks, projects or tools and the stage of learning (Hughes & Morrison, 2020). Typically, educational making is guided, which involves a blended approach of student-centered learning with teachers' facilitation and counselling (Bunterm et al., 2014; Watt & Colyer, 2014). In these environments, the teacher can create conditions to promote interactions with objects, challenge students, and guide them with minimal directed learning based on needs and probing questions to solidify conceptual understanding, process learning and problem-solving techniques (Valente & Blikstein, 2019). The guided inquiry approach can appease students who fear knowing how or where to start an idea or project and how to solve issues during the making process. Over time, and with further practice and knowledge building, educators can apply less influence or guidance to learners who have established effective self-directed practices and confidence in problem-solving.

3.1.2 Constructionism

The fundamental learning philosophy for any makerspace is based on epistemological principles of constructionism. Our STEAM-3D Maker Lab leverages constructionism to guide making activities and practices. As such, this theory will be explored in the following section to describe how learning is constructed and manifested during our research workshops.

3.1.2.1 From Constructivism.

Building from the constructivist ideals postulated by his mentor Jean Piaget, educational theorist and mathematician Seymour Papert (1928-2016) proposed an alternative explanation of how knowledge can be constructed. Papert theorized that understanding develops through active learning by "building something tangible - something outside your head - that is also personally meaningful" (Papert, 1988, p.14). While both conceded a need for active, hands-on learning practices, Piaget believed that understanding is a complex process involving mental constructions in someone's mind. Having studied with Piaget for five years and having an intimate appreciation of the constructivist philosophies, Papert perceived a gap in this focus on abstract thinking versus more situated, more pragmatic knowledge using concrete object manipulation (Ackermann, 2001; Kynigos, 2015; Resnick, 1998). To Papert, "knowledge is not merely a commodity to be transmitted, encoded, and retained, but a personal experience to be actively constructed. Similarly, the world is not just sitting out there waiting to be uncovered, but gets progressively shaped and transformed through...personal experience." (Ackermann, 1991, p.4).

3.1.2.2 Objects-to-think-with.

After working with Piaget, Seymour Papert joined M.I.T. in the 1970s where he began fleshing out the constructionist theory. Influenced by other progressive education innovators like John Dewey, Maria Montessori, and Paulo Freire, Papert consolidated his constructionist ideas in his famous book "Mindstorms" in 1980 and later coined the term constructionism in 1991 (Ames, 2018; Kafai & Burke, 2015). Papert was interested in the process of invention and discovery with "objects-to-think-with," which he described as "objects in which there is an intersection of cultural presence, embedded knowledge, and the possibility for personal identification" (Papert, 1980, p.11). In his book 'Mindstorms,' Papert described how gears imbued a particular fascination in his younger years as "objects-to-think-with" (Papert, 1980, p.11). Yet, constructionism is not just the act of inventing or making with or creating objects-to-think-with. Papert was also inspired by social constructivist theorists like Vygotsky, where he envisioned sharing and collaborative interactions that support individuals' learning experiences as they construct meaningful objects-to-think-with. He explained, "everybody needs the help of other people and the support of a material environment, of a culture and society" (Papert, 1988, p. 13-14). The pioneering theorist and MIT Media lab founder further asserted that learning is a journey manifested through the process of designing tangible artifacts which become truly meaningful through the acts of sharing, collaborating, and discussing their personal inventions (Papert, 1988; Rob & Rob, 2018). The constructionist practices of designing and building with objects-to-think-with are closely aligned with Levi-Strauss's concept known as bricolage (Levi-Strauss, 1966; Papavlasopoulou, Giannakos, & Jaccheri, 2019; Papert, 1993). The bricolage process involves a do-it-yourself mindset by using incremental procedures of experimentation, testing, failing, and trying again with different tools and materials available on-hand (Girvan & Savage, 2019; Resnick & Rosenbaum, 2013). In makerspaces, some equate the bricolage process to that of experimental fun and tinkering (Resnick & Rosenbaum, 2013) practices involved when working with objects-to-think-with and the making community embodies the practices of sharing and collaboration which are both emphasized as essential elements of the constructionist theory (Cohen et al., 2017).

3.1.2.3 Constructionism versus Instructionism.

In line with many other progressive education advocates, Papert was deeply concerned with the traditional, passive, and teacher-centered practices in schools. He proposed his constructionist theory as a direct opposition to instructionism practices in schools (Harel & Papert, 1991; Litts, 2015). To Papert, constructionist epistemology and practice constituted a method of re-evaluating the educational paradigm of schooling (Kynigos, 2015; Papert, 1993). He argued that instructionism involved practices that were too passive, too structured, too authoritative, and too clean, where teaching methods relied too much on textbooks, correct answers, memorization, and formal testing (Litts, 2015; Papert, 1980). Instead, Papert envisioned learning in schools as a messy, active, collaborative process of creating and innovating with objects-to-think-with and sharing their discoveries and knowledge with peers. The curriculum would focus on powerful ideas while teachers establish interactive environments to foster creativity and discovery and act as facilitators who coach, prompt, and help students develop and assess their understanding (Papert, 1980; Resnick, 2002; Rob & Rob, 2018).

3.1.2.4 Computers and Constructionism.

Papert's research involved working with and designing computer environments with constructionist learning approaches. Computers, he argued, were potent objects-to-think-with that could provide cognitive links between abstract concepts and concrete understanding while giving options for diverse accessibility and complexity (Alanazi, 2016; Ames, 2018; Papert, 1993). Some technologies and cognitive tools that were easy to use for young or novice students Papert described as having a low floor, while those that provided powerful potential, but higher complexity were called high ceiling tools (Harel & Papert, 1991; Resnick et al., 2009). Pioneering work with early educational programming and AI, Papert developed a low floor programming language at MIT called Logo (Ames, 2018). In several research projects, Papert used his Logo programming with a turtle avatar and established a digital microworld where children could build as a bricoleur or explore and test mathematical concepts (Litts, 2015; Papert, 1980). These digital constructionist environments supported discovery, creativity, and conceptual learning and helped students develop an appreciation of problem-solving and learning from mistakes through debugging strategies (Ames, 2018; Laurillard et al., 2013). Desiring more hands-on physical interaction with computers, Papert developed a turtle robot to be coded and manipulated by students and later partnered with LEGO to create programmable bricks and robotics kits called LEGO Mindstorms (Sung, 2018). Papert's devotion to learning and research with technology has some critics arguing he is too focused on technology (Ames, 2018). Papert, however, had a keen understanding of the enabling capabilities of technology primarily as powerful objects-to-think-with. He cautioned educators from envisioning technology as what drives learning. He argued that learning should not be technocentric, but the focus for educators should be on the underlying learning processes to guide the construction of knowledge (Ames, 2018; Cohen et al., 2017; Papert, 1988). Unquestionably, Papert has influenced educational technology developments like Scratch and One Laptop per Child projects, and his legacy continues to live on through constructionist learning approaches in makerspaces and academic Maker Labs like the STEAM-3D Maker Lab in this research project (Ames, 2018; Martinez & Stager, 2013; Stornaiuolo & Nichols, 2018).

3.1.3 Situated learning theory

In this study, situated learning theory with Legitimate Peripheral Participation was leveraged as the framework to guide the methods for practical facilitation experiences with student making approaches. Pre-service teachers have the unique educational learning experience of both needing to practice making while also learning how to use these approaches in their future classrooms. Using maker pedagogical approaches requires knowing what authentic making experiences are, how to establish these types of learning environments in a classroom, what is the role of educators, how is making different from teacher-centered approaches, and other aspects including tech teaching considerations, and assessment practices. Talking through and learning effective methods in a Maker Lab is one aspect, but practical facilitation in situated classroom making contexts is arguably where a better appreciation of what is required of teachers can be ascertained (Rodriguez et al., 2021). To establish the most effective strategies for situated and experiential teaching methods for making in classrooms, the situated learning theory and Legitimate Peripheral Participation were adopted for this study. The details of these theories are described in the following section.

3.1.3.1 Lave and Wenger.

Situated learning theory posits that learning is a social endeavour where meaningful and effective education occurs when students are engaged in authentic practices within real-world contexts (Besar, 2018; Brown, Collins & Duguid, 1989; Hansen, 2018). Brown, Collins and Duguid (1989) introduced the first situated learning model in their scholarly paper titled, “Situated Cognition and the Culture of Learning”. These authors categorized authentic learning activities as the typical practices within a culture or work community. This authentic context of learning is the fundamental premise of situated learning theory because as Collins (1988) stipulated, learning within these contexts reflects the way knowledge is applied in real life. Expounding on Brown and colleagues (1989) work and the social constructivist concepts from Vygotsky, notable educational theorists Lave and Wenger (1991) developed a philosophical framing of situated learning as the negotiation between abstract and theoretical knowledge and its application in specific situations and social interactions. These influential researchers emphasized the aspect of acculturation and the ideas that authentic experiences are mediated through social relationships within a CoP (Besar, 2018; Lave & Wenger, 1991). Etienne and Beverly Wenger-Trayner (2015) described a CoP as a group of learners who use a common language, resources and self-identify with the community’s collective goals while building their knowledge through engaging and sharing in experiences as practitioners. In the professional education field, situated learning for pre-service teachers would involve a community of other pre-service and in-service teachers and the practice of pedagogical learnings within classroom or makerspace contexts working with students.

3.1.3.2 Legitimate Peripheral Participation.

In situated learning, new practitioners within the CoP have a unique perspective and Lave and Wenger (1991) recognized this distinction. New practitioners, they argued, should have opportunities to engage in authentic but low-risk or peripheral activities and slowly build towards full participation (Hansen, 2018; Lave & Wenger, 1991). This distinct practice they termed Legitimate Peripheral Participation. The idea of Legitimate Peripheral Practice is built based on the concept of apprenticeship; however, the emphasis is less on the master and apprentice relationship and more on learning through a CoP (Lave & Wenger, 1991; O'Meara, 2020). New practitioners could start through observation or as a supportive facilitator, allowing them to build confidence while they try practices and develop their own approaches and build their own identity in the CoP. Mentors or MKOs within the CoP could provide coaching, scaffolding or model practices similar to some apprenticeship relationships and guide novices to progressively adapt their own interpretations of practice (Collins, Brown, & Newman, 1986; McLellan, 1996). Lave and Wenger (1991) declared how these types of activities can provide great learning opportunities for novices, as they can guide their own approaches and methods and help them build confidence as a member of the CoP. Furthermore, as novices gain proficiency, any support can be slowly removed, shifting a guided practice to a more self-directed praxis (Besar, 2018).

3.1.3.3 Cognitive Apprenticeship and Situated Learning Models.

To develop their theory of situated learning with Legitimate Peripheral Participation, Lave and Wenger (1991) studied various apprentice-type relationships from around the globe, including midwifery, tailoring, Alcoholics Anonymous memberships, butchers, and quartermastery. While observing the practices of these apprenticeships, the authors observed very little direct teaching and unlike formal apprentice-master education, they discovered that mastery is embodied not from a master but through moving toward full participation in a CoP (Lave & Wenger, 1991). Lave and Wenger (1991) advanced the concept of Legitimate Peripheral Participation as a means of understanding the progressive learning curve from apprentice to mastery of a trade, however they avoided creating instructional methods or approaches (Hay, 1993; O'Meara, 2020). Other educational scholars developed operational instructional models for situated learning with an emphasis on cognitive apprenticeship. Similar to Legitimate Peripheral Participation, cognitive apprenticeship emphasizes how students can learn complex tasks through paradigms of situated observation and modelling and then progress to learning through guided experiences and finally full participation within the CoP (Brown et al., 1989; Liu, 2005). The situated learning model of cognitive apprenticeship developed by Brown et al., (1989) highlighted a detailed triad approach with guidance on sequencing learning activities, considerations for social characteristics of learning environments and six teaching methods: modelling, coaching, scaffolding, articulation, reflection and exploration. In professional education, Farmer, Buckmaster, and LeGrand (1992) proposed an instructional model of cognitive apprenticeship comprising five stages: modelling, approximating, fading, self-directed learning, and then generalizing. While McLellan (1996) created a more progressive situated learning model including components of cognitive apprenticeship (modelling, coaching, articulation), multiple practice opportunities, collaborative environments, reflection, and considerations for technology integration. According to Collins, Brown, and Holum (1991) models of situated learning and cognitive apprenticeship are not meant to give a packaged formula for teaching, instead they provide ideas. The ultimate decision is for the teacher to determine what can work for their students within their CoP. Considering aspects of these situated learning models and the theoretical framework of Legitimate Peripheral Participation, in-service or pre-service teacher education maker programs can provide authentic opportunities to have contextual teaching practices with students making in a classroom.

3.1.4 Social Cognitive Theory

In this study, social cognitive theory and in particular, its subset framework self-efficacy theory were applied to guide the methodological approach to develop learning situations that can be used to ascertain participants' levels of confidence, competency, and manifestations of maker mindset characteristics. In addition, the self-efficacy theory was used to provide deductive structure to the data analysis during second coding activities.

The following section describes the theoretical aspects of social cognitive theory and self-efficacy theory.

3.1.4.1 Human Behaviour.

Canadian cognitive psychologist Albert Bandura (1925-2021) developed the social learning theory based upon his famous and somewhat controversial Bobo doll experiments (Cherry, 2020). This influential theory was continuously adapted into the broader social cognitive theory which posited that learning is a social endeavour where human behaviours result from a dynamic and reciprocal interplay between cognitive factors, behavioural patterns, and environmental events (Bandura, 1991). Bandura highlighted that modelling and positive reinforcement opportunities can have some influence on behaviours (Bandura, 1965), a key consideration for health and mental care providers, and educators. However, social cognitive theory expanded the complexity of human behaviour beyond just the impacts of modelling and observation, explaining that humans do not "behave like weathervanes", constantly conforming to various social influences (Bandura, 1991, p.249). Any influence from observation is based upon internal evaluation and determination of any benefits, necessity, and relevance to following a role model's lead. The social cognitive theory emphasizes how humans have perspectives, ideals, and various self-efficacious beliefs that "enable (them) to exercise control and regulation over their thoughts, feelings, motivations, and actions" (Bandura, 1991, p.249).

3.1.4.2 Self-efficacy theory.

A subset of Bandura's social cognitive theory is the self-efficacy theory which describes how people can be empowered with a sense of agency and self-efficacious beliefs to achieve lofty goals or overcome barriers (Bandura, 1977; Gallagher, 2012). Bandura described self-efficacy as a person's "beliefs in their capabilities to perform in ways that give them some control over events that affect their lives" (Bandura, 1999, p.46). Self-efficacy drives the way people feel, their attitudes and how they act in various situations (Conner & Norman, 1996). When someone has strong self-efficacy beliefs, they are confident in their abilities to take action, they make choices to explore and create new situations, they will invest more effort and persist longer even with set-backs (Bandura, 1977; Conner & Norman, 1996). Bandura (1999) described how self-efficacy plays a key role in cognitive motivations and agency through having the confidence to embrace high-standards and aspirations, and then executing the necessary actions to achieve them or attacking obstacles with ingenuity and effort. Self-efficacy encompasses features of competency, confidence, and a growth mindset where failures are recognized as controllable events that can be navigated with diligence and perseverance (Bandura, 1999). According to Conner & Norman (1996), self-efficacy is aspirational, but it does not mean driving towards unrealistic goals because it originates from experience and therefore it will not lead to unreasonable risk-taking. To develop self-efficacy beliefs, self-efficacy theory describes four principal sources which include: mastery experiences, vicarious experiences, social persuasion, and physical and emotional feedback (Bandura, 1999). These sources have been leveraged to guide the methods in this research and then to ascertain specific displays of competency, confidence, and manifestations of growth mindset, therefore it is important to describe each self-efficacy source in the following sections.

3.1.4.3 Mastery Experiences.

Mastery experiences are the most influential source for developing self-efficacy (Bandura, 1999). Through practice, persevering through failures and achieving success through sustained effort, one can build strong self-efficacy beliefs (Bandura, 1977). Designing and ongoing discoveries in a makerspace, taking time to work through challenges and developing new prototypes with some success could demonstrate growing competency leading to stronger self-efficacy beliefs. For teachers to effectively support the various needs of students, this could mean designing progressive and guided learning activities in successive attainable steps (Bandura, 1999). The self-efficacy theory (Bandura, 1977) emphasizes that learning experiences lead to mastery when they are ongoing with progressive success, and involve some struggle through adversity, otherwise the activities do not have the same impact. In makerspaces, the mastery experiences can foster greater understanding and confidence with design processes, various tools, and problem-solving strategies which, according to Bandura (1977), has the benefit of translating to other types of situations thus expanding self-efficacious beliefs to new experiences. Evaluating participants' displays of growing confidence, competency, and growth mindset factors like risk-taking, willingness to accept failures, and perseverance through challenges in mastery experiences can be seen as manifestations of growing self-efficacy beliefs.

3.1.4.4 Vicarious Experiences.

The second way of developing and strengthening self-efficacy beliefs is through vicarious experiences. This source is less dependable than the direct evidence from mastery experiences because it involves modelling and observing behaviours or actions (Bandura, 1977). Watching other students succeed through sustained effort to overcome challenges can instill the belief that one also has the capability to succeed (Bandura, 1977). In makerspaces, vicarious experiences can be delivered through teachers or other students who convey knowledge and skills for managing situations or activities. Bandura (1977) stipulated that more self-efficacious benefits come from witnessing models "overcome their difficulties by determined effort than from observing facile performances by adept models" (Bandura, 1977, p.197). This highlights the benefit of collaborative learning, demonstrations, sharing insights and observing problem-solving techniques in action by other students or teachers (who are considered co-learners). All of these types of observation and modelling are constant in makerspaces in both informal and formal methods, allowing multiple opportunities to build self-efficacy beliefs in one's ability to tackle similar activities or troubleshooting methods.

3.1.4.5 Social Persuasion.

The next strategy for strengthening people's belief in their self-efficacy is through social persuasion. Self-efficacy theory stipulates how people can be led, through suggestion, into believing they are capable of achieving goals or objectives and competent in their abilities to tackle difficult issues (Bandura, 1977). Bandura (1999) further clarified that "effective social persuaders do more than convey faith in people's capabilities, they arrange activities for others in ways that bring success and avoid placing people prematurely in situations where they are likely to fail" (p.47). These conditions support the idea that makerspace facilitators need to consider their learners, the progression of discovery and guided learning, and the types of challenges and designs that students are ready for. In addition, the makerspace facilitator needs to continuously circulate and encourage meaningful discussion and suggestion on developments and the established culture should foster mutual sharing, observing, listening, feedback and respective suggestions from any member, novice or more expert.

3.1.4.6 Physical and Emotional States.

The fourth and final source for informing self-efficacy is people's physical and emotional states. Anxiety, fear, embarrassment, and stress are all emotions that can also manifest in physical reactions and can negatively affect performance and therefore result in low self-efficacy beliefs (Bandura, 1977). In self-efficacy theory, it is recommended to develop situations that can reduce stress levels through establishing activities or challenges that are achievable or realistic and offering modelled demonstrations of how to deal with negative emotions (Bandura, 1999). In makerspaces, encountering problems and troubleshooting is a regular occurrence, facilitators must encourage and mirror accepting and dealing with mistakes, willingness for taking risks, and highlighting their own areas of weakness or learning gaps. Participants in makerspaces need to recognize that some emotions are natural and when managed and harnessed can become drivers of more self-efficacious beliefs. These spaces need to be safe places to fail, to take risks and to try new things, which can decrease the impact of negative emotions that can naturally surface when learning new things. Demonstrations of participants navigating and managing anxiety or fear or other negative emotional states as they problem-solve and work through new discoveries in a Maker Lab can highlight increases in self-efficacious beliefs.

3.1.4.7 Agency.

In his paper on the agentic perspective of social cognitive theory, Bandura (2001) stated that "efficacy beliefs are the foundation of human agency" (p.10). To have agency a person must believe they are capable of making choices and acting on those choices to influence the events and outcomes of their life (Code, 2020). Personal agency emerges through intentional actions that are self-generated but can also be impacted by external influences (Code, 2020). The agentic self-generated internal actions involve intentionality, forethought, self-regulation, and self-efficacy (Bandura, 2001; Code, 2020). The aspect of self-efficacy is particularly potent as it relates to motivation and whether a person believes they can overcome obstacles and will persevere through these issues. There are many challenges and potential barriers to implementing making in the classroom. Teachers that wish to implement making need to become agents of change for this cause. To be this agent of change, teachers need competencies and confidence in their abilities to implement making in class which influence their intentionality, forethought, and self-regulation, but more importantly they need self-efficacious beliefs that they have the power to overcome external challenges successfully.

3.2 Conceptual Framework

This research study involved a complex interplay of guiding pre-service teacher participants through focused and intensive maker technology discovery and maker pedagogical practice followed by the progression from guided facilitation to self-praxis with students. To develop the methodological approach, the constructivist, constructionist, and situated learning theories were evaluated and then adapted to practical approaches. In the STEAM-3D Maker Lab at Ontario Tech University (OTU) Faculty of Education, we have established a making ethos of discovery and making practices in a making community of learners who come to embody maker mindset dispositions (Halverson & Sheridan, 2014). The main theoretical underpinnings of any makerspace, including this Maker Lab, are the constructivist ideals of hands-on active learning and the constructionist theories and philosophies. Constructivist ideals are readily experienced during maker technology exploration, but authentic making and constructionist principles are more complex, requiring consistent, repetitive, and scaffolded exposure. These factors along with limitations in intern availability and committed research time made it necessary to adopt the guided inquiry when learning maker pedagogical approaches and principles. This approach allowed for maximum exposure to maker technologies and maker pedagogies in the shortest duration of time while still providing opportunities for self-exploration and practice.

The STEAM-3D Maker Lab offers multiple student workshop making sessions both at OTU's Faculty of Education and scheduled visits to schools. These sessions provide opportunities for students of varying ages and grade levels to participate in discovery or design-based making activities facilitated by Maker Lab RAs. The strategy for this research project was to allow pre-service teacher participants to start their practical and experiential teaching making experiences in a safe and supportive way as they develop their own maker pedagogical approaches. To develop this progression of guided facilitation to self-praxis with students I leveraged aspects of Lave and Wenger's (1991) Legitimate Peripheral Participation and McLellan's (1996) situated learning model of instruction. Then to evaluate the research questions and interpret the impacts of these facilitation experiences on participants' innovative mindset and pedagogical practices, the self-efficacy sources guided the data analysis methods. The following conceptual model, Figure 3.1, visually displays how these theories interconnect to guide the research practices and analysis.

Figure 3.1: Conceptual Framework

Chapter 4. Methodology

The purpose of this research is to evaluate pre-service teachers' competencies, confidence, and mindset growth as they journey through guided facilitation maker pedagogical practices and inquiry experiences with a Faculty of Education Maker Lab. To accomplish this goal an interpretive case study qualitative approach was used with a specific procedural method built based on the conceptual framework. In this methodology section, I describe the details of the case study approach used, the participants engaged in the study, the procedural design for this investigation, and the data collection and data analysis methods used to capture and interpret the participants' journey.

4.1 Research Approach

This research project involved a qualitative, interpretive single-case study design. According to Merriam (1998), qualitative research has a fundamental view that reality is constructed through the interactions of people within their social contexts. To understand this reality, qualitative research delves deeply into the empirical manifestations of these social situations to interpret and analyze the experiences of the individuals involved (Merriam, 1998). In this study, a qualitative approach was appropriate as the purpose was to explore and understand the experiences of a specific group of pre-service teachers who were involved in an intense and guided Maker Lab discovery and practice teacher education intervention.

When a qualitative research project is investigating a complex educational program or innovation in a specific real-world context, it is often beneficial to employ a case study approach (Simons, 1980; Simons, 2009). Miles and Huberman (1994) describe a case study as the investigation of a phenomenon that happens in a bounded context, while researcher Stake (1995) has defined a case study as "the study of the particularity and complexity of a case, coming to understand its activity within important circumstances" (p.xi). Creswell (2013) view the case study as a type of design for qualitative research where the researcher explores "a real-life, contemporary bounded system (a case) ...over time, through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes" (p.97). In this study, I leveraged the case study design to investigate the experiences of a specific bounded system in which participants were involved in an innovative pre-service teacher maker education program. The bounded system included a small cohort of pre-service teachers who volunteered in the OTU Faculty of Education STEAM-3D Maker Lab internship during their 2019 Fall final semester.

The bounded unit of analysis in case studies can involve a single case or multiple cases where evaluative techniques analyze across sites or across individuals who are themselves considered unique cases (Creswell, 2013). In this research investigation a single bounded case involving a small cohort of pre-service teachers undergoing contextual making practices in a Maker Lab was analyzed by interpreting their collective similarities, differences, insights and overall experiences. To guide the methods for this single case, I leveraged my theoretical conceptual framework. Yin (2009) stated that case study inquiry benefits from "the prior development of theoretical propositions to guide data collection and analysis" (p.18). The conceptual framework guided both the procedural design of this study and the analysis methods which involved multiple forms of empirically collected data and thick descriptive interpretations of the bounded system.

In qualitative research, case studies are one of the most commonly employed methodologies despite a consensus on the design and implementation approaches (Yazan, 2015). Three prominent case study methodologists, Robert Yin, Sharan Merriam, and Robert Stake define distinct procedures for these approaches. In my qualitative case study, I leveraged the insights of Merriam (1998) in terms of how I classified and implemented my research as she provides a comprehensive research methodology that aligns closely with my research objectives. Merriam (1998) suggested an evaluation of case studies by the overall intent of the research which should guide any methodology strategies. She defined three possibilities: descriptive, interpretive, or evaluative (Merriam, 1998). An interpretive case study contains "rich, thick descriptions that are used to develop conceptual categories or to illustrate, support or challenge theoretical assumptions held prior to the data gathering" (Merriam, 1998, p.39). Interpretive case studies are also known as analytical case studies and are differentiated from descriptive and evaluative case studies by their "complexity, depth, and theoretical orientation" (Merriam, 1998, p.39). My interpretive case research involved rich, thick descriptions of contextual data that was interpreted and conceptualized into categories and themes and then used to evaluate theoretical self-efficacy theory assumptions to ascertain changes in participants' confidence, competencies, and mindset perspectives in relation to maker pedagogical approaches.

4.2 Participants

The participants of this study were selected through purposive convenience sampling methods. Fraenkel, Wallen and Hyun (2012) describe this type of sampling as the personal judgment of an investigator in selecting participants and sites for study based on whether they can purposefully inform an interpretation of the research problem and central issue of the study. Creswell (2013) recommended selecting participants that will demonstrate different perspectives on the issue, process, or event under investigation. Initially, a convenience sample was undertaken in this study, based on invitations to the 2018-2019 cohort of pre-service teachers to join the STEAM-3D Maker Lab as part of their mandatory internship course in the OTU B.Ed. concurrent pre-service teacher education program. Six pre-service teachers responded to the invitation providing their Curriculum Vitae (CV), details about their teaching specialities or areas (Primary and Junior or Intermediate and Senior - and teachables), and a brief explanation for why they wanted to participate in the STEAM-3D Maker Lab internship. One pre-service teacher requested to volunteer and participate in the research project even though they had a conflict with another locale for their internship. In total, seven pre-service teachers were purposefully included in this research study, representing different speciality teaching areas, ages and varying making and technology expertise levels.

Before the research study and internship commenced, the lead researcher (myself, Margie Lam) provided each participant a tour of the Maker Lab, an overview of the Lab's mandate and regular activities, and a description of their internship responsibilities. The B.Ed. internship course required each participant to provide a minimum of 20 hours of service to their committed location, which was integrated into the Maker Lab intern responsibilities framework. The head of the Lab and Lab manager then met all the participants, without the lead researcher, to provide an overview of the research project goals and activities and request consent to participate in the research which involved videotaping and photographing workshops and student sessions, completing surveys and one-on-one interviews, and submitting notes, images and internship document assignments related to the research project. All seven participants agreed and signed consent forms, see Appendix A1 for a copy of the consent form. The consent forms and ethics were from the broader umbrella research project "CRC in Technology & Pedagogy: STEAM-3D - Discover, Design, Develop". After the participants consented to the research, they were asked to complete self-reported online demographic surveys, see Table 4.1, prior to the start of the research study. Although pre-service teacher intern participants vary each year based on the candidates that apply, interestingly this particular cohort of applicants were all female.

In all the data reported during this study, the participants were anonymized to remove any personally identifiable information. To ensure an accurate and equitable reflection of each participant, I searched for culturally aligned pseudonyms and used these throughout the paper and data collection.

Table 4.1: Participant Demographic Details

Name	Age	Intern or Volunteer	Ethnicity	B.Ed. Program	B.Ed. Teachables	Education
Shahari	26	I	South Asian	I/S	Biology & General Science	BSc (Honours)
Mansa	40	I	Black	P/J	n/a	Cdn equiv. MA & BSc
Nisha	43	V	South Asian	P/J	n/a	BA (Honours)
Aiza	25	I	South Asian	I/S	Biology & General Science	BSc (Honours)
Kamali	26	I	South Asian	P/J	n/a	BSc (Honours)
Marina	27	I	Caucasian	P/J	n/a	BSc (Honours)
Hadil	23	I	South Asian	I/S	English & History	BA (Honours)

4.3 Design of the Study

The procedural design for this qualitative case study involved leveraging the conceptual framework with the OTU STEAM-3D Maker Lab mandate and internship goals. The study lasted over four months including all aspects of the project, starting from mid September 2019 to the end of January 2020. The bulk of the research activities occurred between mid September 2019 to mid November 2019. The study procedures were designed and conducted by the lead researcher, me Margie Lam, a RA at the OTU STEAM-3D Maker Lab. As having personally participated in the internship at the STEAM-3D Maker Lab as a pre-service teacher in December 2017 then working as an RA in the STEAM-3D Maker Lab for almost two years, I was in a unique position to design and conduct this study to meet the needs of both the internship course and my research goals. In the following sections, I describe the OTU STEAM-3D Maker Lab, the internship goals and the procedural design that was implemented for this study.

4.3.1 OTU STEAM-3D Maker Lab

The OTU STEAM-3D Maker Lab was created and led by Dr. Janette Hughes, Canada Research Chair in Technology and Pedagogy. The STEAM-3D Maker Lab goals include developing competencies in constructionist maker pedagogies, promoting critical making and STEAM learning, and building capacity for investigating and affecting change and innovation in formal and informal education settings (https://janettehughes.ca/lab/#new). To achieve these goals, the STEAM-3D Maker Lab and RAs are involved with various global and local educational research projects, conferences, partnerships, and training initiatives. An important STEAM-3D Maker Lab initiative has been the Mobile Maker task force which leads student making sessions in schools, or at the OTU Faculty of Education or school visits to the Lab itself. The STEAM-3D Maker Lab is located in the OTU Faculty of Education building and is equipped with various making materials, tools, and technical setup to foster research, collaboration, and training initiatives. The maker materials and technologies range from unplugged, recyclable and construction materials to typical educational technologies including robots (programmable, buildable), 2D & 3D equipment (laser cutters, 3D printers, wood carvers, 3D pens), circuitry (paper circuits, Makey Makey kits, e-textiles), microprocessors (Arduinos, Raspberry Pis, Micro:bits, Phidgets), digital storytelling with green screen, coding applications (Scratch, Minecraft Edu, Makecode, etc.) to emerging technologies based on IoT - smart bread boards with sensors, AI robots, 3D digitizers, and Augmented and Virtual Reality design and code applications.

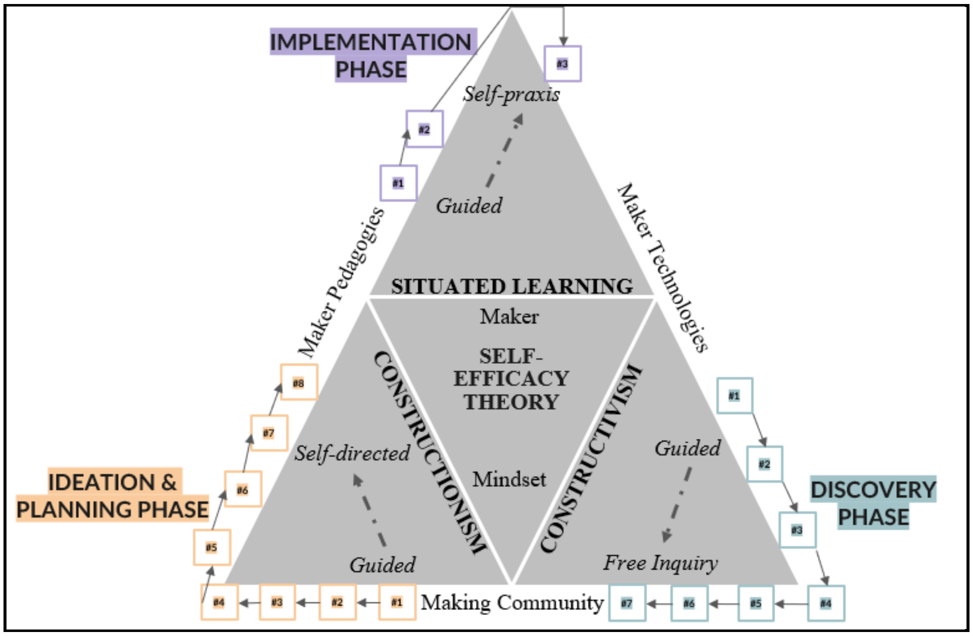
4.3.2 Internship

The 2018-2019 B.Ed. Intermediate/Senior (I/S) and Primary/Junior (P/J) pre-service teacher cohorts were required to complete an Independent Inquiry/Internship course in their final Fall semester. The objective of this course was to identify a professional need or skill set desired and then participate in a practical internship in a field setting (Ontario Tech University, n.d.). The internship required a minimum of 20 hours of participation along with inquiry research proposals, assignments, and final presentations to their class. The STEAM-3D Maker Lab has been chosen as an internship locale for several cohorts in the past with various pre-service teachers. The participants in our research project all had an interest in developing a better understanding of maker technologies, makerspaces, or inquiry-based learning. Typical STEAM-3D Maker Lab internship in the past, involved self-directed discovery of maker technologies with minimal guidance and just-in-time support, and then co-facilitation of discovery learning with the mobile maker unit (Hughes et al., 2018b). While these practices can benefit learning technologies the pre-service teachers often lack authentic making activity or pedagogy understanding and practice (Cohen et al., 2018; Hansen, 2018; O'Brien et al., 2016; Rodriguez et al., 2021).

4.3.3 Procedural Design

To achieve the research goals and help pre-service teachers develop a better appreciation of maker pedagogies and principles within the condensed 20-hour timeframe, it was clear that a guided inquiry approach based on constructivist ideals was required. In addition, a progressive approach was used to help the interns become a community of makers who adopt maker mindset perspectives. I leveraged the conceptual framework and created a design methodology with three overlapping phases where the interns participated in weekly workshops focused on progressive maker fundamental themes and guided-to-free maker inquiry approaches using different technologies. The situated learning theory was specifically adapted to provide a guided praxis experience with the mobile maker student visitation sessions. Figure 4.1 highlights the research design method including phases with numbered workshops over top of the conceptual framework.

Figure 4.1: Research Design Method with Conceptual Framework



The first phase of the design framework was the discovery phase where participants explored maker technologies while being exposed to weekly making themes. The discovery workshops involved various levels of guided-to-free constructivist inquiry learning depending on the complexity of the maker technologies and the experience or comfort level for participants. The second phase was the ideation and planning phase where the interns developed making activities based on teaching areas for their practicum and then proceeded through various planning, testing and assessment activities guided by the lead researcher using constructionist principles. The third phase was the implementation phase where the interns initially started in a support facilitation role, or Legitimate Peripheral Participation, during mobile maker student sessions and then were offered lead facilitation opportunities and a final option where they could borrow any technologies or tools and implement their planned making activities during practicum. Table 4.2 describes each workshop by project phase. Project phases were initially linearly designed but due to student making session scheduling modifications some overlap of phases resulted. Starting from the week of September 23 to November 6th there was at least one workshop per week (often multiple to meet scheduling needs of interns) and attendees typically spent 1-2 hours per session. The overall design approach was flexible to adapt to learner needs, STEAM-3D Maker Lab commitments, and research objectives

(Creswell, 2013), as such workshops were added or modified during the internship, see Figure 4.2 for the timeline of phases and workshops. Each workshop involved informal facilitation approaches where making themes were explained and modelled, maker technologies or pedagogical approaches were introduced from a practical teaching perspective, and emphasis was placed on hands-on self-directed, guided, or collaborative learning through scaffolded activities.

Table 4.2: Workshop Descriptions Organized by Project Phase

Discovery Phase					
Workshop	**Time**	**Attendees**	**Technology**	**Making themes**	**Description**
Discovery1 (Sept)	10 min	All	n/a	What is a Maker Lab?	Welcome & intros. Maker Lab responsibilities & research activities.
Discovery 2 (Sept)	71 min	Nisha	Micro:bit	What are maker activities? Failure-positive spaces Hands-on & active learning	Guided inquiry - coding template, Learn to code & one-on-one. Tech considerations.
Discovery 3 (Sept)	126 min	Mansa	Programmable robots (overview all, focus on Ozobots)	What are maker activities? Low floor concept Failure-positive spaces	Guided inquiry - informal overview, play & just-in-time support One-on-one. AI, ML & tech considerations.
Discovery 4 (Sept)	108 min*	Kamali, Marina, Mansa, Aiza, Shahari, Hadil	Programmable robots (overview all, focus on Ozobots)	What are maker activities? Low floor concept Failure-positive spaces.	Guided inquiry - informal overview, play & just-in-time support AI, ML & tech considerations.
Discovery 5 (Sept)	162 min*	Kamali, Marina, Shahari, Hadil	2D Design (Cricut)	Types of inquiry. Design processes. Interdisciplinary learning	Guided inquiry - detailed overview, play & just-in-time support. Authentication. Remixing
Discovery 6 (Oct)	177 min*	Mansa, Shahari	2D Design (Cricut)	Types of inquiry. Design processes. Interdisciplinary learning	Guided inquiry - detailed overview, play & just-in-time support. Authentication. Remixing
Discovery 7 (Oct)	104 min*	All	Micro:bit	Making theory - constructionism High ceiling & wide walls Real-world learning	Guided inquiry - coding template. Learn advanced code - Block & syntax. Debugging techniques, IoT.

Ideation & Planning phase					
Workshop	**Time**	**Attendees**	**Technology**	**Making themes**	**Description**
Planning 1 (Oct)	153 min*	All	Programmable robots, Cricut, greenscreen	Making challenges Collaborative learning	Free inquiry & mini-planning. Power, Connectivity
Ideation 1 (Oct)	39 min	Nisha	Beebot/Bluebot & Osmos	Making activities with curriculum. Tiering Scaffolding.	Brainstorming activities. Power & safety one-on-one.
Ideation & Planning phase					
Workshop	**Time**	**Attendees**	**Technology**	**Making themes**	**Description**
Ideation 3 (Oct)	58 min	Mansa	Ozobots	Passion-based learning Perseverance Productive Struggle	Practicum teaching areas & ideas. Free inquiry one-on-one.
Planning 2 (Oct)	154 min*	Shahari, Aiza, Hadil, Nisha, Mansa	Ozobots, paper circuits, 3D design (Cospaces Edu), AR building activity	Curriculum making activities, scaffolding, tiering	Practicum teaching areas & ideas. Develop lesson. Initial testing.
Planning 3 (Oct)	147 min	Kamali, Marina	Ozobots, paper circuits	Curriculum making activities, scaffolding, tiering	Practicum teaching areas & ideas. Develop lesson. Initial testing.
Planning 4 (Nov)	88 min*	Kamali, Marina, Aiza, Shahari, Hadil	Ozobots, 3D design (TinkerCAD), paper circuits & lemon battery, AR building	Curriculum making activities, scaffolding, assessment	Testing & revising planned activities. Tech considerations for practicum
Planning 5 (Nov)	64 min	Mansa	Ozobots	Curriculum making activities, scaffolding assessment	Testing & revising planned activities. Tech considerations
Implementation phase					
Workshop	**Time**	**Attendees**	**Technology**	**Making themes**	**Description**
Implement 1 (Oct)	240 min	All	Programmable robots, Cricut, greenscreen	Making challenges. Design & make. Collaboration. Problem-solving.	Maker Day for 1st year TCs. Free inquiry. Just-in-time co-facilitation. Offer to lead facilitation
Implement 2 (Oct)	150 min	Shahari, Aiza	Ozobots	Design & Make challenges. Role of Teacher.	High school English students. Just-in-time co-facilitation
Implement 3 (Nov)**	varies	Kamali, Marina, Shahari, Nisha	Circuitry, Ozobots, AR hands-on building	Implement planned making activities Guided inquiry Making assessments	Lead facilitation Elementary & High school practicums Various subjects/classes

*This is the total duration; interns came at different times & lasted different durations depending on their schedules.
**This implementation session was optional. Interns chose whether to borrow equipment & implement making activities.

Figure 4.2: Timeline of Research Approach: Phases, Workshops and Interviews

Research Design Schedule					
Date	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Sept. 23 - 27	Sept. 23 Pre-workshop survey- DUE #1 - Discovery workshop #1 #2 - Discovery workshop #2		Sept. 25 #3 - Discovery workshop #3	Sept. 26 #4 - Discovery workshop #4	
Sept. 30 - Oct. 4	Sept. 30 #5 - Discovery workshop #5		Oct. 2 #6 - Discovery workshop #6	Oct. 3 #7 - Planning workshop #1	Oct. 4 #8 - Implement student session #1
Oct. 7 - 11	Oct. 7 #9 - Discovery workshop #7				
Oct. 14 - 18			Oct. 16 #10 - Ideation workshop #1	Oct. 17 #11 – Implement student session #2	
Oct. 21 - 25	Oct. 21 #12 - Ideation workshop #2		Oct. 23 #13 - Ideation workshop #3		
Oct. 28 - Nov. 1	Oct. 28 #14 - Planning workshop #2	Oct. 29 #15 - Planning workshop #3			
Nov. 4 - 8	Nov. 4 #16 - Planning workshop #4		Nov. 6 #17 - Planning workshop #5		
Nov. 11 - 15 *practicum after this	Nov. 11 #18 - #23 - Stage 1 final interviews		Nov. 13 #24 - Stage 1 Final interview		Nov. 15 Post-research survey (practicum start)
Jan. 13 - 17	#25 – Implement student practicum sessions #3				Jan. 17 #26-27 - Stage 2 Final interviews
Jan. 20 – 24			Jan. 22 #28 - Stage 2 Final interview		Jan. 24 #29 - Stage 2 Final interview

4.4 Data Collection

Case study approaches typically involve in-depth empirical exploration from diverse perspectives to ascertain and interpret the complexity and uniqueness of the bounded context (Simons, 2009). As such case studies are characterized by thick description which involves the analysis and written descriptions of the entity being investigated, the context and circumstances of the bounded system, the participant characteristics and insights and the nature of the learning and situated community (Geertz, 1973; Merriam, 1985). Merriam (1998) described how a case study is different from other qualitative projects in that it involves more vivid and concrete analysis of multiple sources of evidence and more contextual experiences where there will be many variables of interest. To analyze any changes to pre-service teachers' competencies, confidence, and mindset beliefs with maker pedagogical approaches during guided workshops coupled with guided student facilitation sessions it was necessary to collect a variety of data sources during all three stages (discovery, ideation/planning, and implementation) of the research project. The multiple sources of data are categorized as either surveys, interviews, observations, or artifacts and are described in the sections below. The range of data varied from objective to subjective participant and lead researcher perspectives and resulted in over 450 distinct data sources including over 131 hours of videotaped sessions and interviews. Table 4.3 summarizes the data collected providing descriptions and amounts of each type of data separated by research phase.

Table 4.3: Data Collected and Sorted by Research Phase

Discovery Phase		
Data Source	**Description**	**Amount (Hrs or Number)**
Surveys	Pre-research survey questionnaire	1 survey - 7 participants responded in 1 document
	Exit workshop surveys	5 exit workshop surveys - 5 participant responses
	Exit workshop surveys videos	0.21 hrs (4 responses from 1 workshop)
Observations	Maker Lab discovery workshop videos (multiple views)	60.5 hrs (from 7 discovery workshops)
	Researcher field notes	6 documents
Data Source	**Description**	**Amount (Hrs or Number)**

Artifacts	Participant documents (CV's, notes, photos)	7 CVs; 7 notes; 23 photos (from 2 workshops)
	Facilitator documents (Support material, prep workshop material)	4 support documents; 2 prep materials
Ideation & Planning Phase		
Data Source	**Description**	**Amount (Hrs or Number)**
Surveys	Exit workshop surveys	8 exit workshop surveys with 8 participant responses
Observations	Maker Lab ideation & planning workshops	59.4 hrs
	Researcher field notes	4 documents
Artifacts	Facilitator documents (support material)	18 documents
	Participant documents (reflections, prep materials, photos)	1 reflection; 5 documents (0.62 min); 22 photos
Implementation Phase		
Data Source	**Description**	**Amount (Hrs or Number)**
Surveys	Post-research survey questionnaire	7 survey responses in 1 document
	Exit workshop surveys	2 exit workshop surveys with multiple responses
Interviews	First phase final interviews (end of workshops)	7 interviews totalling 7.04 hrs
	Second phase final interviews (after practicum)	4 interviews totalling 3.67 hrs
	Interview question guide and notes	2 documents
Observations	Facilitated students session videos	0.152 hrs (short clips from 2 visiting sessions)
Artifacts	Facilitator documents (presentations, photos, memoing)	3 PowerPoints, 74 pictures, 1 memoing summary
	Participant documents (photos, notes, reflections, intern materials, practicum materials)	19 photos, 2 notes, 1 reflection, 5 intern presentations, 2 presentation videos (0.24 hrs), 6 assignments, 18 practicum materials with 2 photos)

4.4.1 Surveys and Interviews

Qualitative research is concerned with how people construct meaning and interpret situations as they engage with various social interventions (Creswell, 2013). When asking questions to participants in qualitative research it is important to allow for interpretation and perspective which is best accomplished through open-ended questions that are not narrowly defined (Creswell, 2013). Context and process are also key aspects of case studies, therefore qualitative researchers tend to design their own questions relevant to the situation and project stage rather than using standardized or pre-developed survey questionnaires (Creswell, 2013). In this research, a pre-study survey was developed with ten questions, eight of which were open-ended and related to participants understanding of makerspaces, why they wanted to intern in a Maker Lab, any experience they had with making, their thoughts on making in schools and any concerns they had with future making sessions. The two remaining Likert-type scale questions were meant to gauge participants' understanding of specific maker technologies. The data from these two questions were not used directly in this analysis but helped guide facilitation approaches during the making workshops. This pre-research self-reported survey was completed online by participants prior to the start of the first making workshop, and a copy is displayed in Appendix B1. After the final workshop, the two Likert-type scale questions were re-asked in a post-research online survey for participants to self-report online. The answer to these questions was meant to ascertain changes in confidence levels related to specific maker technologies. The last type of survey was workshop exit tickets which typically contained two to four open-ended questions pertaining to the workshop activities. After each workshop, these exit ticket surveys were submitted to participants online for them to complete prior to the next scheduled workshop. These questions were analyzed as part of the data analysis described below, but also had the added benefit of reflection allowing participants to consider their experiences and provide insightful discoveries or learnings. An exit ticket survey sample from the October 2nd workshop is in Appendix B2.

Interviewing face-to-face or online with individual participants is a common practice in qualitative case studies and can help check the accuracy of impressions gained during observations (Fraenkel, Wallen & Hyun, 2012). Interviewing with open-ended questions provides the subjective experience of participants while also being uniquely advantageous in permitting the clarification or expansion of ambiguous or insightful responses (Fraenkel et al., 2012; Tuckman, 1994). Interviewing in a semi-structured manner allowing free-flowing natural conversations to emerge and flexibility in the sequence of questions, can help establish comfort and trust with participants (Creswell, 2013). Final interviews, in this study, were conducted using these free-flowing semi-structured methods in two stages. The first stage was 20-30 minute final interviews with all seven participants individually and face-to-face. This was the final interview for participants: Mansa, Aiza, and Hadil, who chose not to implement a making activity during their practicum. These interviews were conducted in a quiet office with the door closed to ensure confidentiality and privacy in responses. Appendix C1 shows the general interview guide for the stage one final interviews which were based on ascertaining their complete experience through the research phases. The second stage of final interviews was also 20-30 minute semi-structured interviews conducted online or in-person with specific participants: Shahari, Nisha, Kamali, and Marina, who had implemented making activities during practicum with borrowed materials. The specific questions asked during these second stage final interviews were primarily related to their self-facilitated making activity experiences during practicum, see Appendix C2. As all the final interviews were intended to be conversational and free-flowing, the specific phrasing and sequence of questions varied between participants. As the lead researcher, I led each interview and took notes while also videorecording with two separate cameras for redundancy. Each participant gave permission to be interviewed and recorded with signed consent forms.

4.4.2 Observations and Artifacts

Qualitative research is a situated activity that benefits from various observational viewpoints and is not bound “by tight cause-and-effect relationships” among factors (Creswell, 2013, p.47). Observations can provide a complex picture arising from multiple perspectives highlighting diverse experiences and displays of emotional or physical responses during various interactions, discoveries, or challenges (Creswell, 2013, Merriam, 1985). In the Maker Lab there are video cameras positioned discretely throughout the room allowing for an unobtrusive observation method (Fraenkel et al., 2012) during making workshops. These video cameras often had a stationary view, however, that was difficult to change during dynamic making activities in the Maker Lab. To view the activities of the pre-service teachers as they moved throughout the Maker Lab, we asked them to wear point-of-view or spyglass cameras. These eyeglasses with hidden cameras offer unique perspectives of pre-service teachers' actions and conversations in context (Russ & Luna, 2013). All these types of video cameras were used to record the vast and complex interactions during all the maker workshops in the Maker Lab. These viewpoints provided insightful learnings, formal and informal conversations, and interactions that were transcribed and analyzed with other data sources. I also wrote field notes based on my observations during many research activities including workshops and visiting student making sessions.

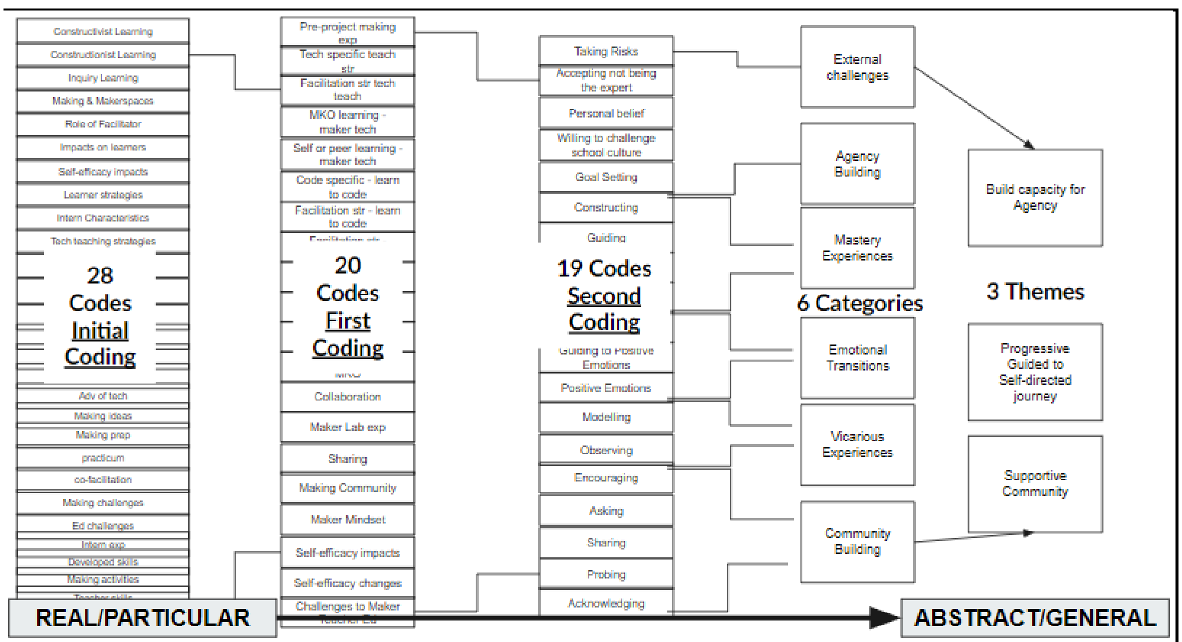
The final source of data collection for this qualitative case study included various artifacts or documents. Artifacts can provide a unique and subjective perspective that can support or refute other data sources and thus are essential for data accuracy and validity (Fraenkel et al., 2012). Participant documents ranged from jotted notes during workshops, reflections after co-facilitating student making sessions, internship course assignments and final presentations, resumes or CVs, making activity discovery and testing pictures and videos, and practicum making lesson plans, classroom materials and pictures. My artifacts included workshop or student session preparation materials, testing images or videos, and presentations, summary research memos, B.Ed. coding course program syllabus, and any additional support documents provided to participants. All these artifacts were collected, organized, saved electronically with redundancy, summarized, transcribed, and included in the complete package for data analysis. The use of these large amounts of data which capture multiple perspectives and interpretations was done to increase the validity of the data through a process of triangulation (Merriam, 1985).

4.5 Data Analysis

The data analysis began with transcribing all video files from all workshops, student sessions and preparation activities. To grasp the full flavour of the lived experience, the transcriptions I conducted involved verbatim documentation including pauses, interruptions, gestures, quotations, self-talk, and non-verbal actions (Poland, 1995). All the data was then anonymized and redundantly saved in secure locations. I then began a comprehensive and iterative process of coding the data. Miles, Huberman, and Saldaña (2014) suggested that a qualitative study involves telling a convincing story. The data analysis is a critical and deliberate effort in this story to uncover the most significant elements and organize them in a coherent and meaningful way that is faithful to the data while answering the research questions (Miles, Huberman, & Saldaña, 2014). In qualitative analysis, coding is the transitional interpretative and heuristic practice of reducing large amounts of empirical data to symbolic and summative codes which can then be analyzed for patterns resulting in categories and themes (Linneberg & Korsgaard, 2019; Saldaña, 2013).

As a novice researcher, my coding practice began slowly and extremely detailed, reading through every word and action, and becoming intimate with the data which resulted in line-by-line codes (Charmaz, 2006; Saldaña, 2013). For this inductive initial or first impression coding cycle, I applied short descriptive and in vivo codes (Linneberg & Korsgaard, 2019; Miles et al., 2014). To streamline the line-by-line codes to the most salient insights and findings, I then went through highlighting and bolding key passages of data applying key insights, considerations, and other pertinent details as notes beside the codes (Saldaña, 2013). My first cycle of inductive coding ended with another pass through the data where I revised, added, removed, and combined codes and subcodes to the data. To begin my second cycle of coding, I gathered my research question, goal, and conceptual framework to focus my efforts and apply a theoretical triangulation (Miles et al., 2014). This deductive second cycle coding process involved re-naming, changing, consolidating, removing, and adding new types of codes and subcodes (process, concept, and emotion coding). I next conducted a within-case cross analysis where I compared findings for each intern resulting in some consolidation and modification of codes. The last actions of the second cycle coding process involved clustering and sorting data according to similarities, differences, frequencies, sequence, and correspondence (Saldaña, 2013) while using the self-efficacy theory as a guiding framework. This final coding process resulted in streamlining the data into codes that provided more meaningful alignment to the research purpose and question, and reduced the final number of codes from 28 to 19. The next stage of the data analysis involved a thorough evaluation of any patterns that emerged from the data and resulted in the higher-level and more generalized categories and themes. As a final act, I reviewed my analytic memos from each phase of the project which helped to reflect on insights and discoveries, while finalizing codes, categories, and themes. Triangulation was obtained by incorporating multiple sources of data with tiered stages of analysis contributing credibility to the findings by interpreting data from various perspectives (Yin, 2009). These final steps of the data analysis resulted in nineteen codes, six categories and three themes - Progressive Guided to Self-directed journey; Supportive Community; Build Capacity for Agency. My entire abduction (inductive & deductive) coding process (Linneberg & Korsgaard, 2019) is displayed in Figure 4.3 which was created using Saldaña's (2013) streamlined codes-to-theory model for qualitative inquiry but adapted with my data.

Figure 4.3: Research Abduction Coding Process



Chapter 5. Findings

In this interpretive single-case study, six categories resulted from the combination of an inductive analysis of the multiple forms of data followed by a deductive analysis using self-efficacy sources from the self-efficacy theory. These findings represent the consolidated participants' experiences with making practices and any adoption of making philosophies during their STEAM-3D Maker Lab internship. To demonstrate the research findings, the following sections will articulate each category using direct quotes, observations, and any other data sources which clearly highlight the interpretations:

1. Vicarious Experiences: Represent the findings that were derived from observation and modelled experiences.
2. Mastery Experiences: Represent the findings that were derived from ongoing, progressive learning through stages of adversity and success.
3. Community Building: Involves aspects of social persuasion and represents the findings that were derived from encouragement, acknowledgement and sharing practices from our making community of learners.
4. Emotional Transitions: Involves aspects of physical and emotional states and represents the findings that were derived from the positive emotions and the impact of transition practices from our making community of learners when negative emotions were encountered.
5. External Challenges and Agency: The fifth and sixth data categories were combined into one finding as they logically align in a cause-and-effect perspective. This section represents the findings that were derived from described challenges of making in education and agentic capacity building practices that were demonstrated during the study.

5.1 Vicarious Experiences

With guided inquiry-based learning in a makerspace or Maker Lab, the facilitator plays the role of guide and co-learner. The facilitator creates a productive context for learning with materials, tools, facilitation strategies, scaffolding, guiding, and reflecting while also recognizing the importance of sharing in the act of learning as never-encountered situations arise (Lock et al., 2020; Stager, 2010). In this study, the lead facilitator's (myself, Margie) methods for guided inquiry provided vicarious experiences that fostered competency and self-efficacy growth for participants through modelling and observation.

During the discovery and planning phases, acting as the lead facilitator, I not only modelled various maker tool discovery and pedagogical instructional strategies but also differing levels of guided inquiry approaches (a spectrum from free inquiry to structured). Through these modelled approaches the pre-service teachers developed an appreciation of how these approaches work and the benefits and challenges they pose. During her phase one final interview, Shahari described how her perspective on the different leveled approaches to inquiry had changed as she progressed through the internship:

> ***Shahari:*** *…it was really interesting…how there's different levels of inquiry. Like structured versus free and actually in the beginning I thought structured is not necessary or like it's almost negative. But the thing is I realized that's not true at all because…we have to structure it based on the readiness of the learner. So if the learner has no idea about the tool or anything like that then structured inquiry might be awesome. Versus free inquiry might, you know, work amazing on people who already have an idea of what it is…So I learned that there is no right or wrong way to do it.*

Shahari recognized how applying these different levels of inquiry can relate to the readiness of learners, an important concept in constructivism where students are guided through learning stages by MKOs when they are ready and in the ZPD (Alanazi, 2016; Fasso & Knight, 2020).

Acting as the lead facilitator, I also modelled facilitation strategies when leading a making activity with large groups or a class of students. In her phase one final interview, prior to her placement, Kamali reflected on the benefits of watching how I facilitated a student making session and how students responded.

> ***Kamali:****…being able to see it being taught at the Maker Day…that was good to see how you presented it, as well as seeing how the students reacted to it. So that was a good experience.*

The interns observed these different modelled, guided inquiry strategies and how they work in a Maker Lab with different maker technologies and making activities. These experiences provided interns perspectives on how these approaches work, but also what aspects they prefer or would revise in their own maker pedagogical approaches.

During free and self-directed inquiry times in the Maker Lab, acting as the lead facilitator, I also modelled just-in-time support practices. Just-in-time support occurs as the facilitator roams the room, observing students making and only providing interventions when the students have encountered roadblocks or are becoming highly frustrated or there is a sudden learning moment to be capitalized on (Papavlasopoulou et al., 2019). The facilitator's interventions include encouragement, hints, collaborative problem-solving and probing or guiding questions versus direct answers. In these just-in-time support moments, the facilitator needs to be flexible and adaptable, recognizing the needs of the learner, the complexity of the situation and then ascertaining the appropriate level of scaffolding and support (Lock et al., 2020). The interns recognized the value of this just-in-time support practice in their own learning during making workshops as described by Aiza:

> ***Aiza:****...it (just-in-time support) was very helpful because you were there and you were constantly there to support and help.*

As participants became more confident, they practiced just-in-time support practices they had observed:

> ***Mansa:*** *(talking aloud to herself in frustration) I can't connect to Cozmo!*
>
> ***Marina:*** *(who has just finished using Cozmo and was sitting nearby) So, mine just turned on and it will say the number on top here (further encourages Mansa to connect to Cozmo while observing her).*

Another example of just-in-time support came from Mansa acting as an MKO with Shahari and Aiza who wanted to collaboratively learn more on Ozobots:

> ***Aiza:*** *(working with Shahari) Ok, so like for programmable robots, I have no idea what I'm doing.*
>
> ***Shahari:*** *So…let's do Ozoblockly together then because I'm kinda new.*
>
> ***Mansa:*** *(listening to Aiza and Shahari talking and then interjecting) I'm good with this (points to the Ozobot)*
>
> ***Aiza:*** *(responding to Mansa) I don't…it couldn't work for me.*
>
> ***Mansa:*** *It's Ozobot, Ozoblockly is the app. So the first thing… (explains how Ozobot is coded and then encourages Aiza & Shahari to try)*

What is particularly poignant about these two examples is that, in one instance, Mansa was the novice and in the other, she was the expert. This is typical of makerspaces where participants can vary in their level of expertise with different tools and materials and can expect to be both needing assistance and encouraged to provide just-in-time support as an MKO (Cohen et al., 2017; Vossoughi & Bevan, 2014). These findings support how modelling these guided, and just-in-time support approaches can help pre-service teachers consider how these practices work and then intuitively act them out with practiced learning in Maker Labs and during student sessions.

In any makerspace, facilitators need to model making principles such as willingness to take risks, acknowledging mistakes, and highlighting when they lack expertise and must learn from others (Lock et al., 2020). According to self-efficacy theory, participants are more apt to adopt modelled practices from co-learners and peers versus experts who accomplish tasks easily (Bandura, 1977). In this study, acknowledging when I made mistakes and highlighting when I was not the expert was an important trigger to shift the mindset of many of these pre-service teachers who have been burdened with traditional teaching expertise expectations. Observing myself, as the lead facilitator, making mistakes and enthusiastically acknowledging that fact helped interns realize they do not have to be the expert. It normalized mistakes and it further emphasized the co-learning role teachers adopt in educational makerspaces. By the end of the study, all of the interns in their final interviews had recognized the importance of teachers shifting their philosophies from traditional teacher-centered mentalities to more growth-oriented maker mindsets, where teachers are co-learners and guide student learning (Lock et al., 2020). Nisha highlighted how her mindset had shifted:

> ***Nisha:*** *I don't still kind of understand everything. However, on the other end my outlook has changed…because my confidence is built…I have a different approach now, that growth mindset.*

Shahari recognized how her mindset shift can translate to helping her future students:

> ***Shahari:*** *You emphasized quite a lot, like, it's ok to not succeed right away. And that made me really comfortable with it. Compared to Maker Day when I first started, I was very subconscious. I didn't want them (the Maker Day facilitators) to think that I don't know anything…But now I've kind of changed my perspective on learning. I feel like as teachers it's important to model that it's okay to make mistakes cause then that way we make our students feel comfortable with making those kind of mistakes.*

This example also highlights how Maker Days or Maker Faires are not enough context in pre-service teacher maker education for many new teachers to understand and adopt maker mindsets.

Changing mindsets and teaching philosophies towards making principles and away from traditional teacher-driven education is a process that takes time and is unique for each person, as recognized by Marina:

> ***Marina:*** *Like I don't need to be an expert ...and I think at the end of the day there's always that potential to fail, and that's ok. And I really like that approach in general for teaching and learning. So I think that's something that I still have to get comfortable with, just because it shows the children that you're also a human, like you make mistakes. It normalizes mistakes.*

All participants recognized a change in their philosophies towards more of a growth-oriented, maker mindset; however, they also recognized there was more practice required particularly with their own students in their future classrooms.

> ***Kamali:*** *I'm a little scared of that (making mistakes in front of students) because it can kind of be embarrassing. Um, like they expect you to know everything. And so I'm kind of scared that maybe they'll think 'well why are we doing it if the teacher doesn't know about it'. So, I think before doing these types of activities, have that discussion of like 'I don't know everything. But this is an activity where we're going to work together to figure out because the teacher doesn't always have to know everything'. I think that would also be a motivating factor for them to not come to you for everything.*

Kamali realized that there is a school culture that has come to expect expertise from teachers and to change this culture will involve various communication strategies and regular making practice with students. These repeated practices can support teachers as they continue to grow in a maker mindset while also supporting mindset changes for students who have become accustomed to traditional teacher-centered ways of learning. Kamali also recognized that making can disrupt the traditional school cultures, but it requires strategic instructional methods to help mitigate these challenges.

Observation was another form of vicarious experiences that positively influenced confidence, mindset, and teaching practices. The findings in this study show that by observing nearby peers problem-solving and persevering through challenges, many interns developed the belief that they too were capable of persevering through similar issues (Bandura, 1977):

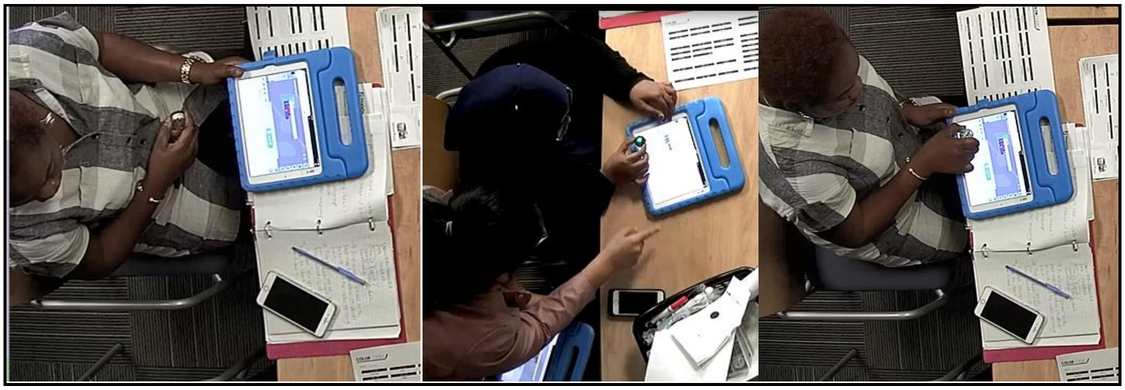
(During workshop #3 working with Ozobots)

Shahari: *(problem-solving with Hadil) It's supposed to turn green, shut it down again.*

Hadil: *(listens to Shahari and turns it off and on again)*

Mansa: *(watching Shahari and Hadil troubleshooting, she then turns back to her Ozobot and says to herself) Ok, let me try this again, I think I can do this.*

Figure 5.1: Observing Problem-solving by Peers



Mansa watched Shahari and Hadil successfully problem-solving and it motivated her to continue working through her challenges, while also providing ideas for different troubleshooting methods. This practice was common in the discovery workshops where interns were using the same maker technologies and would be endeavouring through similar stages of learning.

Inspiration in making ideas was a common finding in ideation and planning phases as interns observed the personalized making activity lessons of their peers. Marina described how she was inspired by an art making activity that Kamali was practicing with paper circuits:

Marina: *And even just talking or seeing some ideas, like generates more ideas. Like even doing that art project with the circuits. Like when I saw Kamali building hers…this gave me an idea to do an art project with them for Christmas.*

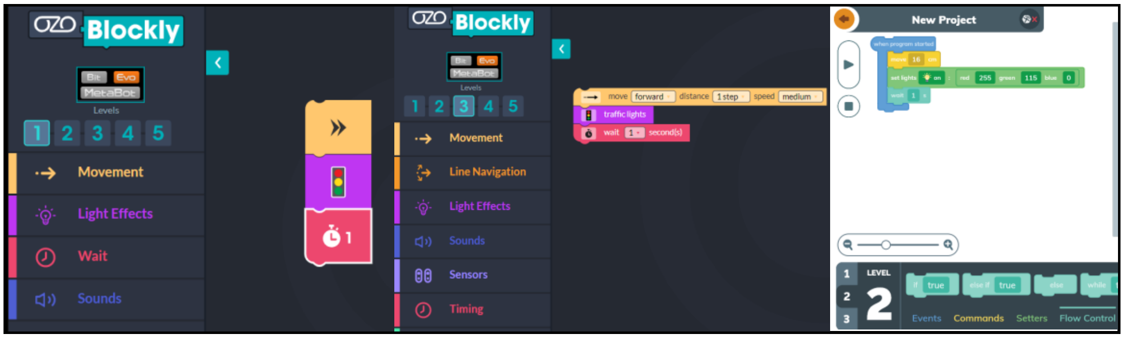
Marina was so inspired by Kamali's making activity that she requested the same materials to implement as a second making activity during her placement. These findings were supported by other researchers who highlighted how inspiration is a common occurrence in makerspaces, as makers can freely walk around, observe, ask, and learn about others' creations or discoveries (Hughes & Morrison, 2020; Vossoughi & Bevan, 2014).

5.2 Mastery Experiences

Self-efficacy theory states that a person’s self-efficacy can be developed through progressive and on-going learning experiences that migrate through adversity and achieve some level of success (Bandura, 1977). In this study, these mastery experiences were achieved through the ongoing and phased guided learning workshops and student facilitation sessions. In the following section, I describe these mastery experiences, which were evaluated to ascertain participants’ making confidence, competency, and any mindset growth or pedagogical shifts related to making.

In the initial discovery phase, the focus was on learning maker technologies while being introduced to making themes such as learning from mistakes, interdisciplinary learning, and design-based thinking. The guided instructional approaches used for these maker technology discovery workshops involved summaries of key functionalities, strategies for teaching with technology (e.g., connectivity, authentication, power) and informal discussions on practical teaching ideas. Overviews of functional or coding environments were then introduced prior to hands-on exploration. These overviews ranged from structured methods to quick reviews depending on the complexity of the technology and the needs of specific learners. In the main guided workshops, there was an emphasis on deeper learning with three primary maker technologies: programmable robots with Ozobots, 2D/3D design with Cricut, and microcontrollers with Micro:bit. These specific technologies were chosen because they were common tools used during school visits, they were particularly effective for making activities, and their coding/design platforms presented common features and functions as compared to many other similar technologies. For example, in workshop #3, when providing the overview of Ozobots, Margie highlighted similarities to a familiar coding environment, Scratch, as well as those of other programmable robots.

Figure 5.2: Same Code Displayed on Different Programmable Robot Apps: Ozoblockly level 1 and level 3, and iRobot root level 2.



This approach was helpful to build on familiarity that interns already had while also providing methods to recognize similarities when they started self-exploration. Interns appreciated these methods as described by Aiza who highlighted her increased comfort in learning other programmable robots after the guided approach with Ozobots.

> ***Aiza:*** *The guided inquiry really helped when we didn't know where to start. And then once we figured out that a lot of, like the coding was similar, for the different programmable robots, we could just kind of use what we learned and then apply it to other aspects as well. So, the guided inquiry really helped getting more comfortable. And then having that more open space to freely play around was also useful because…you could try different things out.*

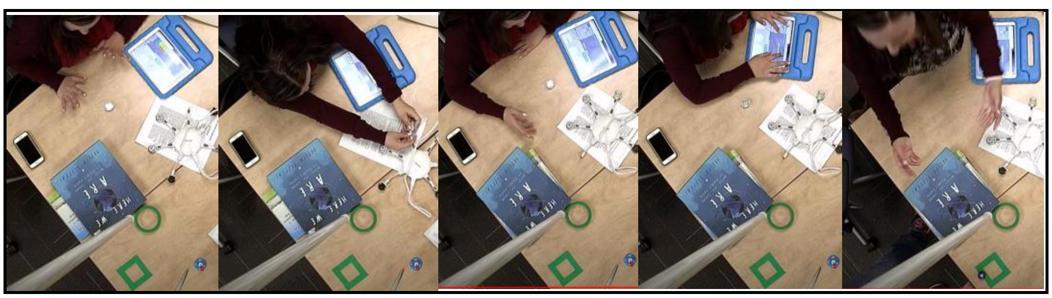
As Aiza highlighted, this strategy of learning a few technologies in-depth while emphasizing commonalities helped interns build confidence as they explored similar technologies and continually tried new things. The interns demonstrated their growing confidence and competencies during many instances of the self-discovery that followed the guided learning.

> ***Kamali:*** *I enjoyed the ability to explore all of the tech tools. When I felt comfortable with one tool, I moved on to the next and never got bored. I also tried to troubleshoot and tried to fix problems or questions on my own before asking for help. I also collaborated with my peers to figure things out.*

The findings support the idea that the guided, hands-on approach with one maker technology helped provide the introductions and strategies to navigate through multiple similar technologies. Then as the participants explored similar technologies, they developed more confidence and competencies.

As interns progressed to self-exploration, they experienced some success, but they also encountered many new challenges that caused initial frustration and anxiety. In makerspaces, these challenging situations are characterized as “hard fun” or “productive failure” (Kapur, 2008; Martin, 2015, p.36; Martinez & Stager, 2013, p.15). In our STEAM-3D Maker Lab, we believe these struggles are necessary for deeper understanding and to develop problem-solving capabilities. We have described these experiences as a “productive struggle” that makers should labour and persist through trying various problem-solving strategies as they attempt to make sense of a problem (Trinter & Hughes, 2021, p.4). In this study, these productive struggle moments were important for interns to try to troubleshoot on their own or collaborate with peers. During free inquiry workshops, as the lead facilitator, I circulated the room observing participants working through their discoveries and challenges. When opportune moments arose or frustrations became overwhelming, I provided just-in-time support through probing questions, functional tips and tricks, hints or demonstrations of common issues or problem-solving strategies. As interns continued to practice, they became more confident to work through their productive struggle moments on their own, which helped them develop problem-solving competencies, and adaptive expertise (Martin, 2015).

Figure 5.3: Demonstrating Multiple Problem-solving Strategies



In Figure 5.3, during her last workshop #15, Marina demonstrated her methods to work through her productive struggle with several different problem-solving strategies that she had developed through weeks of practicing during earlier workshops. In the sequence of images, she initially gestures that something went wrong. Then the next image highlights her first problem-solving strategy which was to switch robots followed by the next image showing her re-starting the upload from the beginning. These approaches failed, so the next image shows her reading the code line-by-line, isolating the issue, and trying again, which proved successful in the final image. During many of the initial workshops, Marina was not always able to solve issues by herself with Ozobot, having to ask peers or facilitators for support. However, at the end of the internship, her capabilities had significantly improved, which not only helped her confidence in her own making and problem-solving abilities, but also in her ability to lead making activities in her practicum with Ozobot. In her phase one final interview prior to practicum, Marina recognized the skills she had developed through the many workshops and challenges she faced:

> ***Marina:*** *I know I experienced some difficulties. I think yeah, like definitely resilience is a skill I developed. Just in terms of my own um, problem-solving ability.*

Interns recognized how these making experiences helped them develop various competencies (e.g., problem-solving techniques, perseverance, resilience) as they worked through various productive struggle moments.

The productive struggle was an experience that pre-service teachers needed to have to develop grit and the ability to handle failure. Jones (2021) recognized that having these professional development experiences involving productive struggle not only benefited the teacher but also provided them valuable insights into the struggles their students may have. In this study, I wanted to provide the interns with the ability to have first-hand exposure to students' productive struggles as they learned maker technologies. To ensure the interns were comfortable during these initial student making sessions, they were asked to use Legitimate Peripheral Participation by observing students and providing just-in-time support if possible. If they were unable to provide students support, they could refer to a lead facilitator at any time, who would then apply cognitive apprenticeship methods and coach interns through just-in-time support practices and encourage reflective discussions afterwards. The methods of Legitimate Peripheral Participation allowed the pre-service teachers to understand the challenges students may face and the productive struggle they will experience while testing their level of confidence in supporting students through problem-solving and learning opportunities. During her reflections on the Maker Day experience, Nisha described how she learned that productive struggle was a key element of the student’s learning journey:

> ***Nisha:*** *(Nisha led the session on greenscreen for Maker Day with Hadil) What I observed in the Maker Day is that when we explained greenscreen many people didn't understand it…like initially they were a little frustrated…like every session you could see there was like a 10-15 minute period of time where you could see like everybody was stressed out, didn't know what to do. And then after a little while you could see like 'Ohhh, Yeah!'. Like you could hear laughs and giggles. And you know like everybody was enjoying themselves because they finally figured out how to do the greenscreen.*

Shahari also observed how students worked through their productive struggle moments during Maker Day, and for Shahari, these observations gave her a better appreciation of the benefits these challenges can provide for her future students:

> ***Shahari:*** *I think this experience was a great way to observe how different learners learn…I had to remind myself a part of this learning experience is students feeling stuck. It shows they are thinking to work their ways around the problems, and that as a teacher and learner, it is important to have a "I can and will solve it" attitude. Maybe a benefit of incorporating this into classrooms is that we enable students to develop a growth mindset and develop grit, as well.*

These student discovery sessions were enlightening to many interns and provided a means for them to test their adaptive expertise and ability to guide students through challenges, while also providing insights on student experiences with maker technologies.

> *(From the exit survey after the student making session on October 4th)*
>
> ***Mansa:*** *Today's workshop was very helpful and interesting. I was able to assess my own learning and skills by helping the students. I can clearly rate myself in my comfort zone levels now. I also learned how the maker tools can be engaging for students and different ways to implement them in the classroom.*

The guided discovery workshops followed by free inquiry provided the means for interns to experience multiple iterations of success and failure. Combining with Legitimate Peripheral Participation during student maker discovery sessions helped teachers understand methods for leading large groups of students through making, how to support them as they encounter productive struggle moments and challenges, and the benefits of these making experiences for students.

The next phases of the project involved the movement towards the development of interns' maker pedagogical understanding. After initial maker discovery workshops, acting as the lead facilitator, I led guided ideation and planning workshops based on interns' practicum teaching contexts. The idea for these workshops was to build a bridge between the theory-based self-discovery learning in the Maker Lab to situated self-praxis in the classroom. Initially, these were one-on-one brainstorming sessions where I presented demonstrations or described making activity suggestions and encouraged interns to talk through their ideas and concerns while considering curriculum expectations, classroom setup and assessment. The sessions focused on each participant developing personalized making activities that they could implement on their placement if they chose. The sessions were initially driven by me to ensure the making activities were appropriately scaffolded to support rich-learning authentic making experiences. Interns appreciated these workshops and how it helped prepare for them to facilitate on their own in their practicum:

> ***Nisha:*** *I like the idea when we were discovering…and then we were just coming up with new ideas. Oh, we can do this! Or we can do that! We were generating a lot of ideas and it was making me think. When we spoke and collaborated, we built off ideas from one another. That's how I got other ideas to do stuff like. That was really, really important. Yeah. I'm very confident in the making part (for practicum), I'm not worried.*

Kamali highlighted some of the key aspects she learned to consider when planning making activities:

> ***Kamali:*** *So the key learning point was trying the activity ourselves. I guess it tells you what would be fun for the students and what wouldn't be and also helps you plan out timing and stuff. And then doing the activity ourselves also tells us which obstacles the students will probably run into…and also the scaffolding was really helpful…so that students at all levels can kind of catch up and make sure everyone's on the same page. So you want to give them opportunities to learn and also create with it.*

These findings suggest that the interns valued these ideation and planning sessions as they developed an appreciation of all the aspects involved in preparing for an authentic making activity in their classroom aligned to curriculum and learning outcomes.

Through the subsequent planning and testing sessions, the interns became more confident with their personal making activities while at the same time they recognized that making was more than just using technology:

> ***Hadil:*** *Like I always assumed like makerspaces was something that you'd need tech for. But I kind of realized that it's not necessary to need tech. You don't need to have fancy tech materials. You can just incorporate it into the classroom like that, just planning and applying it in different ways.*

Marina was able to articulate one of the significant findings in this study, where the emphasis of guided learning was to provide a clearer understanding of authentic making activities and how to develop, prepare, and facilitate them in their classrooms:

> ***Marina:*** *I would say I have a better understanding of what making actually is…Like I have more of an understanding now especially like going through the process myself, I understand that it's the process of making, how you end up with an end product. And having done it myself, I can see everything comes together. Like the understanding comes together. Like why this works.*

Marina further suggested that her internship with the STEAM-3D Maker Lab helped prepare her for her practicum and that she believes her experience should be shared by future pre-service teachers:

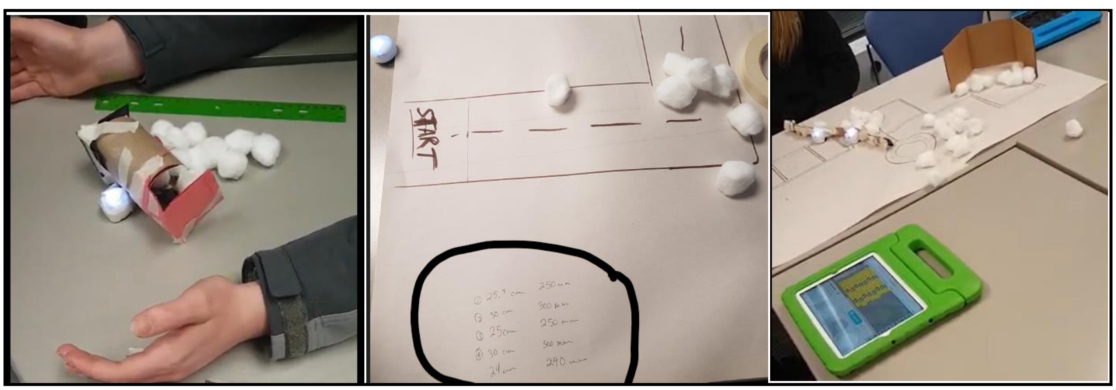
> ***Marina:*** *Like I think these sessions would be really useful for everyone in the program to know. Because it does help. So now when I go to placement, I'm not as overwhelmed. Especially as we're wrapping up assignments. And I think that it's really important for us to try the making process ourselves because for me it really clicked, like how understanding develops when I was working through things on my own. Like you can talk as much as you want about how it builds understanding but until they experience it, it doesn't quite make sense for you.*

These insights suggest that the ideation and planning phase was valuable for interns to develop a deeper appreciation of authentic making practices while the testing and discovery aspects provided them the lived experience of being a maker. The findings also highlight how these workshop activities can benefit interns by helping them to prepare for their upcoming practicum and content they could be teaching.

The final phase was the implementation phase for making activities. These situated practical teaching sessions with students provided pre-service teachers experience with facilitating making activities and an appreciation for the role of the teacher to guide learning and support students through challenges. Participants also observed how hands-on making activities versus just maker technology discovery, are experienced by students and the benefits to their learning. This was significant in motivating pre-service teachers to consider adopting these practices in their own pedagogies as they recognized how making can improve student learning experiences.

> ***Aiza:…****during the High School sessions I specifically remember was one of the students couldn't get it to go how he wanted based on um, the angles I think. So then he altered the approach and he used some directions and they were using rulers for measurement as well. So it was really nice to see students thinking first-hand using problem-solving skills and critical thinking and just knowing that it's not like a focused series of steps that they need to follow, but they can change things. So that was really interesting.*

Figure 5.4: Pictures from High School Design and Make Session

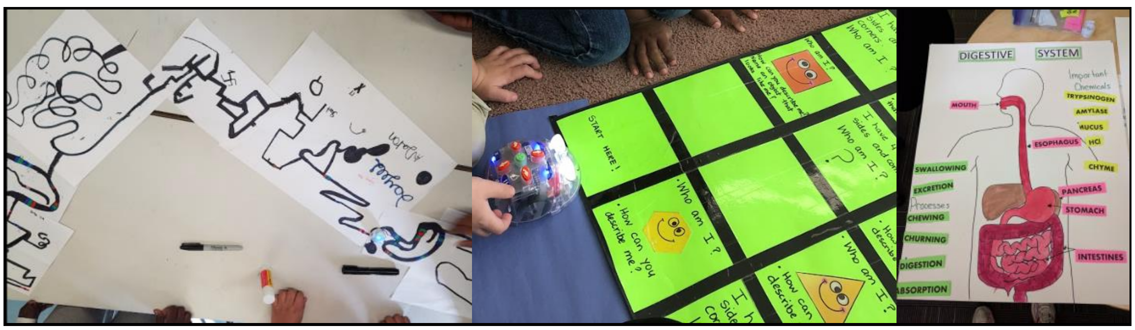


In this student making session on October 17th, a grade 12 class of high school students were involved in designing a 'snow-plow' cover for their Ozobot(s) and then coding their robot through a pathway picking up cotton ball 'snow' and corralling it to the end station. Shahari, who was also co-facilitating this session, described how she believed these making activities were beneficial learning experiences for students because they develop design-thinking and support interdisciplinary learning while engaging students in fun, team building challenges.

The four Interns: Shahari, Kamali, Marina, and Nisha, who implemented making activities (Figure 5.5) during practicum had a unique experience as they were observing and supporting their own students through personalized making activities. Shahari described some of the skills she observed from her students during her making activity:

> ***Shahari:*** *Cause I think that activities like this when they actually do it themselves that's when they're thinking. Hm…what is this? What function does it have? Also engagement I think. That's what he (AT) liked as well…And in terms of perseverance, I think that was one of the best traits because actually a lot of students would always come up to me and ask for help, but with this activity they never asked me for help…*

Figure 5.5: Pictures from Practicum Making Activities Led by Interns (Kamali left, Nisha middle, Shahari right)



The interns also reflected on how important their planning and practical experience was in the Maker Lab and with student making sessions, as situations arose that required adaptive expertise and flexible teaching.

> ***Marina:*** *It's really important (the experiences from the internship) because I know when I saw them start to draw it, I was like 'oh my goodness, I don't know how this is going to work'. Um, but then from our experiences, like in the Lab and like planning and even during the Maker Day, I was like, 'it's ok, um, give them an opportunity to practice. Like I'll find out what the mistakes were'. So it was good to have that like preparation, based on our planning. Otherwise it would have been a little bit overwhelming.*

Even though there were some issues and not everything worked according to plan, all of these particular interns believed in the benefits of making and felt confident with implementing maker pedagogies going forward. After reflecting on their making activities and the lessons they learned from practicum and the internship, all these interns described how they will adopt personalized making in their future classes. Here is Marina's perspective:

> ***Marina:*** *I think it (the practicum experience) actually encouraged me to do more. Because obviously this was more of a trial period, but like now I know how I would have to build up to it. So I wouldn't necessarily start off and have my making activity right away. I'd start them off like to introduce them to the tech...and just doing the guided ones…Um, and then I'd take some time. Like practice it again. So that by the time we go to the making activity, they would have those skills in place. Um, so it really helps me understand how to scaffold…because without that it would be overwhelming.*

What these interns highlight is that maker pedagogies involve a learning journey not one-off, cookie-cutter tasks that only focus on technology. They require teachers' effort in planning, proper exposure and practice with materials and tools, and effective scaffolding to engage all learners. These reflections suggest that these interns have developed competency in maker pedagogies and the experience has significantly influenced their teaching practices. While not all interns implemented their making activities during practicum, and some interns were more driven than others, they all declared in their final interviews that they would implement making activities in their future classrooms and the full experience had improved their making confidence and competencies while also positively influencing their own maker mindset.

5.3 Community Building

Making communities are fundamental to makerspaces (Berman et al., 2016) and they provide a means for social persuasion and support for participants as they discover, design, and encounter challenges. In this research project, the data suggested that building a community of learners to support the development of these particular participants' making competencies, confidence, and mindset changes involved aspects of encouragement, acknowledgement, and promoting open discussion, questions, and sharing practices.

Through the guided workshops, acting as the lead facilitator, I encouraged the participants to engage in hands-on learning, collaborative problem-solving, asking questions, and sharing practices. As interns discovered new things and worked through challenges, I would acknowledge their efforts, creations, insights, and risk-taking. These acknowledgments then became the norm and peers started to acknowledge and recognize each other:

(Workshop #5 working with robots and Cricut)

Margie: *How's it going?(asking Shahari and Mansa)*

Shahari: *We were able to print out her name tag.*

Margie: *Awesome. That's great!*

Mansa: *(pointing to Shahari) She showed me!*

In this workshop, I acknowledged the successful accomplishments of the interns, while Mansa acknowledged the support from Shahari. These vocal acknowledgements helped to positively reinforce a sense of belonging and collective accomplishment which built on individuals self-efficacy beliefs and confidence.

As interns developed practiced expertise it was important for facilitators to encourage them to act as MKO's where they could support and guide others in concepts or procedures they understood. MKO's can be anyone in a makerspace, not just the facilitator (Berman et al, 2016). In this study, recognizing and encouraging interns to act in this capacity as MKO, appeared to positively impact the confidence of the interns while also helping to build a CoP where anyone can contribute and support others.

(Workshop #4 working with Cricut)

Marina: *I'm done (her Cricut decal design)*

Margie *(looks at Kamali who had finished and cut her decal on the Cricut successfully): So actually you're here, do you mind walking her (Marina) through the print because this is the kind of thing that you might have to help and it's good to test what you learned.*

Kamali: *(nods, grins and starts helping Marina)*

Margie: *And I can take this out of your way. And I'll take yours (Kamali's completed Cricut decal). So, we got one printed! (Displays Kamali's work to all the interns).*

After this encouragement, Kamali demonstrating her confidence and competencies, went over to Shahari and Hadil on her own initiative and acted as an MKO:

Kamali: *Are you guys done?(asking Hadil and Shahari)*

Hadil: *Yeah. I'm just, I'm still trying to figure out how to print I guess. But I don't have paper or anything.*

Kamali: *I can help you. I think you have to choose from here (shows the vinyl) ...you can use that.*

Shahari: *So, I take this?*

Kamali: *Yeah. It has to line up let me show you (continues supporting both Shahari and Hadil)*

Encouragement as an MKO also extended to asking interns to teach the facilitator:

Margie *(workshop #8 asking Kamali and Marina, MKOs, for help with Cricut): Can I just ask a question before you leave? So what were you printing? So just in case anybody comes.*

Marina: *Just printing on the paper.*

Margie: *Printing that one. And then what do…what do they do?*

Kamali: *So then they print it on the front. (explains more to Margie)*

Margie: *See. You teaching me!*

These encouraging practices ensured the group of learners appreciated that everyone has the ability to guide or to learn from anyone and expertise should be a shared experience.

Sharing discoveries, learning, emotional experiences, and issues encountered are fundamental aspects of makerspaces and emphasized in the underlying constructionist theoretical construct (Cohen et al., 2017). The results from this study highlighted how sharing practices were both informative and provided voice and outlets for participants. After workshops, acting as the lead researcher, I provided exit surveys to the interns where a short list of questions was asked about their experiences. These surveys both assisted me in understanding intern workshop reflections, and also provided a forum for voicing concerns, anxieties or insights.

(Exit survey from planning workshop #6)

<u>*Any concerns for the Maker Day tomorrow?*</u>

Marina: *I am mostly worried about not being able to provide useful help during the day.*

Shahari: *In general, I tend to feel a bit nervous before any event, but I feel really comfortable because I know if there is something we are stuck with we will take action to resolve it either through trial and error, trying different strategies or by communicating with other volunteers/staff.*

These exit surveys for the group provided the necessary opportunity for reflections after each workshop when participants had time to ponder over their experiences.

Group in-workshop sharing activities were particularly poignant during planning workshops prior to student facilitation sessions. As the lead facilitator, I encouraged all the interns to share any concerns, insights, or problems they encountered during the workshop. Kamali highlighted how these discussions helped them prepare for common errors that they may encounter during sessions with students.

(Phase I final interview)

Kamali: *When we were preparing for the Maker Day, you asked us like what obstacles did you come across because we could use that to teach the students on the Maker Day. So it was like a good thing because when we come across obstacles we can forecast. Ok, the students are going to go through this and like we can prepare for that.*

These in-workshop group sharing sessions typically occurred near the end after interns had practiced encountered issues and tried to solve various problems they found. As Kamali described, these sharing practices offered a means to inform and guide the community of learners as they prepared for the next stage of facilitating student making sessions. These sharing activities of our making community helped build participants' comfort as they developed a growing knowledge base for common insights, problems, and ways to resolve them.

All of these encouragement, acknowledgement and sharing practices demonstrated the development of our CoP where the interns became comfortable trying new things, supporting others and sharing their thoughts, ideas, and discoveries. Shahari described how valuable she found our collaborative making community:

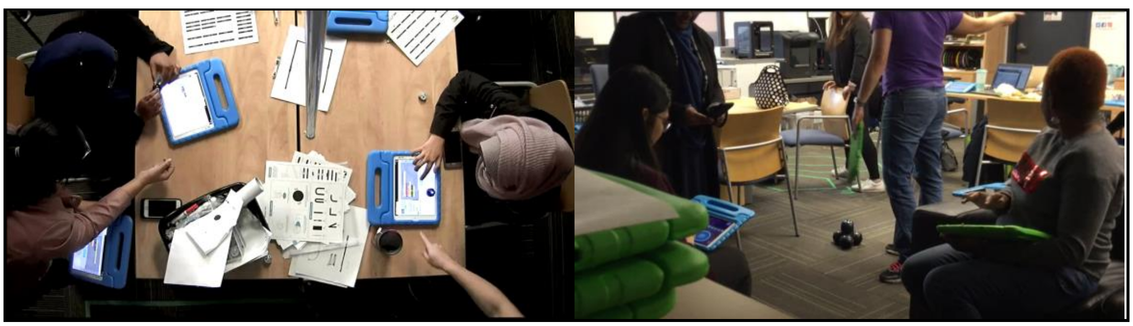
> ***Shahari:*** *I found that coworking it's a good skill because then you learn to trust each other and value each others opinions. And then use those opinions uh, to work together to make, to problem solve and critically think.*

These sharing, encouraging, and acknowledging practices helped to build our making community which each intern described as an essential aspect of their making experience.

> ***Mansa:*** *Talking with my peers, collaboration like 'how do we do this?'...So there's a lot of collaboration skills. Peer-to-peer relationship is so important in a makerspace lab.*

In her final phase one interview, Aiza highlighted the benefits of the collaborative community in our STEAM-3D Maker Lab, see Figure 5.6, while also noting how the collaborative and teamwork aspects during student making sessions benefited the students and their learning experiences.

Figure 5.6: Images of the Collaborative Learning in the Maker Lab



> ***Aiza:*** *We did focus a lot on collaboration here (STEAM-3D Maker Lab), even when playing around ourselves. Like we were always bouncing ideas off of each other. We were asking questions to each other. So one of us might have been more familiar with a certain technology then another or we had different ideas. So it really, really helped the collaboration piece. Just having others to talk to about what you were learning and what questions you had. I also observed it in the maker session for the high school kids and the first year students as well. So them having the opportunity to work in groups to solve the problems. They were*

bouncing ideas off of each other. They were getting really excited to talk about what they were figuring out. So that was really nice.

Making communities are essential to making activities and the development of maker mindsets (Rodriguez et al., 2021). In this research project, the data showed how our making community helped support interns' confidence in discovering and trying new things while also supporting the adoption of new mindsets related to learning and making.

5.4 Emotional Transitions

In self-efficacy theory people's physical and emotional states can contribute to their self-efficacy (Bandura, 1977). Positive emotions can help in the growth of self-efficacy beliefs while negative emotions can adversely impact one's confidence. In makerspaces, learning involves a seesaw of positive and negative emotions, particularly for novice makers. To help participants grow more fluidly in their self-efficacy, the results indicate that guiding learners through their negative emotions and helping them transition to positive emotions was important for their confidence and development of a maker mindset.

At the beginning of the workshops, some interns expressed fear and anxiety of just looking at all the makerspace tools and materials and perhaps feeling overwhelmed before even starting their learning journey:

(At workshop #4 working with Cricut)

Marina: *…when I first came in, I thought it looked a bit complicated. And I thought like "oh no, how are we doing to do this?".*

(At workshop #6 free inquiry & planning session)

Aiza *(describing initial thoughts): I was like so scared. All this complicated stuff.*

While some interns were self-deprecating in their abilities as they initially lacked confidence with technologies and their own abilities to learn with it. The guidance practices from myself, as the lead facilitator, included aspects of positive reinforcement and calming strategies to help interns accept negative feelings and support their transition to a more productive and positive learning experience. In addition, supporting the development of interns' making perspectives was integral to helping them accept aspects of the making process and navigate through initial negative emotions that can result. This was common during discovery workshops when interns were making many mistakes and I would try to normalize this aspect of making and encourage them to accept and learn from the process.

(Working on Micro:bit in guided discovery workshop#1)

Nisha: *So, now I have to download it again.*

Margie: *Yeah, because right now it's not reading.*

Nisha: *I didn't do…see that's…oh my goodness (embarrassed about her mistake)*

Margie: *That's all good. Remember in a Maker Lab making mistakes is so important. I would argue that it's one of the most important.*

Whether negative emotions persisted from outside impacts or during making activities, it was clear that myself, as the lead facilitator, and our community of learners played a role in acknowledging, empathizing, normalizing, and providing distractions with new and positive learning experiences. These supportive emotional interactions highlight our collective community's impact on helping participants accept and deal with any negative emotions.

To establish a transition to positive emotions, however, it was important for the lead facilitator to set up learning environments that provided opportunities for interns to have some success and discover interesting new things. Initially these positive experiences were guided:

Hadil: *Oh my that's so cool! (After Margie guides her through a coded scene in Cospaces Edu an AR/VR coding app)*

Kamali: *(troubleshooting lemon battery circuit): It kind of moved a little.*

Margie: *Ok, switch (they switch wires then the multimeter dial moves) Ah! There we go!*

Kamali: *Oh wow!*

Mansa: *Ahhhh!!!! Wowww!! This is so….oh my!*

Margie: *(talking about Cozmo) he can sneeze…he's excited.*

Mansa: *(full body laugh) Oh my goodness!*

These positive emotional expressions of interest, joy, and enthusiasm were common during guided workshops, particularly as the interns discovered new maker technologies. As the interns progressed to free-inquiry and developing making activities, these positive emotions tended to align with a stronger sense of confidence in their own capabilities and how to adopt making in their future classes.

> ***Aiza:*** *Do you want to try some more? (She places Dash on the table)*
> ***Shahari:*** *Yup. Let's do that! (They both start revising the Dash code)*
> ***Aiza:*** *This is fun!*
>
> ***Shahari:*** *(Examining 3D printed objects & talking to Hadil): Wow! These 3D objects. You can make chemical structures! Cool!…very cool!*
>
> *(Discussing making activities with paper circuits and other materials)*
> ***Kamali:*** *So then the next thing you could do like, ok now make an art project. Like you could add like coloured tissue paper.*
> ***Margie:*** *Right. We did the same and made Northern lights.*
> ***Marina****: That's so cool!*

Over time, as the interns discovered new things and our making community grew in terms of sharing and encouraging practices, there were many instances where positive exclamations of excitement became enticing and infectious to others. At the end of a guided discovery session with Micro:bits, Nisha's enthusiasm enticed Shahari to ask what she learned:

> ***Nisha:*** *(Margie hands her additional material on Micro:bits) Ok awesome! That's really cool. Thank you so much! (enthusiastic)*
> ***Margie:*** *Hopefully that was helpful…*
> ***Nisha:*** *thank you so much. That was good, that was really good!! I wish we had this in first year...It's really good! I wish I could do it in the summer. Thank you so much Margie.*
> ***Shahari:*** *What were you discussing?*
> ***Nisha:*** *We were with the Micro:bits. It's so interesting, you put a code in and then we could go to different parts of the room and give us different readings. So*

we went into the dark room and it gave a reading of zero. So it was measuring like kind of light…This was so nice. It was amazing!

In the free inquiry planning workshop #6, Mansa is loudly enthusiastic and excited as she is learning with Cozmo. She catches the attention of Aiza and Shahari:

Mansa: *Ahhhhh!!! So it's recognizing me. Wow! I love this! I love this part! (Talking loudly to Cozmo) Drop that cube thank you! (laughs)*

Shahari: *How did you do that? (Asking Mansa)*

Aiza: *How? How? How? Teach us!!!*

These outward positive emotions intrigued their peers which often led to more collaborative discovery, more practice, and greater self-confidence.

For some interns their positive emotions and enthusiasm became a motivating driver for them to want to learn more, try new maker technologies and making activity ideas, and come to even more sessions:

(After her first workshop (#2) with programmable robots)

Mansa: *I loved the session! Yeah, everything was, oh my GOD! Now, I can foresee what I can do now. Like bit by bit, even for you to come and practice. That's why I'm so eager to come back. I really want to come back tomorrow! (giggles). This is cool because you don't know how long, you're just here playing and time goes so fast!*

As Mansa learned about the teaching possibilities with maker technologies and her confidence started to grow, her commitment and interest increased. These positive and engaging emotional experiences during discovery workshops drove several interns to participate in more than one session per week to have additional opportunities to learn and have fun.

The progression to free inquiry was important to gain new insights and have fun experiences that led to positive emotions like pride and feelings of personal accomplishment. However, these exploration moments also typically involved trying new things, taking risks, and challenges. Trying to navigate through issues and errors resulted in moments of productive struggle and frustration which grew when interns were unable to successfully solve their own problems. Interns like Marina, Mansa, Hadil, and Nisha were very vocal in their frustrations. Here are some examples from Hadil and Marina:

(Workshop #4 working with Cricut)

Hadil: *I have to start all over. (Her Cricut design, looks and sounds frustrated)*

Shahari: *Me too!*

Hadil: *I'll just give up on UofT. It's ok. It wasn't meant to be. (Sounds dejected)*

(Workshop #6 planning and free inquiry)

Marina: *(After multiple attempts at getting her Ozobot code uploaded) It's turning, but I don't know why it's turning by itself? Ugh! (frustrated)*

Acting as the lead facilitator, I played a key role with just-in-time support practices trying to recognize when interns had encountered roadblocks, or they had reached high levels of frustration. This was an important practice, as highly frustrating moments can impact learning and willingness to persevere through issues:

(Workshop #8 discovery session with Micro:bits)

Nisha: *I don't know where it goes like. I, it's so frustrating. I just don't...my stuff would just disappear. And I would have to re-do this. It's annoying.*

Margie: *Right. That's frustrating.*

Nisha: *Annoying. Yeah.*

Margie: *So, can we look at one of your codes and you tell me what you thought it was doing and then... (Continues troubleshooting with Nisha).*

Mansa: *So I'm supposed to add that, but it's not. (Getting frustrated)*

Margie: *Yeah. Sometimes it's a little challenging. You always have to wait until it gets to be…see how it gets to yellow there (demonstrates)*

Mansa: *Yeah. Ok.*

Margie: *I know it's a little bit of a challenge trying to get that going.*

The timely support ensured that the interns were not overly frustrated and willing to give up, but just as significant was the validation of feelings and their efforts which support their transitions to more positive emotional states. This was an important finding in this study, where just-in-time support was not solely about guiding one towards a successful outcome, but also towards more positive emotions.

Our community of learners also played a key role in guiding interns from negative emotions to more positive ones through listening, empathy, and offering support.

(Aiza working on her paper circuit making activity near Shahari, workshop #13)

Aiza *(Looking through the paper circuit kit anxiously and talking to herself): I don't know!*

Shahari: *Do you need help? (Asking Aiza) How can I help?*

Aiza: *What does the switch look like?*

Shahari: *The switch is supposed to look like, like a rectangle or something (starts looking through the kit and tries to help Aiza)*

This type of support from peers was a regular occurrence where nearby interns would immediately come to the support of frustrated peers who outwardly expressed anxious or negative emotions. Often supportive peers did not have the answers but were willing to work collaboratively or provide an empathetic ear and listen to their friends who were experiencing moments of frustration. This was an important finding to suggest that a making community has the potential to positively impact emotional states by being available, listening, and supportive.

As our making community grew, participants regularly shared and expressed both positive and negative emotions. An interesting finding during this study was the influence that mutual venting of negative emotions had on re-invigorating problem-solving and transitioning to more calm and positive emotional states.

Marina*: (Trying to execute the code on her Ozobot. She looks frustrated. Then talking to herself). It's not doing what it's supposed to be doing!*

Mansa: *me too!*

(Both go back to individually trying to troubleshoot…Then a little time later)

Mansa: *(talking to herself) I don't know why. It just moves around randomly!*

Marina: *Yeah! (Watching her robot move around randomly). Every time I tried to calibrate it. I've tried a few times now. It's not…it's still doing its own thing!*

Mansa: *You too! I don't know why, it's not doing it. It's just moving around.*

(Both Marina and Mansa go back to individually trying to troubleshoot again.)

Perhaps the mutual venting made the interns realize they were not alone or isolated in their challenges and that others were feeling the same things. What was interesting is often after the venting both would power through trying new troubleshooting strategies seemingly determined to solve their own issues. This presents an interesting idea that a community of learners may have the power to inspire even through adversity and failure.

Our community of learners and myself, the lead facilitator, helped guide learners towards more successful making and positive emotions, but it became clear to many that learning how to manage your own emotions was a key part of making and developing a maker mindset. Once learners accepted inevitable failure and developed some problem-solving capabilities, they started to become better able to manage any negative emotions by transitioning to a calmer state and staying focused:

> ***Marina:*** *So, I definitely, I don't know if it's a skill but I learned just staying calm and not panicking when the maker tech was not working. Just take a deep breath and you'll figure it out. It doesn't have to be instantaneous that you figure it out. But if something's not working try the next thing. So, just having that um…being okay with not being an expert, that was a really helpful skill.*

Developing these abilities to manage emotions was keenly tested during student making sessions where interns were facilitating or providing just-in-time support. Many interns described how they were particularly anxious or fearful prior to the student sessions:

> ***Kamali:*** *I'm concerned about the amount of students there are and answering all the questions.*
>
> ***Aiza:*** *I was just concerned about not knowing all the answers that students may ask.*
>
> ***Mansa:*** *A little bit worried about Ozobot troubleshooting steps but I have my bags of tricks with Ozobot now.*

All the interns were experiencing natural nervousness and anxiety that comes with leading or supporting making activities for the first time. To ease the negative emotions and ensure interns knew they were supported through these student sessions, the lead facilitators provided a mini pep talk prior to the first time slot to help ease the anxiety and fears interns had. For many interns, this became a relief and eased their emotional state knowing there were experts who would help, and they could refer to them at any time.

Nisha had a unique situation in that she had an internship with the Tech Playground and therefore was leading her own greenscreen session for students during

Maker Day. Nisha was constantly expressing fear and anxiety to Margie about having to lead this session:

(During workshop #4)

Nisha: *I'm a little scared because like this stuff is like…and I don't know much about what we are doing. It's intimidating being in front of all those people…(a littler later explaining her greenscreen setup to Margie and then saying) So, I have nobody involved in the process. That's why I am panicking.*

Margie: *You sound very stressed about it.*

Nisha: *I am, I feel stressed.*

Margie: *We don't want you panicking (said in a reassuring way) I feel like if you (talks to Hadil) can help in that way.*

Hadil: *I can definitely.*

Margie: *I feel like what we just need to do is get you used to it before. And I would suggest (walks through some facilitation and presentation strategies)*

To help Nisha navigate through her negative emotions of fear and anxiety in leading a student making session during Maker Day, Margie acknowledged her emotions and provided a solution to have Hadil facilitate with Nisha. To further support these two pre-service teachers, Margie provided overviews of how greenscreen works and strategies for facilitation. The guidance and support from Margie helped ensure both interns had less concerns with their role as facilitators. Nisha was extremely appreciative and relieved to have support and feedback on how to facilitate effectively calming her down and helping her transition to a positive emotional state. These findings also suggest that using Legitimate Peripheral Participation could be helpful for managing highly anxious emotional states as there is less pressure and concern when experts are there to support and guide, particularly as pre-service teachers facilitate making activities with students for the first time.

During the student sessions, interns observed students who encountered issues and made attempts to guide them to success. Sometimes they were successful in supporting the students, other times they were not, but the experience helped them grow particularly in how they manage their emotions during some tense moments.

Shahari: *Some students were quietly engaged, others were frustrated and it came out very easily! That had me a bit flustered, but I did my best to keep calm and navigated it with them.*

The fact that interns were supported by peers and lead facilitators was also helpful to calm anxious feelings and fears:

Marina: *I don't think there were any issues for which I was completely unprepared. If I really wasn't sure about something, I was able to ask someone else in the room.*

The experience helped many realize the significance of staying patient, calm, and accepting that with making activities there will be failures, you may not have all the answers, but you can always try and solve issues collaboratively or find solutions.

Hadil: *Patience is another skill. Like you need a lot of patience to support making cause they don't always work for them right away.*

Shahari: *I found that this situation actually gave me a chance to change my perspective. I found that by, you know, maintaining your calmness and maybe, you know, just thinking out loud. You know we (during student making activities) figured it out by thinking out loud. We're both solving the problem. It's not just me and they're actually developing skills as well. Again re-emphasizing the fact that you don't have to be the expert. All that matters is you're keeping an open mind and you're constantly trying different uh, different things to solve the problem.*

This shift in mindset to acceptance of mistakes as part of the learning process, willingness to not be the expert, and being patient and working through multiple efforts of problem-solving was a significant insight for many of the interns in adopting maker pedagogies and managing emotional states. Along with the support of their making community and lead facilitator, many interns learned how to handle negative emotions and transition to a more positive emotional state.

5.5 External Challenges and Agency

Any teacher wanting to implement making in their class will face challenges (Cohen et al., 2017; Hira et al., 2014). Pre-service teachers, who have no class or students of their own and must participate in a full course teacher education program, encounter further unique challenges based on the nature of their situations. Any pre-service teacher maker education program should work with the pre-service teachers to understand the unique obstacles they face when implementing making with students and collaborate on mitigating strategies (Rodriguez et al., 2021). The final phase of this study involved identifying all obstacles perceived by participants, collaborating on mitigation strategies, where possible, and providing interns the opportunity to face these challenges and implement their own making activities during practicum. Many of these obstacles posed a risk to pre-service teachers and their willingness to challenge and overcome them represented a growth in their agentic capacity towards making in education. Furthermore, the reasons participants chose not to face challenges gave insight into how future maker education programs may combat these obstacles and better support agentic behaviours. The results of this study highlight that the types of challenges faced by pre-service teachers are more strongly perceived as barriers by the Intermediate/Senior participants who teach secondary school. In addition, motivations evidenced through observations, demonstrations, and formal and informal conversations provided further connection to agentic behaviours towards making in education.

The challenges to making in practicum, identified by Intermediate/Senior (I/S) pre-service teachers were discussed during the ideation and planning phase of the research study. At this point in the study, we moved from vague ideas for making based on specific maker technologies to curriculum-aligned, design-based making activities that could be implemented during their practicums. The idea of actually making in class became real and caused I/S interns to evaluate their own capabilities and the practicality of implementing a making activity in their high school practicum. For Aiza, this caused some anxiety and concern as her AT did not use making or technology but primarily teacher-centered instruction methods:

> *(Ideation workshop #11, Aiza is talking with Shahari as they review demos)*
> ***Shahari:*** *I'm trying to think. I think a lot of this (looking at demoed making activities) works for grade 10, grade 9.*

Aiza: *I don't know how to do this in grade 12 because in grade 12 my teacher (AT) teaches more lecture style. She teaches and goes through a lot of content. Like they (students) don't have time to figure this stuff out in a biology class.*

Shahari: *Maybe like if it was your own classroom you'd be able to kind of make sure that they learn the application and then you can have free time with them.*

Aiza: *Yeah*

In addition to her concerns with making during practicum, Aiza lacked a strong confidence with any one particular technology causing further anxiety when pondering her own ability to facilitate an effective making activity on her own.

Aiza: *...so I think I'm more comfortable with the idea of learning a technology to adapt it into my teaching. So I don't think I'm completely comfortable with any one technology as of yet to just go in and start using it right away. I would need to think about it and think about it in the context of teaching. Um, but I'm more comfortable with knowing that I can learn a technology and then use it to my advantage.*

During the one-on-one ideation session with Aiza, there were some discussions and brainstorming, however lacking clear direction on her practicum teaching concepts or subjects (she only mentioned teaching grades 9 and 12), Margie encouraged a grade 9 physics paper circuit making activity. Aiza spent some time setting up and testing this making activity, however it became clear that she was having some struggles and lacked some interest. Each making activity prepared during the ideation and planning phase was completed individually as it was being planned for each intern's unique practicum teaching. For Aiza, this setup was not ideal, as most of her successful making had been done collaboratively in the Maker Lab. She often struggled on her own and appeared more motivated when working with peers.

The challenges Aiza faced, the lack of interest in the making activity, and the idea of working alone all combined to decrease her motivation and any agentic potential she had towards making during practicum. In her final interview, Aiza indicated that she would consider making in her future class but there are strong considerations for using any making activity or tools:

> ***Aiza:*** *So um, like the circuitry that I tried, that is something I would consider using in my grade 9 classes when we are doing that unit cause I think that just translates very well. And even other making activities with Micro:bit using it for biology, the soil measuring the dryness uh, the humidity levels and things like that. I would love to try to incorporate it…but for sure tying it with the curriculum, so that it's not just using technology for the sake of using technology but there's a purpose behind it for that class. And also just the timeliness of it. Also, uh, thinking about different needs of students. But I really see the value in it and I would love to see more maker pedagogies being used in classrooms.*

Aiza may not have developed enough confidence or belief that making was the best pedagogical approach to use during her practicum, however from her statement she has a better appreciation of what making is and a desire to see it used more often in secondary schools. Aiza recognized that making in high school is a challenge and she described several of these obstacles during various workshops and her final interview:

> ***Aiza:*** *I think uh, sometimes it might be like there's a lot of curriculum to cover within a certain time period, that introducing a new technology where the technology would first need to be taught and then you use in ways to be meaningful with the curriculum that can take time. And that might not be feasible with the planning of curriculums for different subject areas, especially for like, senior level courses…*

> ***Aiza:*** *Uh, it might even be a little bit of a stretch where it's like this concept could be, um, learned but like there is that connection there, but a lot of time is being spent on the technology itself than instead of the concept. So that's where it can get tricky.*

> ***Aiza:*** *And even like when you are getting into teaching and if you have courses that are more rigid and you have to plan with other teachers it can definitely be hard.*

This list of perceived challenges from Aiza, who was an I/S pre-service teacher, provides some meaningful context for the unique secondary teacher concerns with making in education.

Hadil was another I/S pre-service teacher who presented numerous barriers to implementing making during her practicum and declined the opportunity to borrow any maker technologies:

> ***Hadil:*** *(talking about her AR/VR making activity): I don't know if I'd do it in this placement only because I have a bit of a challenge with my grade 10s. Who I'm kind of stressed out about because they don't want to do anything.... I would use makerspace with them but I don't know if I can trust them to not misbehave with the materials…But once I get to know them and understand their level of responsibilities and their overall learning styles and understand the different levels of scaffolding then I might feel comfortable to try out some makerspaces activities with them.*

Although Hadil would not commit to a making activity during practicum, it was clear that she would consider doing something if the opportunity arose. During the research workshops, Hadil projected keen interest and motivation in learning making activities. Hadil was a natural leader, quick learner with maker technologies, and willing to persevere through numerous challenges. Considering Hadil's obstacles to making at her practicum, but recognizing her potential for agentic capacity, I encouraged Hadil to take risks and pursue other ways to demonstrate her growing competencies and confidence with making. Specifically, I asked Hadil to work as a lead facilitator during the Maker Day with Nisha for the greenscreen activities. Hadil had limited experience, but was more than willing to lead the session and agreed without hesitation:

> ***Hadil:*** *I don't mind switching and leading the greenscreen.*
>
> ***Margie:*** *Do you know greenscreen?*
>
> ***Hadil:*** *I remember greenscreen because last year's makerspace. I remember how it kind of worked.*
>
> ***Margie:*** *I'll walk you guys through greenscreen, let's test it out in the hall.*
>
> ***Hadil:*** *Ok that makes sense, I'm not worried.*

Another opportunity arose where Margie encouraged Hadil to lead a session on an AR/VR making activity to a group of I/S pre-service teachers in the B.Ed. program. Again, Hadil did not hesitate to step up, take the risk, and face the challenge even though she had limited exposure to the software and no time to prepare an overview. These situations demonstrate Hadil's agentic capacity despite her resistance to the obstacles faced with making at her practicum. These findings support the idea that given the right opportunity, participants can still demonstrate some agentic capacity in alternative ways, as some obstacles are too risky for pre-service teachers to overcome in terms of making during practicum.

In her final interview Hadil mentioned that she was interested in implementing making activities in her class in the future, however like Aiza, she felt she needed more time to explore and find the right making activities for her future students.

> ***Hadil:*** *I think the only challenge (with the Maker Lab internship experience) I would say is just the time…I definitely think this is something that if I had more time I would explore a lot more of, and maybe actually take some with me onto my placement.*

Considering the secondary school challenges that Hadil and Aiza perceived in making during practicum, it is not surprising they felt the need for more expertise and more practice, as compared to the other pre-service teachers. Hadil described her perspectives on these obstacles to making in education:

> ***Hadil:*** *I think it's also…that pressure to get to university is something that really comes into the last years of High School. Everyone's like 'no we don't want to do this, let's just focus on what we need to know kind of thing'.*

> ***Hadil:*** *One challenge I think with I/S is with the grade 10s for English they have their OSSLT prep (standardized test). So in that case, if you brought in a maker tech tool to use…they're probably like 'why do we have to, we don't have time for this. We need to practice our OSSLT prep'. So, in that case, I guess not understanding the value of it. How schools emphasize certain things can play into that.*

> ***Hadil:*** *…an older group probably view tech tools more of like a 'primary' thing. So just having that negative connotation associated with it. So I guess as a teacher our challenge would be to find ways to adapt like the makerspace activities to fit the curriculum, but also all age levels.*

Although these perceived obstacles prevented Hadil from committing to a making activity during her high school practicum, it is important to acknowledge her willingness to consider the possibility of making and overcoming these issues.

These lists of challenges related to implementing making in their high school practicums did present significant risk to these pre-service teachers from a professional perspective. Both Hadil and Aiza perceived they would need to combat traditional secondary school cultures in order to implement making during practicum. That was too hefty a price particularly knowing that they were evaluated during their practicum. For these pre-service teachers who lack any authority or flexibility during practicum, their perceived challenges became barriers.

The remaining I/S pre-service teacher participant was unique to the other I/S teachers in her perspective on making during practicum. Shahari was keenly interested in implementing various types of making activities during placement. In fact, Shahari was dedicated to learning about making and makerspaces throughout the entire internship. She participated in the most workshops and came to all student making sessions, volunteering more than 20 hours. Shahari was also unique in her attitude; she was calm, and considerate and rarely was openly frustrated even when faced with numerous issues. She was always willing to collaborate with others, offering support when they were struggling or frustrated. Dedicated to learning, Shahari was always curious, asking questions, taking notes, and documenting her learning journey with pictures and videos, see Figure 5.7.

Figure 5.7: Notes and Images of Shahari's Making Journey

The only challenge with Shahari was narrowing and focusing her making ideas to one activity for practicum to ensure she was adequately prepared. Shahari's making activity was an unplugged, Biology building activity that she used as a fun diagnostic with her grade 11 students. Her AT appreciated the activity and the engagement it offered the students. Shahari's activity would be considered a mini-making activity as it was subject-specific, lacked technology and options for creativity. However, prior to her placement we had reviewed methods to integrate Augmented Reality (AR) and Shahari reflected after practicum how she would enhance the activity with AR:

> ***Shahari:*** *When I came to the placement I, there was so many things I wanted to do, but I didn't really get the time to do it. Because of that, I had to keep the augmented reality out, but if I was to do this again, I would definitely have augmented reality. And then that way I can give more higher order thinking questions. So that was one thing, that was one skill that I wanted to expand upon like the critical thinking.*

Shahari's enthusiasm for making and interest in providing meaningful learning experiences for her students was highlighted here as she was already reflecting on how she would improve her making activity for her future classroom.

Shahari's experience during placement was unique in that she did not encounter any issues from her AT with her making activity. In fact, she only identified one issue about a general observation of the school culture that was unrelated to her making activity but concerning to her. She noticed how her high school students were highly focused on grades and unwilling at times to participate in learning activities that were not graded. Despite this challenge in secondary school, Shahari reflected on how this experience made her want to implement more making activities on a regular basis and create a small classroom makerspace to encourage critical thinking, creativity, and collaborative learning:

> ***Shahari:*** *We need activities like this…So I'll definitely be incorporating some sort of (making) activity every class actually…And then, I want to make some sort of makerspace. And also maybe make, like I'm still thinking of activities in which, you know, they can actually make models or like some how connect it to real life. So that's something that I'm still exploring. What I really like about the, like the makerspace here is that you guys have math, arts, engineering. You bring it all together. So that's another reason why I want to bring like these makerspace things into my science classes.*

Shahari clearly demonstrated consistent motivation, competency, and confidence growth with making and the willingness to act as an agent for change with making in education. Shahari's experience suggests that offering more opportunities to implement making activities should be encouraged and perhaps they can partner with peers, like Aiza, who lack the same motivation or require more time to build competencies in facilitation. The partnership could be mutually beneficial for both, guiding one and fostering further challenge and learning for the other.

In addition, Shahari's making activity was well received by her AT:

> ***Shahari:*** *He (her AT) actually really loved the activity. Like he was actually monitoring how the students are interacting and things like that. And he took to it very well.*

Unplugged, mini-making activities such as Shahari's seemed to be a more palatable version of making activities for high school senior courses. These findings suggest that providing demonstrations and working through these types of making activities, particularly for those interns working in a more traditional learning environment, may be a helpful starting point for some I/S pre-service teachers.

There was a significant difference in the perceived challenges with making in practicum for Primary/Junior pre-service teachers. In fact, the only initial challenges described were related to feeling pressure to implement and use technology during placement. This was an interesting finding, but not entirely surprising considering OTU is known as a technology university. Nisha and Mansa, who both came into the internship with limited experience and knowledge of educational technology, were particularly anxious in being ready to implement making activities during placement. Mansa also considered this a challenge because she felt that even volunteering as an intern in the Maker Lab, involved great risk for her, as she was stepping outside of her comfort zones.

> *(Workshop #2 discovery with programmable robots)*
>
> ***Mansa:*** *I'm trying to come out of my comfort zone here (Maker Lab) …At placement, the first thing that the AT told me was 'we're glad to have you here. I'm going to learn a lot of technology from you'...I came out of there like 'ok I gotta learn tech!'* (Sounding stressed)

To help them overcome the challenge, Margie provided one-on-one sessions with both Nisha and Mansa to help them build competencies with maker technologies and making activities quickly and to support their confidence growth, so they were comfortable working with peers and feeling equally capable.

Throughout the study, Nisha was extremely motivated to learn, be prepared, and develop competencies in leading her making activities. As a volunteer, she was not required to commit 20 hours, but even so, she was constantly participating in discovery workshops with her peers or one-on-one sessions ideating, testing, and planning with me. Prior to her placement, she reviewed all activities with me to receive feedback and proclaimed that she was ready and confident to implement her making activities:

> ***Nisha:*** *I'm very confident in that (making activity for practicum), because I sent her, the teacher (AT). She knows exactly what I'm doing. At least for the maker part of it, I'm not worried about that.*

Nisha had considerable growth in her technology and making confidence which was aided by her motivation and mindset changes. She continually demonstrated her growing competencies throughout the workshops and ultimately became confident enough to help support another teacher outside of the Maker Lab internship:

> ***Nisha:*** *I'm also helping one of my cohorts in another section because um...she wants to do uh...light and stuff (Micro:bit making activity) with her grade 4's in her practicum. So whatever you taught me and whatever I learned um.... I'm*

teaching her that as well...and you know the best thing about teaching another person is that you become stronger.

From where Nisha had started, as someone who lacked confidence with making and maker technologies and was afraid of making mistakes, this willingness to help others to grow in making, represents how far she had come in her abilities and her capacity as an agent of change for making.

Mansa started with a similar level of motivation and interest as Nisha, but as her schedule and external impacts grew, she became more distracted and less ambitious in implementing her making activity during placement. This could also have been related to some of the challenges she faced when testing her making activity which required multiple revisions and growing concerns about not knowing her students very well:

(After having difficulties testing her making activity in workshop #13)

Mansa: *Um, Margie let me tell you what I've done. It was so funny and so tough.*

Margie: *Yeah. So you see. And so scaffolding your students is so important right.*

Mansa: *We think it's gonna be easy, but it's not easy.*

Even with these testing challenges she faced and external distractions, Mansa still intended to implement a making activity during her placement and borrow equipment, highlighting her growth in making competencies and confidence.

The original pressure Nisha and Mansa faced to use technology during placement was interesting considering the contrasting actions from their ATs once they arrived and started teaching at practicum. In both instances their ATs were adamant about the use of making or technology by these interns. In Mansa's situation, she accepted the decision and cancelled her making activity and the equipment she was going to borrow. In terms of agentic capacity, Mansa demonstrated some drive and motivation towards making, however her situation highlighted that no matter how motivated a pre-service teacher can be, there may be uncontrollable factors that inhibit their ability to implement a making activity during their practicum.

For Nisha, the change in perspective by her AT was not only confusing but extremely disappointing for her. She came into her placement prepared, competent, and confident in her making activities. However, the barriers and restrictions placed on her by her AT limited her ability to fully implement her making activities. Yet, as opposed to accepting and conceding to this situation, Nisha continuously fought to implement different making activities during her placement:

> ***Nisha:*** *It was really unfortunate. She didn't let me do what I had planned to do. And I kind of had to fight for getting that (making) centre on there like.*
>
> ***Nisha:*** *Actually, for parent/teacher, parent meeting in our classroom, I emphasized I needed to put this (making activities) more out. I just told her 'if you have a making hour it's going to look really nice on you'.*
>
> ***Nisha:*** *I wanna do that so bad (making challenges with spare parts). And she said 'what's the point of doing that?'. I said it's such a good thing, you know, to go through the process of, they make a mistake and they, they need to think about it. It's all critical thinking and stuff like that. And she didn't want them to do that.*

The experience seemed to expedite Nisha's agentic capacity in making. In her final interview, after placement, Nisha explained how she is more determined than ever to implement and truly test her developed making activities in future.

> ***Nisha:*** *So in my future classroom, I would definitely have one dedicated (making) area…If I had my own class I would like, once I worked with my kids (in making), I would let other classes like switch students…like let another class come in. Let other kids experience it too. Let other teachers experience too like. Have some kind of partnership.*

When describing her thoughts, Nisha expressed determination and insistence after the adversity she experienced during practicum. She became keen in her desire to be a leader for making, promoting the practice for not just her class, but other students and other teachers, truly demonstrating her capacity to be an agent of change for making.

The barriers presented to these interns at their practicum from their AT's are not surprising, as the literature is rife with details of resistance to change and innovative learning experiences despite the growing number of library makerspaces with educational technologies (Campos et al., 2019). All three P/J participants who planned on implementing their making activities during placement were confronted with animosity towards their activities and the technologies they were using. Nisha's AT stated that:

Nisha: *Like she was not, she didn't like the technology much. She says 'what do you think you're going to be teaching them by this?'*

While Kamali's AT adamantly described her views towards maker technologies:

Kamali: *So when I talked about, when I told my teacher (AT) about the making activity um, she wasn't excited about it. At first, it was more like 'ok, yeah like you can try it. Let's do it on one morning, if you want.' Cause she never heard about or used it before.*

And Marina's AT highlighted how some teachers believe making and maker technologies will just pass by like past educational initiatives:

Marina: *So when I first suggested it (making activity), um well, there was another student teacher and they're like 'ok, they don't really think that all the like coding and things like that are important. Um, like she had other technology (she taught with), she just didn't think coding was that important…Yeah. She thought it was more of a fad.*

These comments and reactions to making from these ATs, who are meant to mentor their pre-service teachers and guide their pedagogical approaches with students, demonstrated the challenges that still exist in some schools with not just making activities, but the creative use of technology for students. It was clear in these schools that any making, coding, or building with technology was done solely through tech day at the library makerspace or visits once a week from a tech teacher. In her placement, Nisha described her disappointment in the way the technology was used with the students during visits from the tech teacher:

Nisha: *He was their tech teacher and he just brought this huge Lego robot that he'd already built. Kids didn't even get much of a chance to actually move the Lego robot. They had no idea what they were doing. That kind of made me think how important unplugged and scaffolded activities are for them to actually understand what they are supposed to do with the tech, you know. Even I didn't understand what we were supposed to do with it.*

Nisha's description demonstrated not only some ineffective methods that some schools are using to introduce technology to students, but also her own growth in recognizing the importance of providing meaningful learning experiences and the critical aspects that are required to develop authentic making activities.

Despite the challenges confronted when preparing for their making activity during their practicums, Kamali and Marina, like Nisha, worked on convincing their ATs to allow them to implement their making activities in some capacity during placement, demonstrating their agentic growth. Marina’s making activities were thorough and planned with successive scaffolded steps to ensure that students were competent with the technology prior to the making activity which was aligned to a language learning outcome. When developing her making activity, Marina was committed to making the experience meaningful and therefore planned and designed with the curriculum document. To challenge herself and her making competencies, Marina chose to use Ozobots which was the maker technology that caused her the most difficulties during the research workshops. Marina's motivation to bring meaningful making to her class with a maker technology that she had the least competency with, demonstrated her willingness to take risks, overcome barriers, and her growing confidence in her own making abilities and adaptive expertise. Much like Nisha, her AT limited the scope and duration of her making despite student engagement and observed competencies with the initial making activities.

> ***Marina:*** *Um, sometimes it felt like she was a bit more resistant to the change…So if I did this in my own classroom, I think I would plan just a little bit more for time. Because I felt a little bit rushed. Because my AT just wanted to get it done. It was a little discouraging.*

Somewhat disappointed, Marina took this as a learning experience and transferred her drive to how she would implement making in her future classroom.

> ***Marina:*** *I would do it with a grade 3 class but I think I would do it, I think I would build up to it. So obviously, on placement we don’t have as much time. But I’d have them test out the Ozobots, so they know how to use them and maybe have them do an activity like this once they’re more familiar with it. And then after, it’s probably introduce the um, the Ozoblockly. And then basically throughout the year just like build up to it. So kind of shift the responsibility onto them.*

Marina demonstrated that you do not need to be an expert in making. You just need to build some competency, but more importantly, as a teacher, you need to adopt the making principles.

> ***Marina:*** *I think it (internship) helped me a lot because like I don't need to be an expert in it (making activity). I just need to look out for common mistakes. You need some trial and error. It doesn't have to be perfect right away. Um, and then actually implementing it like gave me the ideas of how I actually, um, put it into my own classroom.*

Through all the workshops, student sessions and practicum Marina demonstrated her commitment to learning and adopting making in class, highlighting her growing agentic perspective.

Kamali was equally dedicated and motivated to learn and participated in most of the maker workshops and the Maker Day session. Kamali initially indicated a passion for learning with technology, but soon came to appreciate the full aspects of making as she indicated in her final interview:

> ***Kamali:*** *Yeah, well I think um, I guess there's technology but then there's maker technology. So I think I got more familiar with the maker side of it and how you can actually use the technology to help students like um, actually like encourage those skills of teamwork and creativity and stuff. Cause like tech is one thing where you can tell kids to like go play with the tech, but to actually be able to make it a learning experience for them that's related to the curriculum um, that was the hard part and I think that's what I got more familiar and comfortable with.*

Kamali was a self-directed and fast-learner, extremely competent with technology and quickly demonstrated her competencies in making activities as she progressed through the workshops. Kamali was calm, not easily frustrated and became a leading MKO in the STEAM-3D Maker Lab. She originally planned a paper circuit making activity and requested access to Ozobots for a second making activity during practicum. Although she was not able to implement her paper circuit making activity, she was able to quickly adapt a discovery making session with Ozobots that impressed her AT.

> ***Kamali:*** *Also my AT was really impressed by it (the making activity) that she wanted me to show the teacher next door. Like what we did. Like she told me to bring the Ozobots over and show her what we did. So yeah, she was really impressed by that.*

It was not surprising that Kamali was able to impress her AT despite their original disapproval of making or maker technologies. Kamali consistently demonstrated competencies with making, technology, and adaptive expertise during workshops and students' sessions, and was clearly capable of implementing a making activity for her practicum and future class.

Kamali expressed how she will implement making in her future classroom where she intends to use guided approaches, scaffolding, and focusing on curriculum to make the student learning experiences meaningful. Kamali's competencies with making were evidenced through her ongoing success and perseverance when participating in making activities in the internship workshops and adaptive expertise at student making sessions. Kamali demonstrated she was highly motivated and has a powerful capacity to be an agent for change. Kamali's experience impressing her AT during her placement and how quickly she adapted to the role of MKO in the STEAM-3D Maker Lab suggested that next level challenges and opportunities should be considered for those who show strong leadership and competency in making.

Chapter 6. Discussion

Earlier in this paper, I echoed the thoughts of Miles et al. (2014) who suggested that a qualitative study involves telling a convincing story. At this point in the research, we arrive at the climax of the story where the original research question is answered based on the data that were evaluated and presented in the findings. My goal for this research was to understand how guided approaches to pre-service teacher maker education can contribute to growth mindsets and agency, and influence the adoption of maker pedagogical practices for new teachers. My case study was bounded within the learning context of the STEAM-3D Maker Lab and practicum experiences for a small group of seven pre-service teachers representing both I/S and P/J streams. I investigated numerous situations involving many variables of interest and collected multiple sources of data to assert the findings that support my research question:

To what extent does guided inquiry, coupled with hands-on facilitation, promote pre-service teachers' confidence and competence with maker pedagogical approaches and influence their mindset and teaching practices?

- *What challenges do pre-service teachers face and risks do they take to implement maker activities in their own practicums?*

The data categories presented in the findings section align to three overarching themes that can explain and answer the research question and sub-question. These themes suggest that building confidence and competencies in maker pedagogies and developing maker mindsets was best accomplished through a 'Progressive guided to self-directed journey' with a 'Supportive Community' and the opportunities to 'Build capacity for Agency'. To initiate the discussions, I provide a description of the internship making objectives as they provide the context for this research study.

6.1 Internship

The making ethos consists of a triadic interplay of three components: making as a set of *activities* within a making *community* of practice where makers adopt similar growth or maker *mindsets* (Clapp, Ross, Ryan, & Tishman, 2017; Godhe et al., 2019; Halverson & Sheridan, 2014). Any pre-service teacher maker education program must recognize these three integral aspects and ensure they are developed throughout the course (Hughes et al., 2021; Jones, 2021). This internship study developed a guided approach to learning making that attempted to build the competencies and confidence in maker pedagogies while encouraging and supporting the development of a community of makers who learn the value of collaboration, importance of mistakes, taking risks, and sharing in all learning and expertise. The data supported this approach and highlighted the benefits of adopting this journey of learning that takes time, guidance, and authentic experiences.

Time is often a luxury that most pre-service teacher education programs lack. For pre-service teachers competing courses, regular assignments and preparation for practicums means there is little extra time for them to explore or learn on their own (Stevenson et al., 2019). All the pre-service teachers who participated in this internship research project identified how they wished for more time or opportunities to expand on their own discoveries and learning in their B.Ed. program. Nisha articulated this issue after I displayed some making options she could explore further on her own, "*That's the problem of getting the time to actually, you know, examine, look through, explore (on her own)*". Even for those interns who may have had a little extra time, the challenge with learning on your own or unsupported is that it typically takes longer to learn concepts and the focus tends to be solely on learning technologies versus understanding making activities with technologies. Integrating guided approaches to learning maker technologies and maker pedagogical approaches was essential for helping to maximize the amount of time (20 committed hours) devoted to this internship pre-service teacher maker education program.

6.2 Supportive Community

The internship focused on three phases: discovery, ideation and planning, and implementation. Each phase was conducted in a similar manner where, acting as the lead facilitator, I provided initial guidance and progressively released that support while the pre-service teachers developed confidence and competencies. As the discovery phase was at the beginning and the interns were all relatively new to makerspaces, it was important to establish an engaging, collaborative, and supportive space. During each of the discovery workshops as participants learned a specific maker technology, I promoted various making themes and community building practices. Discoveries and creations were enthusiastically acknowledged, mistakes were encouraged as was collaborative learning and sharing practices. The workshops were loud and messy with interns wandering the room observing, interjecting, collaborating, laughing, and sharing. Emotions ranged from excitement to anxiety to frustration to a sense of pride in accomplishments. Peers supported each other through their productive struggle and challenges directly or vicariously, and the community helped transition any negative emotions to more positive feelings. During the ideation and planning phase, the informal and open learning environment often involved interns taking breaks from their making projects, walking around, observing, and testing the diverse range of peers' projects, providing thoughts, sharing feedback, and getting inspired.

With each session, our community became stronger and for some this collaborative and supportive collective had the largest impact on their learning journey. Aiza described how the Maker Lab's collaborative aspects benefited all the interns, "*We did focus a lot on collaboration here, even when playing around ourselves. Like we were always bouncing ideas off of each other. We were asking questions to each other. So, one of us might have been more familiar with a certain technology than another or we had different ideas. So, it really, really helped the collaboration piece*". As the making community is an essential aspect of any making experience (Litts, 2015), developing this from the very beginning is critical. Much like the making learning journey, the findings suggest that building this community takes time, but it gets stronger through each session as each participant observes, engages, and thus contributes to the collective body of learners. In this study, the characteristic making community features of sharing, collaboration and supportive practices were evidenced and guided the overall learning journeys of each participant. While unique community practices of encouragement, acknowledgement and supporting negative emotional transitions were particularly helpful to the development of our pre-service teachers' confidence and competency with maker pedagogical approaches and adoption of making mindset perspectives.

6.3 Progressive Guided to Self-directed Journeys

In the initial discovery phase, the learning focused on developing foundational knowledge of maker technologies which were commonly used as tools in our STEAM-3D Maker Lab. We started with a guided inquiry approach to support initial confidence through functional overviews and key considerations prior to self-exploration. The benefit of this approach was highlighted by Aiza, "*The guided inquiry really helped when we didn't know where to start…it helped getting more comfortable with it*". This idea was supported by Davidson and Price (2017) who summarized how structured experiences, particularly at the onset of making, were important to ensure that novice learners were not disengaged but comfortable in making practices. This was particularly evident when comparing interns' learning experiences in the free inquiry Tech Playground at the OTU Faculty of Education. Nisha explained the challenges with the free inquiry approach in a B.Ed. program, "*None of the people there know how to use the things (Tech playground). When I have to finish my assignments and pass the course, I'm not going to come and try* *and learn something new on my own. It's too time-consuming, it's frustrating, and I'm not going to do it"*. Kamali, who was very proficient in technology, explained how even she had challenges with the self-directed aspect when learning new technologies: *"You kinda had to figure it out on your own…when I first saw Ozobot I had no idea what to do with it. Like I didn't know it was a separate draw and also like coding. So, I was trying to put them together and like it didn't work. So, I didn't get much from that…I didn't know what to do"*.

The role of guidance and structured learning with making in education has been debated by many researchers (Campos et al., 2019; Fasso & Knight, 2020; Vuorikari et al., 2019) however, this study found that ensuring there was a balance between guidance and self-discovery was a useful strategy for time-constrained pre-service teachers. Furthermore, what proved particularly effective was focusing on learning a few technologies in-depth while emphasizing common functions and features with similar maker technologies. The benefits of this constructivist approach were illustrated by interns as they demonstrated an understanding of how to approach and navigate similar maker technologies. Several interns also compared these approaches to their B.Ed. coding course that focused more on covering a breadth of technologies in short duration windows. Marina suggested the coding course approach did little to support her growth in confidence with maker technologies: "*In coding we covered more technologies…Even though we had some peer-facilitations, they're very quick and there's not a lot of time. This (internship at STEAM-3D Maker Lab) was a little more focused and that helped a lot and that built my confidence in a way that the class wouldn't necessarily build it*". In this study, following the guided approaches with peer- or self-discovery was essential to provide opportunities to enhance competencies while having fun learning which further motivated interns to try new things and take more risks. Through these discovery workshops, the pre-service teachers began to understand that becoming an expert in any one technology was not realistic or required. Interns recognized they only needed to develop basic functional knowledge while recognizing commonalities, to have the confidence to work with these maker technologies as tools for making with their students. This understanding was particularly important to establish at the beginning of their learning journeys.

The role of the facilitator through the initial discovery phase involved three aspects that were consequential to the effective support and development of interns' self-confidence and competency with maker technologies: modelling instructional approaches, mindsets, and problem-solving strategies. It began with the lead facilitator’s role in modelling guided instructional inquiry approaches and adaptive expertise through just-in-time support. Inquiry-based learning involves a spectrum of facilitation options from more structured to minimal guidance (Hughes et al., 2021). Although all approaches in these discovery workshops were informal and emphasized hands-on constructivist learning, the scaffolding and methods to guide learners were adapted to the complexity of each of the maker technologies. These diverse guided inquiry approaches allowed pre-service teachers to experience varying instructional methods and determine which options they prefer or would revise, contributing to the development of their own pedagogical approaches. Although these guided approaches helped develop a foundation, the bulk of personal growth and confidence came through self- or peer-discovery workshops where participants experienced success and learned to overcome failure. During these free inquiry workshops, the facilitator provided the time and space for interns to explore multiple similar maker technologies while wandering the room providing just-in-time support to guide learners through struggling challenges or opportune learning moments. Just-in-time support requires flexibility, adaptability, and methods to guide learners so that they can solve their own problems (Lock et al., 2020). These just-in-time support practices also require consideration of emotional perspectives, acknowledging positive experiences and helping transition negative feelings to more positive emotional states. These practices not only supported learners as they encountered overwhelming challenges but provided them with an indication of the methods and adaptive expertise required by teachers in order to effectively support students.

A second key aspect for lead facilitators is to model maker mindset principles such as acknowledging mistakes and recognizing their importance, willingness to take risks and try new things, and acknowledging lack of expertise and willingness to learn with and from others. These types of modelled behaviours had a significant impact on the participants in this study as they normalized these behaviours that are often perceived as counter to what people have come to expect of teachers in schools (Rob & Rob, 2018). It also permitted the interns to start accepting their own mistakes, acknowledge their lack of expertise without shame, and recognize that learning in makerspaces involves willingness to take risks and to learn with and by others, including students. These practices promote a safe space for participants while they are discovering and attempting new things and learning to deal with failure in a more positive manner (Jones, 2021). Over time and through repeated failures and successes in these supportive workshops, interns developed some confidence and competencies in maker technologies and intuitively started to change their perspective on learning. Nisha summarized how her perspective on learning changed, "*I don't still kind of understand everything. However, on the other end my outlook has changed. It's changed tremendously. I have a different approach now, that growth mindset…My outlook on making mistakes is completely flipped. Because I think in order to learn something we have to make mistakes*". These developments are inline with the self-efficacy theoretical construct where mastery and vicarious experiences contribute to the development of self-efficacious beliefs and confidence.

Failure is a common experience in makerspaces, but not a negative one. It is seen as an opportunity; an opportunity to improve, to learn, and to persevere (Blikstein, 2013; Papavlasopoulou, et al., 2019). In this study, mistakes and problems were also an opportunity for the lead facilitator to provide guidance in learning specific problem-solving techniques. Recognizing the opportune moments to demonstrate or guide with problem-solving techniques or highlighting common errors or key functional considerations can help interns combat overwhelming anxiety while supporting the development of a repertoire of strategies to combat issues. These guided moments appeared to be particularly valuable to the interns' confidence with maker technologies and mindset growth as described by Mansa: "*...I'm so confident. I'm not even scared to fail…Whatever will happen we're going to find a way around it*". Continuous browsing, listening, and observation was key for the facilitators to recognize these learning moments and capitalize on them to help these interns develop the tools and techniques to be able to solve issues on their own. Once participants had established some level of competency in troubleshooting, the facilitator needed to hang back and allow them to persevere or collaborate to solve their own issues. Starting the pre-service teachers' learning journey in this way, built the foundational competencies and confidence required to take the next step in their learning journey through maker pedagogical approaches and situated learning experiences with students.

Maker pedagogical approaches take the triadic elements of making and infuse them into formal education contexts to create meaningful making experiences for students (Cohen et al., 2017). In this study, to develop interns' maker pedagogical approaches they first experienced authentic making activities, then ideated and planned their own practicum making activities, followed by situated and experiential learning opportunities with students. The philosophy behind this staged approach was to bridge the playful discovery with maker technologies to more concrete and real classroom learning experiences aligned with teaching ideas, expectations, and constructionist learning theories. Essentially moving the focus away from technology as the solution, to technology as an enabler and maker pedagogy as the driver. At this stage, pre-service teachers had experienced the hands-on maker technologies and understood the capabilities of these tools and the possibilities they could provide to support contextual making in class.

A guided approach was leveraged again to support interns' learning and development of authentic making activities. The facilitator worked one-on-one with each intern providing demonstrations for inspiration and then collaborated on thoughts, insights, and discussed concerns or challenges to making in practicum. This practice provided interns with a better appreciation of the characteristic features of making activities and how to develop meaningful learning experiences in the classroom. This guided practice by the lead facilitator is aligned with suggestions that were presented in the research by Hansen (2018) where they proposed that pre-service teachers could benefit from guidance to develop activities better aligned with the goals of educative making versus self-developed tech-focused, recipe-style activities.

Through the guided ideation workshops each intern developed a making activity; however, the findings did indicate that those I/S pre-service teachers who deal with siloed subjects and packed curriculums and are more resistant to making during practicum, require more variety and tiered options for making activities. To improve on the lack of options presented during this study, one-on-one meetings could be replaced with I/S group collaborative ideation and planning sessions. This type of forum could have provided expanded options, and further inspired and motivated interns through the discussion and evaluation of various making ideas and potential solutions to perceived obstacles. For P/J teachers, however, this phase was particularly enlightening as they did not perceive the same obstacles to making in practicum as I/S teachers and appreciated the collaborative nature of ideating with the facilitator who had real-classroom making experiences. These pre-service teachers learned all aspects of implementing maker pedagogies including the scaffolding, testing, assessment strategies and how to align activities to curriculum expectations and learning goals. Kamali described what she learned in terms of the planning and testing of the making activities, "*...the key learning point was trying the activity ourselves…it tells you what would be fun for students and also helps you plan out timing and stuff…also tell us which obstacles the students will run into…and also the scaffolding was really helpful…so that students at all levels can kind of catch up and make sure everyone's on the same page. So, you want to give them opportunities to learn and also create with it*".

Interns learned that it is not enough to simply add technology to make an activity meaningful, nor was it effective to just make artifacts. Marina explained how she had developed a better appreciation of the making process: *"...I have a better understanding of what making actually is…especially like going through the process myself. I understand that it's the process of making, how you end up with an end product. And having done it myself, I can see everything comes together. Like the understanding comes together. Like why this works"*. During the planning workshops, the participants learned that authentic making activities need to be planned, prepared, and tested, all of which takes time and effort. The interns understood that these preparatory steps were essential because often during planning and testing they encountered problems. Although these practices were informal and no lesson plan templates were required, participants were actively engaged in multiple cycles of revision and testing, documenting how the activities would proceed. Supporting interns through this process was important as some became disengaged, and others were overwhelmed by obstacles or problems encountered. At this stage, it was also critical for the facilitator to re-initiate conversations related to teaching with technology considerations such as power, authentication, connectivity, security, etc. Not preparing for these contingencies could have had negative consequences for those interns who decided to borrow the maker technologies to use for their making activities during practicum.

For participants to truly appreciate the benefit of these making activities while testing their levels of making competency and confidence, it was necessary for them to experience situated making with students. This was a key stage in the study for participants and the most unique aspect of this particular research on pre-service teacher maker education. Marina explained how significant these sessions were to her: "*Having that (student) session helped a lot…because it was through facilitating, helping facilitate, that I found out the importance of finding common problems…And now I feel way more comfortable and I don't think I would have considered implementing it in my class for this practicum if I hadn't had this experience"*. For the situated sessions of making with students, acting as lead facilitator, I demonstrated how I ideated, planned and prepared for the session and modelled my facilitation methods with students. During these sessions, the pre-service teachers observed students making and then contributed through Legitimate Peripheral Participation. The practices of Legitimate Peripheral Participation involved watching and supporting only when the interns felt comfortable and capable. If they struggled to support students, they referred to a lead facilitator. Applying cognitive apprenticeship methods, the lead facilitator coached the interns by demonstrating and talking through methods of just-in-time support and co-reflecting afterwards on the effectiveness of various strategies used. As these sessions progressed, interns attempted more and more support practices on their own, testing their adaptive expertise. The results highlighted the benefit of these experiences in terms of observing the learning and skill development of students during making activities, and the opportunities to assess pre-service teachers' own just-in-time support competencies in a supportive environment. However, incorporating a few more opportunities where interns could practice facilitation or leading these sessions once they became comfortable may have provided interns with some needed final testing opportunities before practicum. It might also have provided the final boost of confidence needed by some I/S teachers who desired more practice and experience in making.

Reflecting on these experiences informally and through exit surveys provided interns the opportunity to consider what worked well and aspects that could be improved.

Through their reflections, interns also acknowledged these sessions as an essential element of learning maker pedagogies because it prepared them for behaviours, emotions, and experiences of students with making. These experiences often involved new challenges that interns had never encountered but they learned how to stay calm, talk aloud through the issues with the students, and work collaboratively on solutions. Shahari described her experience and how she learned to manage her emotions, "*Some students were quietly engaged, others were frustrated, and it came out very easily! That had me a bit flustered, but I did my best to keep calm and navigated it with them*". These practices were necessary for testing their own emotions and maker philosophies because they understood that being an expert and trying to prepare for every situation was unrealistic. For many interns, particularly P/J pre-service teachers, this was the critical turning point because they learned how to adapt to adverse or novel situations, helping them feel confident that they could implement their own making activities in their classrooms.

6.4 Build Capacity for Agency

Although all the pre-service teacher participants stated they would implement making activities in their future classrooms, there were only four of the seven who implemented their making activity during practicum. Making during practicum involved a willingness to take risks as pre-service teachers were evaluated by ATs who did not appear to share in the benefits of making or maker technologies. Kamali described the risks that she took to implement her making activity during practicum: *"Like they do coding but it's with the librarian. So, they didn't do a lot of making in the classroom…So then when I talked about the (making) activity she wasn't excited about it…It did feel like a risk"*. The various risks pre-service teachers needed to overcome were related to issues that can threaten the effectiveness of classroom making activities and those related to environmental and cultural challenges in schools (Jones et al., 2017). The participants mitigated risks related to potential issues with making activities through preparatory action and the development of adaptive expertise during student sessions in the internship. However, the risks related to environmental and cultural challenges in schools were particularly potent for most of the I/S pre-service teachers. They articulated the range of these challenges from packed curriculum to standardized testing to negative perceptions of making and makerspaces to a focus on grades to the pressure of having to align to teacher-centered instruction methods used by their AT. Despite discussions on these obstacles, it became clear that these perceived barriers were too great a risk for many I/S participants to overcome. The one I/S intern who did implement a making activity during practicum was highly motivated to adopt maker pedagogies and did not perceive the same challenges as her peers. This may have been the reason she was more than willing to implement making during her practicum (Davidson & Price, 2017). However, it is important to consider that her willingness may be related to the specific type of making activity that she implemented during placement. In comparison to the other I/S participants, Shahari's making activity would be considered a mini-making unplugged simple building activity compared to the more complex circuitry activity or AR/VR coded history enactment activities for Aiza and Hadil, respectively. Considering how these I/S interns differed in their willingness to implement making during practicum, it would be recommended to consider complexity, duration, and type of materials, tools or unplugged options when ideating making activities with participants. Had the resistant I/S interns been presented with more making options with varying dimensions of complexity perhaps they might have been more amenable to one of these activities. Furthermore, additional high school student sessions where these diverse making options are tested may have provided the necessary practice to take a more measured risk and then implement these making activities during practicum.

Risk-taking is not only related to maker mindsets, but it also relates to agentic capabilities along with self-efficacy beliefs (Krueger & Dickson, 1994). Motivation to take risks and belief in one's capabilities to achieve positive outcomes can be significant drivers for agentic change (Bandura, 2001; Code, 2020). These risk-taking endeavours and self-efficacious beliefs are required to implement maker pedagogies and become an agent for change with making in schools (Sang & Simpson, 2019). For the interns who were motivated and took the risks to implement their making activities during practicum, the experience had a profound impact and ignited a spark in their sense of agentic purpose with making. Despite the adversity and challenges they experienced, these particular interns were driven to not only implement maker pedagogical approaches in their future classes but advocate for making as well. Nisha emphatically described the impact of her experience and how she will implement making not just in her classroom but in her school, "*It was really unfortunate. She didn't let me do what I had planned to do. And I kind of had to fight for getting that (making) centre…So in my future classroom, I would definitely have one dedicated (making) area…Once I worked with my kids (in making) I would let other classes like switch students. Like let other class come in. Let other kids experience it too. Let other teachers experience too…Have some kind of partnership"*.

This final step of implementing making during practicum appeared to be essential in developing agentic capacity for making. However, two of the participants refused to implement during practicum, and a third was inhibited by her AT. The two I/S pre-service teachers who refused presented numerous barriers to making in school. Batane and Ngwako (2017) who conducted a similar study noted that pre-service teachers will engage in risk-taking behaviours and use technology during practicum if they believe it will add value to their goal of passing their teaching practice. The fact that these OTU pre-service teachers were evaluated during their practicum, and they perceived significant barriers to making, it is not surprising that they refused to take the risk. What this does highlight is that other options for pre-service teachers should be considered to allow them the same opportunity to take risks and develop agentic capabilities. During the study, opportunities arose for Hadil to take risks including facilitating a student making session and leading a session for a class of pre-service teachers on an AR/VR making activity. More opportunities to take these kinds of calculated and measured risks for various pre-service teachers should be considered to provide self-praxis opportunities. Options should extend to in-class making activities at schools where making is a requested or accepted practice. This can provide an opportunity to replace practicum self-praxis experiences when there are significant barriers to making. Although not a guarantee, these alternative solutions can provide similar experiences to allow the self-praxis of maker pedagogies and potentially support the development of agentic capacity.

In this study, the research question asked:

To what extent does guided inquiry, coupled with hands-on facilitation, promote pre-service teachers' confidence and competence with maker pedagogical approaches and influence their mindset and teaching practices?

- *What challenges do pre-service teachers face, and what risks do they take to implement maker activities in their own practicums?*

The findings demonstrated that through the progressive guided to self-praxis with a supportive community, interns can develop competencies and confidence with maker pedagogical approaches, and the experience positively influences a shift to growing maker mindsets. However, the influence on teaching practices, while appearing extremely positive for many P/J pre-service teachers who implemented making during their practicum, is unclear for the remaining I/S pre-service teacher participants in this study. What was abundantly clear is that pre-service teachers were required to take risks to implement making during practicum and they face real and perceived challenges which can impact their agentic capabilities. For many I/S pre-service teachers the risks were too great as they perceived challenges that became barriers to making based on the nature of secondary school siloed subjects, packed curriculums, and scholarly focus, especially during the senior grades. While many P/J pre-service teachers believed they could overcome the risks they faced and continue to do so in their future practices. Considering the risks to these pre-service teachers in general, the practice of coordinating diverse and less-risky options for self-praxis making in class can potentially support the development of agency in alternative ways. Building this capacity for agency is key to any pre-service maker education which is supported by the findings from Priestley, Biesta, and Robinson (2012) who suggested that if we want to encourage teachers to be agents of change, we need to establish professional development that supports their agentic capacity to interrupt habitual ways of learning in education and encourage innovative practices and mindsets. Those pre-service teachers who have developed agentic capacity, I believe, are in a better position to continue taking risks and implement maker pedagogies in their future classrooms as new teachers.

Chapter 7. Conclusions

7.1 Limitations

As a past intern participant who progressed to an RA and facilitator in the OTU STEAM-3D Maker Lab, I was uniquely positioned to design the methodological approach and conduct this research study. I leveraged my experiences of over two years to develop a condensed design that would allow participants to progressively learn maker technologies, making principles, and practice maker pedagogical approaches all while building our making community. As integral as my passions and history were with making and maker pedagogies in driving and conducting this study, it was essential for me to attempt to reduce any of my own perspectives on the data analysis of this study. I recognize that in any qualitative case study project, the analysis and interpretations are intuitively influenced by a researcher's philosophical perspective and beliefs (Creswell, 2013; Merriam, 1998). So, to be transparent, I identified my interpretative frameworks and professional influences at the outset. Then to provide a credible account of the findings in this study, I collected multiple sources of data from various perspectives, and carefully evaluated and triangulated the data. To further reduce any researcher bias, due to my personal involvement as the lead researcher, I attempted to provide a collective interpretation of the study using participants' words and actions from multiple sources and detailing these perspectives using thick description (Geertz, 1973).

This case study has limited generalizability due to the small sample size and the highly contextualized nature of this study (Fraenkel et al., 2012). Although strategies for trustworthiness were taken, the fact remains that this study involved informal maker pre-service teacher learning approaches in a small, research-focused STEAM-3D Maker Lab with limited participants. The evaluation of the rich detail obtained through this bounded context, however, provides value through its transferability to other contexts (Bitsch, 2005). Transferable research is reviewed by the reader who decides how the findings may connect to their own experiences and contexts.

Finally, I had originally hoped to use member checking and peer researcher review to ensure integrity in my data evaluation. However, shortly after I completed this study, we were entrenched in the COVID-19 pandemic which caused significant struggles for my thesis analysis. In addition, my participants had graduated and were no longer as easily accessible which was compounded by restrictions due to the pandemic. Therefore, I leveraged my supervisor to provide some guidance through data analysis reviews as an alternative method of trustworthiness in my study.

7.2 Future Research Directions

The data provided some interesting findings during this study, but they also invoked ideas for further exploration. For example, it would be insightful to learn whether these pre-service teachers implemented maker pedagogical approaches in their new classrooms as they became certified teachers. Although all the participants stated that they would implement maker pedagogical approaches in their future classes, and some were particularly driven to do so, it would be intriguing to determine if they actually did and their experiences, or their reasoning if they did not. This extension would be challenging, however, as there is no guarantee that the new teachers have a Long-Term Occasional contract or permanent teaching position.

There were a few aspects of this research methodology that a future study could expand on to further elucidate influences of making on teacher practices and mindsets. A research partnership with a local school who is interested in making and maker pedagogical approaches would be an interesting comparative study versus the pre-service teachers' traditional practicum placements. An extension in the duration of internship hours from 20 to 30 could permit more exploration, ideation, and implementation options for making in the classroom. Alternatively, the internship could be migrated to an optional full term elective course that includes situated and experiential making in classrooms at local schools. These modifications of the current study could provide meaningful insights and address some of the concerns from I/S pre-service teachers.

7.3 Implications for Pre-service Teacher Maker Education Programs

As this study evaluated an approach to making and maker pedagogical education there are some valuable insights that can be considered by a pre-service teacher education program. Perhaps the most significant finding is the necessity of time for discovery learning in a makerspace. These hands-on authentic learning opportunities provide insights on maker technologies and the making process but perhaps more importantly, they encourage teachers to become makers and to develop maker mindsets while also fostering a sense of identity in their making community (Lock et al., 2020). As the survey analysis from Cohen (2017) described most of the exposure to making practices in pre-service teacher education programs has been focused on short modules or units of instruction or even one-off Maker Days. These experiences are not enough time to learn making approaches, maker technologies, and adopt making principles. Several researchers have advised that in any maker education program, the pre-service teachers need to become makers and experience all that comes with that practice (Godhe et al., 2019; Lock et al., 2020). For pre-service teachers, becoming a maker is important to learn about making but more significantly the lived experience of making helps them realize the power and competencies required to implement making in their own classroom.

The second aspect that is critical for any making education program for pre-service teachers is to provide opportunities for hands-on facilitation with students. Teachers need to become makers, yes, but teachers need to teach and learn how any pedagogical intervention will be experienced by students. They also need to understand the complexities that are involved in planning and preparing these sessions and the role of the teacher as these methods are vastly different from most instructional methods they have been exposed to (Bullock & Sator, 2015). These situated learning experiences with students are important because a lot can go wrong in making, and you cannot prepare for every scenario. Learning how to manage these types of situations that require adaptive expertise is an important step prior to implementing making in their own classroom (Hammerness, Darling-Hammond, & Bransford, 2005; Rodriguez et al., 2021). In this study, starting with a guided approach to facilitation and just-in-time support practices through Legitimate Peripheral Participation was important to build the confidence of pre-service teachers who had a limited learning window. Regardless of the approach chosen, having these lived classroom making experiences facilitating students is essential (Rodriguez et al., 2021).

Authentic making discovery time and situated practical facilitation with students are two key elements I recommend for any pre-service teacher maker education. In addition, there are several other aspects that should be considered for the effective learning of making and maker pedagogical approaches in a pre-service teacher education program:

- Focus on a few maker technologies but highlight commonalities to similar technologies.
- The lead facilitator needs to model making principles such as making mistakes, not being the expert, taking risks and learning from others.

- Although learning in the makerspace should be primarily informal, documentation journals should be encouraged to promote meta-cognitive learning and reflective practices.
- Encourage and empower pre-service teachers who have developed the confidence and competencies with making to lead making workshops or student sessions to support their next-level growth and agentic capacities.
- Encourage personalized making activities that include assessment and curriculum linkages but start with collaborative ideation and planning sessions addressing all aspects of making in classrooms, including challenges.
- Classroom making activities should have run-throughs and mock sessions in the Maker Lab or makerspace as a final preparation prior to implementation with students.
- Establish partnerships with elementary and secondary schools to ensure there can be situated classroom making sessions with students for participants to lead.

7.4 Conclusion

Technology has become embedded in almost all aspects of our daily lives and is changing the way we interact, work, and communicate (World Economic Forum, 2020). Many industries have benefited from continuous technological advancements, but in education the promise of enhanced learning experiences and future-ready skill set development has not been achieved (Hughes, 2017; Martin, 2015). Simply adding technology to the traditional teacher-centered school environments provides little in the way of enhancing student learning experiences. Maker pedagogical approaches provide a means to develop innovative learning experiences where students learn about and then leverage the enabling capacities of technology to invent, design, develop and problem-solve meaningful creations (Cohen et al., 2017; Hughes, 2017). These approaches do not simply add technology -- they change the way students learn and think by rewarding risk, encouraging failure, iteration and improvement, and emphasizing sharing, collaboration, and the development of a supportive community of learners. Teachers who adopt these maker pedagogies have experienced making and the benefits and challenges the learning approach provides (Blikstein, 2013; Petrich, Wilkinson, & Bevan, 2013). They have maker mindsets with agentic perspectives on making which encourages them to take risks and overcome traditional and formalized learning environments that have become slow to change and adverse to novel learning practices (Clapp et al., 2017; Schad & Jones, 2020).

The findings of this study suggest that the progressive guided to self-directed learning approaches to pre-service teacher maker education coupled with hands-on guided facilitation opportunities supports the development of growing confidence and competencies with maker pedagogies and positively influences the development of maker mindsets of time-constrained pre-service teachers in a B.Ed. program. Furthermore, the experience of self-praxis with making during practicum had a significant influence on the adoption of maker pedagogical approaches and agentic capacity for making in education for elementary pre-service teachers. However, the perceived barriers to making in education by many secondary school pre-service teachers are significant and impact their willingness to adopt maker pedagogical approaches and agentic capacity with making. Any pre-service teacher maker education should consider the unique and threatening challenges that pre-service teachers face to implement making in education and offer alternative self-praxis options to support the development of agentic capacity in making. New teachers who choose to adopt maker pedagogies will face many challenges and will need to have had educational experiences building and testing their agency with making. These practices could help support a wave of new teachers who can help drive innovation in schools organically from the bottom-up as they become agents of change for the maker movement in education.

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Appendices

Appendix A.

A1. Participant Consent Form

OntarioTech
UNIVERSITY

Discover, Design, Develop: Exploring Production Pedagogies in Teaching and Learning

LETTER OF INTRODUCTION - REQUEST FOR CONSENT

We are a team consisting of a professor and research assistants at the Faculty of Education at the Ontario Tech University (Ontario Tech). With the approval of the Ontario Tech Research Ethics Board [REB #15-094, approved on June 2016], we are about to embark on a project designed to learn more about the development and evaluation of production pedagogies and their effects on performative competencies in digital literacies. Production pedagogies are student-centered and inquiry-based approaches to teaching and learning. They are most often used in a makerspace and include problem- and project-based learning; constructivist learning and constructionist learning. A makerspace learning environment stands in opposition to the transmission-based teaching and learning model of the traditional classroom. In a makerspace environment, learners are referred to as "makers" and they construct their knowledge by working on projects, creating with tangible and digital tools -- ultimately – by making. Performative competencies are the ability to perform a variety of skills – traditional literacy, digital literacy, inter- and intra-personal skills, problem-solving and trouble-shooting skills. Digital literacies refer to the knowledge of how to both produce and consume digital texts. The production pedagogies framework for design, discovery, and development, as well as the incorporation of the Arts in STEM (Science, Technology, Engineering, Math) learning, will be used to investigate learning through a series of workshops.

We anticipate using this information in the development of future courses that will increase awareness and implementation of makerspaces and related technological tools in Ontario classrooms, extra-curricular school spaces, and communities. Data results may also be published in journals and presented at conferences.

We invite you to participate in this study. All participants will study a variety of texts and media related to various constructing tools (both digital and tangible) found in makerspace learning environment. Participants will also be required to produce projects that exhibit understanding of the technological tools introduced at different points in the study and their implications. Topics that will be addressed in the study include digital making, electronics, wearables, 3D printing, and coding, gaming, and programmable robots. Your participation would involve the following: (1) Completion of a 15-20 minute pre-survey; (2) Participation in makerspace sessions at the Faculty of Education at 11 Simcoe Street North (rm 415) (3) Submission of your work created during the sessions to the research team; (4) Participation in one focus group; (5) Participation in a ten-minute long exit interview and possible participation in 1-5, five-minute-long interviews during or after the sessions. Data will be collected at various times during the modules. However, only data collected from participants who have given consent will be used in the analysis and reporting of findings. Unobtrusive observation notes will be taken during the sessions and shared with you prior to any publication of findings to ensure words and actions have been accurately represented.

Participation in the research is entirely optional and there will be no academic penalty for not participating. Data will be collected in the following ways:

- Participants will complete a pre-study questionnaire to determine their level of engagement with and understanding of the digital tools and technologies that will be used in the study. The questionnaire should take no longer than 15-20 minutes to complete. An analysis of responses will be conducted to identify themes that emerge. The summarized findings will be used for discussion purposes. This data will be used as a baseline for tracking how participants' views of makerspaces and related technologies change and/or develop over the course of the project.
- Members of the research team will collect data of participant work using observation notes and audio and/or videotaping
- Members of the research team will collect data of focus group discussions using observation notes and audio and/or videotaping
- Members of the research team will analyze digital texts (videos, infographics, participant journals/reflections, etc.) and tangible products (3D printing, Cricut products, etc.) created by the participants.
- Selected participants will be interviewed at the beginning and at the end of the study to track any changes in perspective and to gain more in-depth understanding of perspectives identified through observation. Interviews will take place in the Ontario Tech STEAM3D maker-lab.

You may withdraw from the study at any time without penalty and can choose not to answer specific questions by saying "pass" in an interview situation. If, during any of the above described activities, you decide not to participate, you can stop the activity by approaching the researcher or teacher and indicating that you wish to withdraw from the study. You will be notified if an activity or discussion is being taped and will have an opportunity to object. The information you provide will be accessible to the research team only. Pseudonyms will be assigned to each participant once the data has been collected and any images or video where participants are visible will be altered to obscure faces. Any names that are present on participant work will be removed before publication as well.

The tapes and transcripts of makerspace sessions, along with any other data collected, will be stored securely at Ontario Tech under the lead researcher's supervision over a three-year period and will be destroyed after 5 years. By consenting to participate, the participant does not waive any normal legal rights or recourse.

Your signature on the consent form indicates that you have read this letter, understand its contents, and agree to participation in this research project. If you have any questions about this project, feel free to call Dr. Janette Hughes at 905 721 8668 Ext. 2875, or the Ontario Tech University Research Ethics and Compliance Officer, who can provide answers to pertinent questions about the research participants' rights, at compliance@ontariotechu.ca 905 721 8668 Ext. 3693. Thank you for considering participation in this research study.

Dr. Janette Hughes, Faculty of Education, Ontario Tech University

Discover, Design, Develop: Exploring Production Pedagogies in Teaching and Learning

CONSENT FORM

Participant Concerns and Reporting:

If you have any questions concerning the research study or experience any discomfort related to the study, please contact researcher, Laura Morrison at 416-617-0869 or Dr. Janette Hughes at (905) 409-9800.

Any questions regarding your rights as a participant, complaints or adverse events may be addressed to Research Ethics Board through the Ethics and Compliance Officer - compliance@ontariotechu.ca or 905.721.8668 x. 3693.

This study has been approved by the Ontario Tech University Research Ethics Board REB #15-094 on June 2016.

Participant:

I have read the Letter of Introduction/Request for Consent relating to the above titled project, I understand the proposed research and my questions have been answered to my satisfaction.

I understand the following (please check each item you understand and agree to):

- ☐ I have the right to withdraw from the study at any time if I do not feel comfortable and I understand that the information collected is for research purposes only and no personal identifiers will be used.
- ☐ If I withdraw, my information will not be used in the research and will be destroyed.
- ☐ Participation is entirely voluntary and that choosing to participate or choosing to withdraw from the study has no negative consequences for me
- ☐ Data will be collected through field notes, audio/video/photo recordings. All notes and interview transcripts will be shared with participants for verification before any findings are analyzed and disseminated. I can choose to withdraw my contributions or clarify items with no negative consequences.
- ☐ I understand that there are limited physical risks working in a makerspace, but some risks could include: burns from hot motors or glue guns or cuts from sewing needles or scissors. Emotional risks could include anxiety from sharing projects with researchers or peers.
- ☐ I understand that I will be instructed how to use the tools in the makerspace lab and that I have the right to pass and not share one or all of the projects I create in the lab. There will be no negative consequences if I choose not to share.

By signing below, I give my consent for participation in the research study.

Title/Program of Study: ____________________________

I give consent to be recorded (audio/video/photo): ☐

I give consent to be audio-recorded only: ☐

I give consent to be video-recorded only: ☐

I give consent to be photographed only: ☐

Full Name (please print): ____________________________

Signature: ____________________________

Date: ____________________________

Appendix B.

B1. Pre-study Online Survey for Participants

Questionnaire for Teacher Candidate interns/volunteers

Please complete each question to the best of your ability.

Email *

Valid email

This form is collecting emails. Change settings

Please provide your name, undergraduate degree and which Bachelor of Ed program you are in and your teachables.

Short answer

Short answer text

Required

Please describe, why you want to volunteer or intern with the STEAM-3D maker lab? *

Long answer text

How would you describe a maker lab? What kinds of materials and tools might you see there? *

Long answer text

What do you believe is the difference between technology labs and maker labs? *

Long answer text

Have you ever experienced a makerspace, whether observing or participating? Please describe the experience. *

Long answer text

We are interested in your experience with maker technologies and tools. Please indicate whether you have used many times, used seldom/once, not used, or unsure for the following maker technologies/tools: *

	Used many times	Used seldom/once	Not used	Unsure
Block coding (i.e. s...	○	○	○	○
Syntax (i.e. python,...	○	○	○	○
Programmable rob...	○	○	○	○
Lego robotics	○	○	○	○
Microbits	○	○	○	○
Arduino	○	○	○	○
Raspberry pi	○	○	○	○
Augmented and/or...	○	○	○	○
Paper circuits	○	○	○	○
makey makey	○	○	○	○
e-textiles	○	○	○	○
greenscreens	○	○	○	○
3D printing/design	○	○	○	○
Cricut	○	○	○	○

What is your confidence in teaching with the following digital/electronic maker tools? Please select a level from 1 to 5, level 1 being 'no confidence' to level 5 'highly confident'. Please also indicate if you want to learn (more) about that particular tool/technology. *

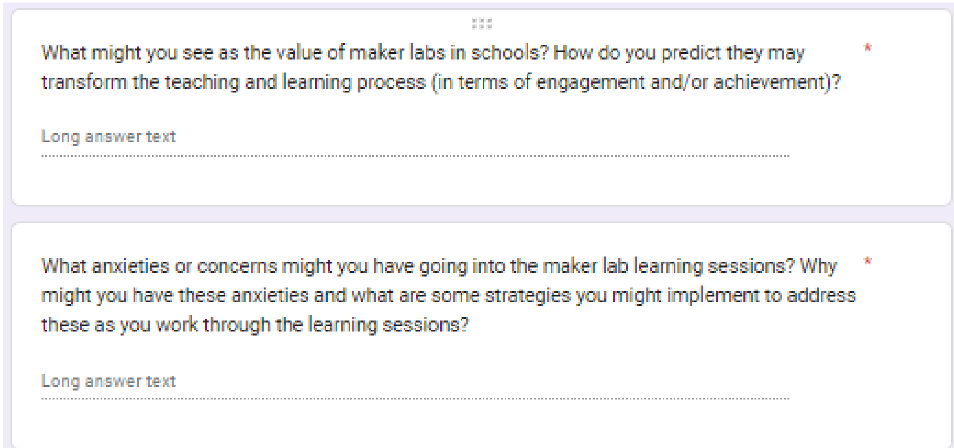
	Level 1, no c...	Level 2, a litt...	Level 3, som...	Level 4, con...	Level 5, high...	Want to lear...
Block codin...	☐	☐	☐	☐	☐	☐
Syntax (i.e. p...	☐	☐	☐	☐	☐	☐
Programma...	☐	☐	☐	☐	☐	☐
Lego robotics	☐	☐	☐	☐	☐	☐
Microbits	☐	☐	☐	☐	☐	☐
Arduino	☐	☐	☐	☐	☐	☐
Raspberry pi	☐	☐	☐	☐	☐	☐
AR &/or VR	☐	☐	☐	☐	☐	☐
Paper circuits	☐	☐	☐	☐	☐	☐
Makey Makey	☐	☐	☐	☐	☐	☐
e-textiles	☐	☐	☐	☐	☐	☐
greenscreens	☐	☐	☐	☐	☐	☐
3D printing/...	☐	☐	☐	☐	☐	☐
Cricut	☐	☐	☐	☐	☐	☐

For any maker technology you have a level 4 or 5 from the previous question, please indicate the name of the tool and why you have confidence in it.

Long answer text

Please describe any design project or prototype (digital or hands-on) you have made using digital/electronic maker tools and what the process was like for you? *

Long answer text



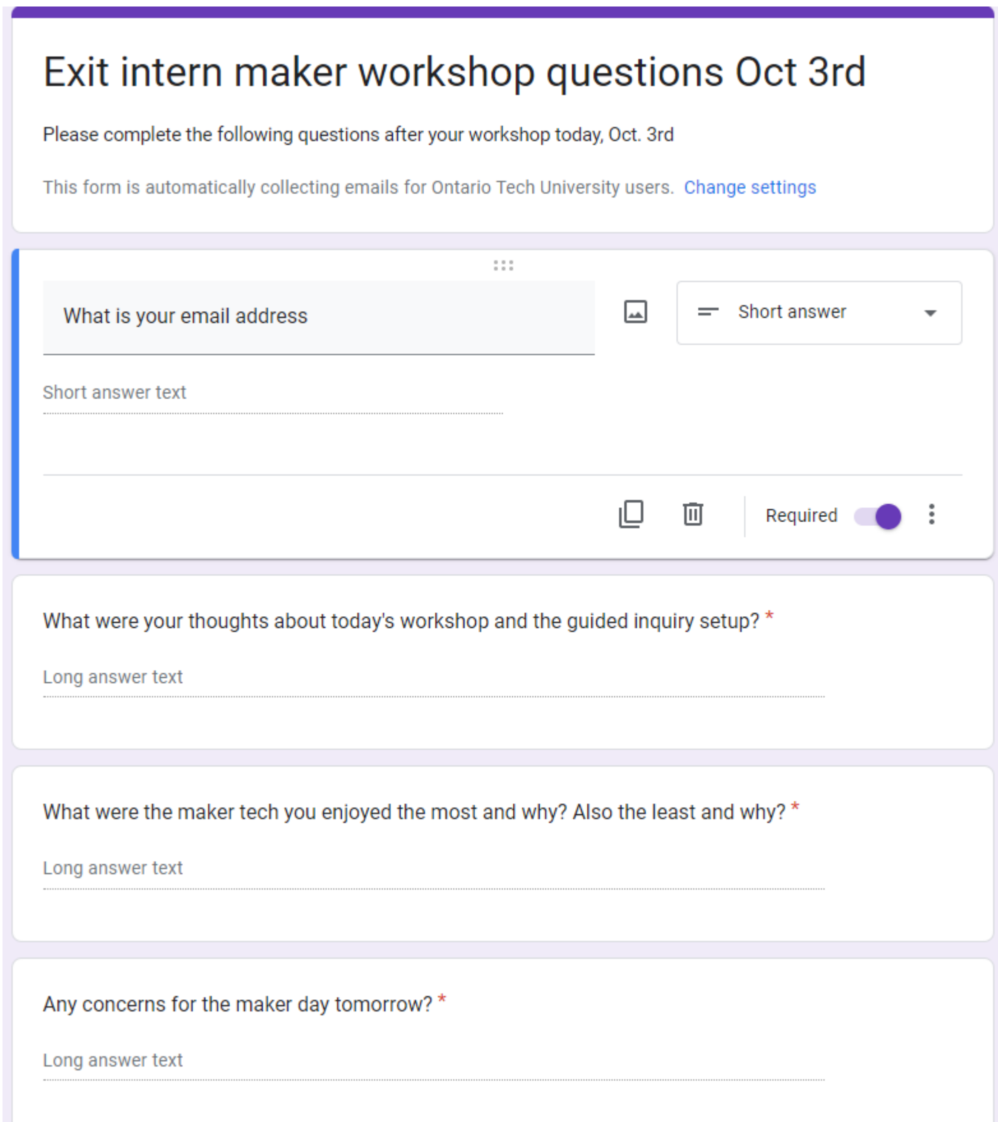
What might you see as the value of maker labs in schools? How do you predict they may transform the teaching and learning process (in terms of engagement and/or achievement)? *

Long answer text

What anxieties or concerns might you have going into the maker lab learning sessions? Why might you have these anxieties and what are some strategies you might implement to address these as you work through the learning sessions? *

Long answer text

B2. Exit Survey from October 3rd Maker Workshop



Exit intern maker workshop questions Oct 3rd

Please complete the following questions after your workshop today, Oct. 3rd

This form is automatically collecting emails for Ontario Tech University users. Change settings

What is your email address

Short answer

Short answer text

Required

What were your thoughts about today's workshop and the guided inquiry setup? *

Long answer text

What were the maker tech you enjoyed the most and why? Also the least and why? *

Long answer text

Any concerns for the maker day tomorrow? *

Long answer text

Appendix C.

C1. Stage 1 Final Research Interview Guide

Intern Stage 1 Final research interviews (1:1) for thesis

1. At the start of the internship I asked you why you wanted to volunteer or intern with the lab – describe your experience and whether it met your needs and wants for the internship.
2. How has your understanding of makerspaces and making activities changed or not changed, grown or not grown from the start of the internship?
3. How has your confidence changed related to maker technologies (please describe specifics)?
4. As you experienced hands-on, discovery and collaborative making sessions focused on some specific technologies – some guided-inquiry and some more free-inquiry –
    a. what are your thoughts on the progressive inquiry approach we all took to learn maker technologies
    b. and how would you apply or modify this approach with future students
5. Can you describe any individual-making/learning experiences you had or observed (for example with interns, alone in maker session, during B of Ed makerday or student workshop) – good or bad or interesting or insightful? Please describe any skills you gained from the experience.
6. What are your thoughts on making and the encouragement of making mistakes (failures) and learning from them in making activities? What about as a teacher – how do you feel about making mistakes in front of your students with these activities?
7. What about thoughts on problem solving in making activities – was this something you observed, please describe. What about the collaborative environment & having ongoing peer & teacher guidance/support – was this something you observed, please describe.
8. We worked on planning maker activities for placement – what are some key insights you learned from this planning process?
9. What anxieties or concerns do you have with the planned making activities for your upcoming placement?
   OR
10. If you decided not to do a making activity with tech – why? What challenges do you face? I noticed this was primarily with I/S interns, what do you think the challenge is to use maker tech in Secondary school?
11. Do you think you will be willing to try making activities with different tech in future? What are some considerations for you to create & use these activities?
12. Please describe or share any other thoughts, ideas, concerns, challenges, etc.

C2. Stage 2 Final Research Interview Guide

Intern Stage 2 Final research interviews (1:1) for thesis

- This was asked in January 2020 to only the interns who took the tech to their placements.

1. How was your placement overall?
2. What activity did you do with what tech? (please provide lesson plans and pictures)
3. You had a planning session before your placement, do you feel that you were prepared appropriately?
4. What would you do differently from a planning perspective?
5. What were some of the positive outcomes from this activity?
6. Was there any resistance from the AT, class or culture to do these activities with tech? **
7. Would you do this activity again?
8. After having implemented a making activity how do you feel about doing this in your own practice in future? Do you think it is important, relevant and necessary for future ready skills, why or why not?
9. Do you feel your internship helped prepare you for creating, planning and implementing making activities with maker technologies?