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Makerspaces in Higher Education: Student Engagement

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MAKERSPACES IN HIGHER EDUCATION: STUDENT ENGAGEMENT

by

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Abstract

The makerspace movement is gaining prominence within higher education. With the promise of improving the student learning experience, institutions invest space and resources to support making and the maker movement. The focus of my study was how postsecondary students engage in learning through makerspace in non-STEM (Science, Technology, Engineering, and Mathematics) courses in an eastern Canadian university.

The qualitative case study investigated the implications maker activities have on learning in three non-STEM (Education and Geography) courses. The following questions guided the inquiry: How do postsecondary students engage in learning through makerspace activities in non-STEM courses? What is the nature of academic, social and intellectual student engagement when learning through making in non-stem course environments? Furthermore, what factors influence or hinder the usage of makerspaces in non-STEM postsecondary course contexts?

Data were collected using interviews, observations, and questionnaires with three different classes with subsequent thematic analysis. Three common themes emerged: how students perceived engagement, the impact of an experienced instructor, and the challenges associated with makerspace in a classroom environment. What differed between the three classes was the level of expertise between instructors, the maker activities' format, and the technology used.

This study's significant contribution is that it reveals the importance of engagement for both instructor and student. Using makerspaces is one tool that could be considered in non-STEM courses in a university to enhance learning through engagement. For instructors and students to use makerspaces successfully, they must help solve an authentic problem, have experienced staff, have adequate infrastructure, and allow students to reflect on their problems. Implications for practicing makerspaces can be considered at various university leadership levels, from instructor to educational development.

Preface

This thesis is original, unpublished, independent work by the author, Shawn Christopher Pendergast. The research methodology outlined in Chapters 3 was covered by Ethics Certificate number REB17-1512, issued by the University of Calgary Conjoint Faculties Research Ethics Board (CFREB) for the study “MAKERSPACES IN HIGHER EDUCATION: STUDENT ENGAGEMENT” on July 31, 2018.

Acknowledgement

This body of work has been a six-year journey that has had many ups and downs. During this time, I have been confronted with several family issues, including watching my mother, Wenda Temple, who was diagnosed with Alzheimer's at 54, slowly slip away. At the same time, I have seen my three children Christopher, Darby, and Adia grow into young adults, and my wife completed her Masters, be it at a faster pace than me.

To my supervisor Dr. Jennifer Lock, I appreciate the patience, support and insight you have provided me over these last years. Dr. Lock took me on with no hesitation and guided me throughout my journey with professionalism, dedication, and care. Over video conferencing, we made plans, set goals, and had a few chuckles. With a family, work, and coaching hockey, I found it hard to keep on track; however, Dr. Lock was always there to encourage, guide and send gentle reminders when necessary. I would also like to thank my doctoral committee, Dr. Petrea Redmond and Dr. Sharon Friesen. Their guidance and insight pushed me to question many of my assumptions that helped my research and allowed me to grow academically.

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Most importantly, I would like to thank my family, especially my wife, Dr. Amanda Pendergast. Amanda has been instrumental in helping me finished my dissertation. She provided guidance and was always there to provide support. She gave countless hours of proofreading and suggesting improvements. I will forever cherish our time discussing the dissertation in front of the computer or on one of our countless walks.

Dedication

I dedicate this dissertation to my loving wife Amanda (aka Bean), three children Christopher, Darby, Adia, and our family dog Bergie. Without you, this achievement would be far less meaningful. Thank you all for your support.

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CHAPTER ONE INTRODUCTION

Makerspaces are increasingly recognized for their potential to foster innovation among students. Over the last several years, makerspaces have appeared on the educational landscape in schools, museums, and public libraries (Regalla, 2016). Makerspaces and their associated activities have great potential as educational tools (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Halverson & Sheridan, 2014). Makerspaces are developing within the K to 12 educational system, yet have been less common within a higher educational setting (Johnson, Adams Becker, Estrada, & Freeman, 2015). The maker movement has the potential to engage and enrich the learning experience of students in formal education.

The term *maker* is a relatively recent term and is synonymous with words like tinkering, forging, fabricating, building and producing (Vossoughi & Bevan, 2014). While the term may be new, the activities it embodies are timeless and interminable (Johnson et al., 2015; Peppler, Maltese, Keune, Chang, & Regalla, 2015). Many people participate in the act of *making* outside formal education, which can range from someone working in their garage to individuals engaging in quilting sessions at a local church.

From a constructionist lens, maker activities offer students the opportunity to control their learning and creation (Papert, 1999). This power is connected to a shift in students' focus and the instructor's changing role. Instead of the instructor being seen as an expert who disseminates knowledge to students, the instructor becomes more of a facilitator who enables students to create new and meaningful works (Halverson & Sheridan, 2014).

Context of the Study

While the maker movement has gone by many names, the term first gained popularity with the publication of *Maker Magazine* more than a decade ago (Wong & Partridge, 2016). Since 2005, the maker movement transitioned from exclusively informal learning settings, like public libraries, museums, and non-profits, to formal learning environments (Davee, Regalla, & Chang, 2015; Halverson & Sheridan, 2014; Regalla, 2016), establishing itself in the higher education echelon (Carlson, 2015). The movement also breached mainstream culture, culminating in discussions at the White House (Halverson & Sheridan, 2014).

My research aimed to investigate how makerspaces can be used in higher education to engage students, specifically in a classroom setting for non-STEM (Science Technology Engineering and Math) disciplines. My study aimed to contribute to the body of research focused on student learning through the maker movement in education. Current literature tends to concentrate on the K-12 school system's maker movement (Wong & Partridge, 2016). In higher education, the focus has been on the STEM disciplines (Halverson & Sheridan, 2014; Peppler, Halverson, & Kafai, 2016b; Wong & Partridge, 2016). For example, while fabrication labs in engineering may not have been called *makerspaces* they have allowed students to create and experiment in some of their courses.

The context for my dissertation involved three undergraduate courses taught at one university selected for this study. Each of the three faculty members teaching said classes used maker technology in the following courses: a geography class in the Faculty of Arts, and two education classes in the Faculty of Education.

Rationale for the Study

Research by Willms, Friesen, and Milton (2009) suggested that student engagement faces a steady decline as students progress through the K-12 system. Shaienks, Gluszynski, and Bayard (2008) noted that positive high school engagement was a vital engagement indicator at the postsecondary level in Canada. Those students reporting low levels of high school engagement were far more likely to drop out of university or college. Groups like the California Council on Science and Technology (2016) and Kurti et al. (2014a) suggested the maker movement has the potential to increase student engagement.

The impact of makerspaces from an economic and cultural standpoint is emerging outside education. This rise in popularity may be a factor in the growth of makerspaces within colleges and universities (Johnson et al., 2015), which has increased the creation and spread of maker facilities in schools (Paulo Blikstein, Kabayadondo, Martin, & Fields, 2017). While places that resemble makerspaces have existed in higher education on a small scale (for example, at the departmental level), there is a growing trend towards institutionally supported making (Halverson & Sheridan, 2014). Johnson et al. (2015) suggested that the maker movement will become more integrated into higher education within the next two to three years.

The maker movement can help students learn (Kurti, Kurti, & Fleming, 2014b). To achieve this, one must fully understand how to deploy makerspaces within their classroom activities. While some research focuses on makers and how they impact education, most educational research examines how they influence middle and high school students (Vossoughi & Bevan, 2014). At the time of the review of the literature, there was less focus on higher education. Focusing on two undergraduate classes and interacting with a makerspace environment will give better insight into the maker movement's potential effectiveness within a higher education setting.

This dissertation investigates how students engage in learning when working on makerspace projects in a postsecondary classroom setting. Based on the emphasis on improving student engagement, the potential importance of the maker movement in higher education within the next few years (Johnson et al., 2015), and the lack of non-STEM related research around makerspaces at the postsecondary level, this study is a timely and relevant contribution to the field.

Significance of the Study

This dissertation explores how students engage in learning through maker activities, what factors influence the degree to which they engage, as well as the nature of their engagement through making. The results provide insight to support practitioners who want more substantial experiential learning through non-STEM courses in higher education. The findings can further shed light on the types of projects that engage learning through making in contemporary higher education. While the study does not attempt to be a roadmap with respect to starting makerspaces in the classroom, it may serve as a guide to help instructors implement maker activities outside of STEM disciplined areas.

Statement of Problem

Improving student engagement is an important issue for many postsecondary institutions (National Survey of Student Engagement, 2017; Newmann, 1992; Trowler, 2010). The challenge is to discern what can be done to address a lack of engagement in learning. While there are still many unknowns with regard to how makerspaces impact student learning (Martin, 2015; Peppler et al., 2016b; Wong & Partridge, 2016), this researcher believes makerspaces can increase student engagement learning in a higher educational context. Within makerspace research, the nature of makerspaces usage in a classroom setting is relatively unknown (Fields & Lee, 2016). Even with this limited knowledge, many universities are starting to acquire more novel maker technologies (e.g., 3D printers, Arduinos, laser cutters and Raspberry Pi computers) (Johnson et al., 2015) and are establishing spaces in locations such as libraries for makerspaces. How are these technologies being used to support student engagement in learning in the postsecondary context? Studies which examine student engagement in learning while using makerspace in non-STEM courses in postsecondary education are scarce. Therefore, this dissertation aims to gain a better understanding of how students engage in learning through maker activities and what factors influence the degree to which they engage. The research questions are:

1. How do postsecondary students engage in learning through makerspace activities in non-STEM courses?
    a. What is the nature of academic, social and intellectual student engagement when learning through making in non-stem course environments?
    b. What factors influence or hinder the usage of makerspaces in non-STEM postsecondary course contexts?

Scholars such as Martin (2015) observed that more research on the impact of makerspaces in higher education is necessary, especially around how to implement makerspace projects. Furthermore, STEM instructors have long understood the value of a maker-like set up in their classes (Peppler et al., 2016b; Wong & Partridge, 2016). Research into non-STEM subjects may provide insight into how students from non-STEM backgrounds use makerspace in a postsecondary environment. For this reason, I intentionally chose non-STEM disciplines for this study.

Definition of Key Terms

Student Engagement. "Students' involvement with activities and conditions likely to generate high-quality learning" (Radloff & Coates, 2010, p. 3). Willms, Friesen, and Milton (2009) suggested that student engagement comprises three distinct dimensions: academic, intellectual and social engagement.

Academic engagement. "Participation in the formal requirements of schooling" (Willms et al., 2009, p. 7). Academic engagement is directly related to participation in schooling's formal requirements (Willms et al., 2009).

Social engagement. "A sense of belonging and participation in school life" (Willms et al., 2009, p. 7). This connection occurs if the student feels part of the activity in which they are participating. Formal participation in the curriculum would be considered a requirement for one's engagement in the academic portion of one's education (Willms et al., 2009).

Intellectual engagement. "Requires an emotional and cognitive investment in learning, using higher order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge" (Willms et al., 2009, p. 7).

Formal Learning. "Learning that occurs in a formal domain and has any one of the following characteristics: a prescribed learning framework, an organized learning event or package. The presence of a designated teacher or trainer, the award of a qualification or credit or the external specification of outcomes" (Eraut, 2000, p. 114). Formal learning usually takes place within a space resembling a classic classroom setting (Livingstone, 1999). Other characteristics of formal learning include a planned curriculum, formal assessments, and a classic style of student-teacher relationships (Tusting, 2003).

Informal Learning. "Any activity involving the pursuit of understanding, knowledge or skill which occurs outside the curricula of educational institutions, or the courses or workshops offered by educational or social agencies" (Livingstone, 1999, p. 4).

Making. Making may include: **"**Building things, being creative, having fun, solving problems, doing social good, collaborating and learning" (Martin, 2015, p. 4).

Makers. "Anyone who builds or adapts objects by hand, often with the simple pleasure of figuring out how things work, creating an aesthetic piece, or seeking to solve an everyday problem, fall under this distinction. Makers frequently have pride and a desire to share projects and the creative process with others, which is what fuels the larger communities of physical and online makerspaces" (Peppler, Halverson, & Kafai, 2016a, p. 25).

Makerspaces. “Makerspaces are part of a growing movement of hands-on, mentor-led learning environments to make and remake the physical and digital worlds. They foster experimentation, invention, creation, and exploration” (Institute of Museum and Library Services, 2014, p. 1).

Maker Movement. **“**A form of informal and formal education made up of three components: making, makerspaces and makers” (Halverson & Sheridan, 2014, p. 496).

Reflection. It involves the learner looking back at an activity (Bransford, Brown, & Cocking, 2000). In essence, a learner reviews an activity or event and examines what worked well, what did not work well, and assesses where there are areas for improvement. Dewey (1933) believes the act of reflection results in a deeper understanding of learning content. Furthermore, reflection can result in a greater awareness by the learner about their thinking process. Schön (1984) views reflection as the process by which learners gain a greater awareness by learning from their own experiences.

Organization of the Study

This study investigates the utilization of makerspaces in postsecondary non-STEM classrooms in higher education. The study is comprised of six chapters. In Chapter One, the Introduction, I provide an overview of the study. Chapter Two, the Literature Review, discusses the study's relevance and makers, makerspace, and the maker movement more broadly. Learning theories associated with the maker movement and the role that engagement plays in learning and the maker movement are also discussed. Chapter Three, the Research Design, positions the study based on gaps uncovered while conducting the literature review. This section describes and discusses case study methodology, the study participants, and the data collection methods and analysis. Finally, the researcher's role and ethical considerations are discussed. Chapter Four, Findings, describes the participants, themes that emerged from each class, and common themes across each class. Chapter Five, the Discussion, presents the linkage among the themes found in the literature sources. In the final chapter, Chapter Six, the Conclusion, I share an overview of the research, a discussion of the limitations of the research and the implications for further research

CHAPTER TWO: LITERATURE REVIEW

This review explored the academic literature on makerspaces, current research within the maker movement, learning theories related to the maker movement, and student engagement. The research undertaken provides the theoretical underpinnings for the remainder of the research proposal.

This chapter's literature review contains six sections. First, I provide an overview of the major areas connected to makerspace, including the following: what is making, who are makers, and where makerspaces exist. This chapter then transitions to the second section, which features an examination of the maker movement's history. The third part explores the underlying learning theories involved in the maker movement, which the fourth section follows with an overview of the challenges and opportunities within the maker movement. I follow these limitations with my fifth section, where I evaluate the learning theories that contributed to making and my conceptual framework used for the study. The sixth and final section concludes by identifying gaps in the literature which I have positioned in my research study.

Making, Makerspaces, and Makers

Any significant discussion of making requires clarification of what it encompasses. Halverson and Sheridan (2014) and Peppler, Halverson, and Kafai (2016) see the maker movement comprised of three separate categories. First, making are activities associated with the maker movement. Second, makerspaces serve as both physical spaces and communities. Third, makers are the individuals involved in the making process. The following section discusses each of these three categories.

Making

In a broader sense, the maker movement has created an environment where people can express themselves collectively and individually (Brahms, Werner, & Werner, 2013; Halverson & Sheridan, 2014). However, what constitutes making and a maker environment is a bit more fluid, as Martin (2015) pointed out that there is no absolute set definition of the term making. Some scholars like Sheridan et al. (2014) explained making as the activities that occur within a dedicated makerspace. For example, the term making can be thought of as a set of learning activities (Peppler et al., 2016a). The specific activities can blend many types of disciplines, for example, art and science, and often result in unique outcomes, both physical (i.e., artifacts) and academic (i.e., learning outcomes or technical skills). These activities can appeal to all ages and promote a community of sharing, openness, and creativity (Johnson et al., 2015). This view of making puts emphasis on the actual activities and the physical communities present. Other scholars focus more on the attitudes associated with making. Horvath and Cameron (2015) suggested that making is “more of state of mind than a well-defined activity” (p. 3). Some scholars treat building and playing via making as a process of inquiry (Vossoughi & Bevan, 2014). Advocates for this attitude note that making may potentially activate a person’s sense of agency and develop a feeling of empowerment (Clapp, Ross, Ryan, & Tishman, 2016). The imagination of the makers working together is the only limitation in the activities (Peppler et al., 2016b). Both approaches overlap, emphasizing that the activities and participants’ attitudes towards them foster the most significant growth opportunities.

These flexible views of making offer students alternate avenues through which to meet the same overarching learning goals as traditional educational strategies. As Kafai, Fields, and

Searle (2014) noted, making shares a common interest with traditional learning: the mastery of core competencies. This shared interest may allow for making to complement school-based approaches to teaching and learning (Halverson & Sheridan, 2014). However, making can be done almost anywhere, giving it a distinct advantage over school-based education. Making can occur in more formal areas such as classrooms, museums, libraries and labs, as well as informal areas such as garages and basements (Halverson & Sheridan, 2014). This shared interest in learning, combined with its potential to complement school-based approaches, may be why making is becoming more popular in formal learning spaces.

Makerspaces

A physical makerspace can vary widely and take many forms, but a makerspace is a place for people to work and share ideas at its heart. These spaces allow for sharing knowledge, collaboration, experimentation, and offer a place in which to foster inquiry-based learning (California Council on Science and Technology, 2016). The term makerspace is a generic term commonly used in schools, museums, and library environments (Horvath & Cameron, 2015). According to Halverson and Sheridan (2014),

> Makerspaces are the communities of practice constructed in a physical place set aside for a group of people to use as a core part of their practice. While making activities are a part of the community, they do not fully constitute it. (p. 502)

Spaces acting as makerspaces are only limited to the physical space allocated, the funding available, and the creators' imaginations. Makerspaces may be categorized to understand their roles further. According to Davee, Regalla, and Chang (2015), there are three broad categories of makerspaces: dedicated makerspaces, mobile makerspaces, and distributed makerspaces.

Dedicated makerspaces occupy a permanent space located in a fixed physical location. Within this space, there is maker equipment, material, and furniture. These facilities also have safety equipment, appropriate ventilation for smoke and dust, and noise management for the machinery within the makerspace (Davee et al., 2015). Dedicated spaces can take many forms in a university setting. For example, at the Massachusetts Institute of Technology (2017), makerspaces are allocated based on their purpose and the community they serve. Davee et al. (2015) suggested dedicated makerspaces fall into three subcategories: machine shops, project makerspaces, and community makerspaces. Machine shops are geared more towards experienced makers, are more specialized, and have skilled staff available. In contrast, community makerspaces allow for unrestricted access for the early or novice user. The diverse makerspace community drives the support for these spaces rather than a need for high-quality production. Project makerspaces are primarily concerned with supporting classroom activities and curriculum-based learning. These makerspaces tend to have spaces that primarily promote teamwork and collaboration.

A mobile makerspace contains multiple types of makerspace equipment and can move between locations. For instance, a group of students at the University of Stanford conceived a SparkTruck to bring makerspaces to local schools. These students funded the original truck and equipment through a Kickstarter campaign. The ideas quickly expanded to other regions. In the summer of 2012, the Sparktruck drove over 15,000 miles, visited 33 different states, and, more importantly, conducted maker workshops with more than 2,700 students in 70 unique locations

(SparkTruck, 2017). Graduate students from Western University developed a similar idea, whereby they transformed an old school bus into a mobile makerspace. They created the moving space to reach out to places that generally lacked access to a makerspace. With maker technology, the students bridged the digital divide for rural communities, libraries, at-risk youth, and schools across Ontario. They promoted the idea of making and encouraged learners to think laterally. This service was a fun, non-conventional way of encouraging experimental play with the combination of technology, digital literacy, and collaboration (Makerbus, 2017).

Mobile makerspaces are not limited to large trucks that roam across the countryside. Smaller mobile carts allow smaller makerspaces to visit classrooms and other areas within institutions. In addition to reaching a larger audience, smaller mobile makerspace allows educators a low-cost option to start a maker environment without having to invest significant time, space, and money (Davee et al., 2015). For example, at Memorial University of Newfoundland, The Learning Commons has a mobile makerspace that includes two large instructional carts containing equipment such as a Computer Numerical Control (CNC) router, 3D printer and laser cutter. These carts are taken to classrooms across campus, where students can better understand the workings of a makerspace (The Commons, 2016).

Distributed makerspaces are multiple makerspaces existing within an organization (Davee et al., 2015). Each space's function, the type of equipment used, and the clients served are dependent on how the spaces are organized within the university (Davee et al., 2015). Essentially, distributed makerspaces are a combination of dedicated and mobile spaces. For example, the Massachusetts Institute of Technology (2017) has a centralized approach to its makerspaces. The Massachusetts Institute of Technology’s Provost initiated Project Manus in

2015, with the mandate to promote and grow academic makerspaces. As of late 2017, there were 45 major makerspaces within project Manus. They are in multiple places within the Massachusetts Institute of Technology and serve different purposes, such as promoting makerspace and collaboration with other universities.

Another example of a distributed makerspace is at Memorial University of Newfoundland. Memorial University has a more decentralized makerspace environment, whereby different maker type facilities are working independently of one another. There is a Digital Media Centre that allows for creating multimedia products such as video, images, and sound; a mobile makerspace located in their Learning Commons; and engineering workshops and fabrication labs designed exclusively for engineering students (Memorial University, 2019).

The Composition of a Makerspace. The size, composition, and equipment of a makerspace can vary widely in an educational setting. Factors influencing the equipage viable for a makerspace include the amount invested in the space, the age of the user and the expertise of those who run it. An elementary school makerspace, for example, can contain objects as simple as Legos and tin foil. An illustration of a simple, low-technology making project was Papert and Harel's (1991) observation of a *knot lab* where children used rope knots to represent their family trees. On the other end of the spectrum, a Makerspace can contain new technologies (Wohlwend & Peppler, 2015). Makerspaces can contain more high technology equipment, including 3D printers, laser cutters, CNC routers, and electronics (Johnson et al., 2015). Barrett et al. (2015) reported that the most common pieces of maker equipment within university makerspaces are 3D printers and laser cutters. In a Peppler et al. (2015) study, of 51 makerspaces, most makerspaces surveyed reported having laptops, computers, other electronic devices, multimedia software, and many included conventional maker equipment such as 3D printing, laser cutters, and crafting materials. Based on their survey, makerspace equipment can be divided into the following categories, with the following tools and equipment (Peppler et al., 2015):

- computers, including laptops, tablets and smartphones;
- digital fabrication equipment including 3D printers, CNC routers and laser cutters;
- software including multimedia, coding, and 3D modelling software;
- wood cutting tools, such as saws and drills;
- electronic equipment, such as soldering irons and circuity tool kits;
- maker kits, such as robotics and Makey Makey kits; and
- textiles, including sewing machines and vinyl cutters.

Makers

Makers can be anyone interested in how things work and have a curiosity about building or modifying (Peppler et al., 2016a). To gain a better understanding of a maker's traits, Clapp, Ross, Ryan, and Tishman (2016) interviewed many adult makers. They found makers to be curious, playful, persistent, resourceful, and collaborative (Clapp et al., 2016). Dougherty (2016) supported the attribution of many of these traits to makers. Clapp et al. (2016) and Dougherty (2016) also suggested that makers are good at improvising and desire to share their work and expertise with others. Users of makerspaces are not always heavily associated with the STEM fields. Makers can be inventors, artists, crafters and many others (Slatter & Howard, 2013). Kurti, Kurti, and Fleming (2014a) pointed out that people are the driving force behind makerspaces: at their very core, makerspaces are about people and communities.

Makerspace expertise can also vary considerably among users. Some individuals are knowledgeable in lower-tech makerspace equipment, such as craft-focused activities, knitting, and sewing, while others are more comfortable with new technologies, such as 3D printing (Slatter & Howard, 2013). It is not necessary, as Kurti et al. (2014a) noted, to be a technical expert to establish a makerspace.

In the United States of America, makerspace usage in youth is similar to the demographic distribution of this population. However, the adult population is less diverse, comprising more middle-aged white males (Peppler et al., 2015). Buechley (2013) observed that white men and boys accounted for 85% of the *MAKE Magazine* covers. Peppler et al. (2015) believed this demographic to be reflective of STEM fields, as recruiting women and non-white employees to such lines of work has proven to be difficult. Women's attitudes towards technology are changing partly due to an increased number of role models in the workplace and the media (Anthony, Clarke, & Anderson, 2000). This culture is slowly evolving, and makerspaces are becoming more inclusive and supportive of diversity where they operate (Lewis, 2019; Roldan, Hui, & Gerber, 2015). For example, the development of feminist hackerspaces supporting women's creative pursuits (Hurst & Kane, 2013) and makerspaces empowering individuals to create or modify assistive technology has become more prevalent (Fox, Ulgado, & Rosner, 2015). The changing demographics, no matter how slow, demonstrates the evolution of the maker movement.

The Maker Movement

The History of the Maker Movement

While the spirit of making has been around for a long time (Burke, 2014), this section focuses on when the terms *make*, *making* and *makerspace* became part of the mainstream. The term makerspace can be traced back to *Maker Magazine's* early publications in 2005 (Bevan, 2017; Wong & Partridge, 2016). Makerspaces also appear under different monikers: hackerspaces, fabrication labs, and workshops (Johnson et al., 2015; Peppler et al., 2015). While the term maker was coined in 2005, the first true makerspaces appeared a few years earlier. In 2001, the Massachusetts Institute of Technology created a fabrication outreach project (Slatter & Howard, 2013). The successes of projects like this led to the expansion of similar fabrication projects.

Early successes in the maker movement included Maker Faire, which celebrates maker and DIY (do it yourself) culture; it has since spread worldwide (Johnson et al., 2015). Before the successes of Maker Faire and *Maker Magazine*, the maker movement existed in rudimentary forms. It existed in backyards, sheds, garages, sewing rooms, and in the minds of inventors (Bevan et al., 2015). Most of the attention given to early makerspaces had been on the technology and was focused on the process of creation, collaboration, and sharing resources in non-academic settings (Slatter & Howard, 2013).

The popularity of the movement has increased globally in recent years (Bevan et al., 2015; Johnson et al., 2015; Peppler et al., 2015). A simple example that illustrates this is the number of Google searches on the word *makerspace*. Between 2012 and 2014, the number of searches on the term *makerspace* increased four-fold (Davee et al., 2015). Not only has it become a topic of interest on the internet, but also a mainstream movement. The former President of the United States of America, Barack Obama, referenced the phenomenon during the first-ever White House Maker Faire in 2014. He encouraged Americans to support creativity and inventions in their communities (Halverson & Sheridan, 2014).

Demographics of the Maker Movement

The maker movement grew from individuals who had a passion for creating (Barrett et al., 2015). Two examples of this creative push were Silicon Valley employees in the early days of the computer industry (Dougherty, 2012), and MIT staff and faculty's hedonized computational collaboration with the creation of Spacewar! in the 1960s (Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013). Unfortunately, the maker is often associated with a white, male-dominated culture. White, middle-aged males dominate the adult demographics of those who attend maker conferences or hold subscriptions to *Maker Magazine* (Halverson & Sheridan, 2014; Peppler et al., 2015). Peppler et al. (2015) reported in their survey of 51 makerspaces across the United States of America that many of the makerspace participants were Caucasian. Caucasians represented 42%, followed by 20% African Americans, 18% Hispanics, and 14% Asians. Peppler et al. (2015) also observed that the younger, non-adult maker demographic's composition is far more representative of the American population. In these younger demographics, makerspace has seen an increase in diversity (Iwata, Pitkänen, Ylioja, Milara, & Laru, 2019). Additionally, movements like Maker Fair Africa are beginning to change what a *typical* maker looks like (Tanenbaum et al., 2013).

The Maker Movement in Education

The maker movement allows for many individuals with varied backgrounds to work side-by-side on their ideas. Makerspaces have the potential to span both informal and formal learning environments (Papavlasopoulou, Giannakos, & Jaccheri, 2017), and they are now visible in informal learning environments, such as public libraries and museums (Halverson & Sheridan, 2014). Makerspaces in education are rooted in formal learning environments, similar to Papert's Logo coding to help teach math to students (Papert & Harel, 1991), and MIT's *Scratch* programming to promote digital fluency (Resnick et al., 2009). Makerspaces in educational institutions may enhance learning but not replace existing forms of learning. Vygotsky (1978) gave an example of an adolescent who learned about the visual arts through the creation of a physical artifact used to help the adolescent master the subject material. Kafai, Fields, and Searle (2014) suggested that this type of an example demonstrates maker activities' potential to enhance learning.

Makerspaces are spaces where artists, engineers, builders, and tinkers can take ideas and turn them into reality (Johnson et al., 2015). Makerspace environments can increase students' creativity, imagination, and autonomy (Kajamaa & Kumpulainen, 2019). However, achieving these transformative elements requires a considerable commitment from only students and a sustained commitment from the teachers that develop these makers' projects (Kajamaa & Kumpulainen, 2019). At the primary educational level, there is evidence suggesting that teachers are sometimes reluctant to engage in STEM activities (Blackley, Sheffield, Maynard, Koul, & Walker, 2017). It is important that educators realize the benefits of makerspace projects and their transformative potential (Kajamaa & Kumpulainen, 2019).

Despite reluctance at the primary education level (Blackley, Sheffield, Maynard, et al., 2017), interest in makerspaces and the maker movement has gained popularity within education (Johnson et al., 2015; Martin, 2015) and makerspaces are emerging in educational institutions. Educators and researchers have been looking at making and what role it could play in learning (Halverson & Sheridan, 2014; Papavlasopoulou et al., 2017). Teachers participating in makerspace style projects not only can improve their proficiency with the technologies they work with; they also gain confidence around the integration of technologies in their classrooms (Miller, Christensen, & Knezek, 2017).

Some scholars (e.g., Barniskis, 2014; S. Schön, Ebner, & Kumar, 2014; Slatter & Howard, 2013) agreed that a significant influence in the maker movement was the book *Makerspace Playbook School Edition* (Hlubinka et al., 2013). An essential purpose of the book was to showcase several schools using makerspaces (Oliver, 2016). Maker Media wrote and distributed *The Makerspace Playbook* 2013 School Edition. It is available through the Creative Commons License agreement. Multiple prominent authors contributed to the document, including Dale Dougherty, founder of *Make Magazine*, Michelle Hlubinka, who worked at MIT Media Lab and Parker Thomas, Managing Partner of Mirus Labs (Hlubinka et al., 2013). The book can be used as a blueprint on how to create a makerspace. It covers topics such as where to set up, safety considerations, organizational structures, how to share projects, and what tools are necessary. According to Hlubinka et al. (2013), the book was intended to help educators create a makerspace.

Benefits of the Maker Movement in Education

The maker environment offers learners the opportunity to work in a safe, flexible environment with other like-minded individuals to solve problems, learn, and create (Preddy, 2013). Learners who are engaged in maker activities do not usually work in isolation. The spaces themselves help bring individuals together to work on ideas. In many cases, groups work on larger projects that require collaboration and communication (Peppler et al., 2015; Preddy, 2013). Peppler et al. (2015) reported that 48% percent of those surveyed assumed shared responsibility for collaborative work and valued the contributions made by their group members multiple times per week. In the same study, 55% of those surveyed reported having to use oral, written, and nonverbal communication skills while working in the makerspace environment multiple times per week, with another 19% doing this once a week.

Within the library context, the spirit of making aligns with libraries' roles, such as knowledge creation and equal access to information and equipment (Slatter & Howard, 2013). Access to the makerspaces for community members is not limited to libraries. Some institutions use makerspaces for the public conjoint with access for faculty and staff. An example of this is Sierra College partnering with a local hacker lab to make the space more accessible to groups outside of the university, such as local small businesses and start-ups (Johnson et al., 2015).

An important feature of makerspaces is that they allow students to experiment, build and prototype. For example, using additive manufacturing, an individual using a 3D printer can quickly prototype artifacts that would have been far more difficult to model 20 years ago (Dickinson, 2018). Barrett et al. (2015) pointed out that prototyping improves the final design of projects and links material covered in class to real-world applications. Prototyping allows students and educators to build one-of-a-kind objects quickly and at a relatively low cost. While the final artifact is itself important, so is the process of building the artifact. Horvath and Cameron (2015) suggested that it can be beneficial when students create something tangible from what they just learned. Making in groups encourages more experienced students to adopt a supportive role. Those student makers with less experience reported learning not only from the building process but also through observing more skilled makers (Vossoughi & Bevan, 2014). This cycle of learning, collaborating, and prototyping can provide students with a richer learning experience than being relegated to passive participation in learning (Horvath & Cameron, 2015).

Challenges of Makerspace in Education

While maker activities are potentially a powerful approach to learning, there are drawbacks (Bevan et al., 2015). In this section, some of the challenges that the maker movement is facing, such as validation, institutionalization, adoption, location, perception, and demographics, are noted relating to education.

How can the maker movement in education prove it can improve learning? Some research suggests that the success of using technology for educational purposes can be overemphasized (Oliver, 2011). How do you provide clear evidence that competencies will increase through establishing a makerspace in your school? Bevan et al. (2015) suggested that part of the problem may be our narrow definition of learning in school. New approaches, such as makerspaces, differ from traditional learning, which leads to tension and unease between educators and stakeholders. Individual institutions need to address how the makerspace will fit or even replace the curriculum before adopting a makerspace program.

A more significant challenge is how institutionalization will affect the maker movement and what it means to participate in maker activities going forward (Burke, 2015; Halverson & Sheridan, 2014). Advocates of the 1990's computer technological innovations and proliferation promised to help revitalize educational opportunities. However, research conducted later showed that teachers did not often use computers or comprehensively integrate them into the curriculum (Bauer & Kenton, 2005; Friedman, 1997; Gorder, 2008; Jacobsen, Clifford, & Friesen, 2002b). Ifenthaler and Schweinbenz (2013) came to the same conclusion when they introduced iPads into the classroom. They noted that full integration of technology would prove difficult until we understand why teachers do not embrace and incorporate technology in their classrooms. Based on this research, care should be taken when introducing new approaches, such as a makerspace, into educational institutions. Halverson and Sheridan (2014) felt that the level of institutionalization partially depends on the democratizing that will occur. In other words, the learner's freedom to experiment and produce artifacts may determine the movement's success. Even when an institution shares the same ideologies as the maker movement, logistical challenges may still exist.

Finding space and staffing can also be challenging. Makerspaces often house specialized equipment that requires a certain level of expertise to use. The prerequisite skills for this equipment often combine proficiency with traditional shop equipment (i.e., table saws and routers) and more high-tech equipment (e.g., 3D printers, electronics, and laser cutters). Finding someone with a diverse mix of skills can prove difficult (Horvath & Cameron, 2015). Space is also often at a premium in most learning institutions. Finding space to house a makerspace in an educational setting may also prove problematic. Even when space is available, traditional universities often comprise large lecture halls, small classrooms, or libraries designed for books; none of these locations make ideal makerspaces. While science and engineering departments do have lab spaces, they are often not designed to be used in tandem with other activities such as making (Peppler et al., 2016b).

According to Halverson and Sheridan (2014), embracing the maker movement inside the K-12 school system can prove incredibly challenging. Questions around accountability, trendiness, and curriculum integration are often brought up for debate. The maker style approach to learning differs from traditional learning and may challenge teachers and students regarding how they perceive learning (Bevan et al., 2015). While technical schools in fields such as engineering and computer science are establishing a growing number of makerspaces, these STEM schools are often encouraging new approaches to learning rather than traditional teaching (Peppler et al., 2015).

Once schools establish makerspaces, a vital factor to consider is how makerspaces fit into the broader curriculum. Martin (2015) noted that there was a common belief that increased access to computers in schools would lead to improved learning and an increase in students using computers. Cuban (2001) observed that only schools that tried to integrate computers saw advancements in teaching and learning. Many schools did not integrate the technology, and, resultingly, many of the computers sat idle with no change to the curriculum. This failed integration resulted in faculty and students only using computers in superficial ways: searching the web and creating a basic PowerPoint presentation (Ertmer & Ottenbreit-Leftwich, 2010).

Martin (2015) concluded, for makerspaces and the maker movement to take hold in schools, they must be embraced and integrated into teaching and learning frameworks. While somewhat unclear on how to adequately embrace maker technology, initiatives may include providing proper funding (Horvath & Cameron, 2015) and allotting time for teachers to attend maker workshops and plan maker activities (Butler & Sellbom, 2002; Horvath & Cameron, 2015).

Many of the challenges discussed may only prove to be short term problems. For example, while demographics may initially be a challenge, there is optimism that the population who use makerspaces are becoming more representative of their existing communities (Peppler et al., 2015; Tanenbaum et al., 2013). Additionally, maker technologies may also become more comfortable to use and more accessible.

Makerspaces in Higher Education

The occurrence of makerspaces is becoming increasingly common in learning institutions (Fourie & Meyer, 2015; Halverson & Sheridan, 2014; Johnson et al., 2015). Many of these spaces are present outside higher education in libraries and museums across North America (Davee et al., 2015; Yu, 2016). In addition to location, makerspaces also take different forms, such as dedicated labs, pop-ups and mobile configurations (Regalla, 2016). The 2015 NMC Horizon Higher Education Report highlighted that makerspaces would begin to play a significant role in higher education within two to three years (Johnson et al., 2015). Becker et al. (2017) considered makerspaces to be a key driving factor in the current redesign of learning spaces and an educational technology trend for the next three years in higher education. Considering the potential establishment of the makerspace movement in post-secondary institutions, there is limited research on the impact of makerspaces at the post-secondary level (Wong & Partridge, 2016). This section will look at the maker movement's growth in higher education, highlight some examples, and discuss staffing compositions and access to makerspaces on campuses.

In 2014, Barrett et al. (2015) surveyed 127 of the top-ranked universities in the United States. Of the 127 respondents, 37 of them had a makerspace. In addition to the universities that had makerspaces, others indicated that they were planning on building them in the future. While the number of makerspaces seems proportionately low, Barrett et al. (2015), in a review of university makerspaces, suggested many undergraduate programs lacked a creative compliment in their curriculum, which could benefit from maker activities.

A few universities indicated that there would be a major shift in their thinking with respect to makerspace culture through significant investments in essential resources and creating new maker facilities that promote innovation (Barrett et al., 2015; Carlson, 2015). According to Johnson et al. (2015), makerspaces are becoming part of the dominant culture with increased recognition for their economic potential. The University of Nebraska planned to construct a 17,000 square foot makerspace at their innovation campus, and Wichita State University received $4 million in funding to open an 18,000 square foot makerspace (Carlson, 2015). In 2020, the University of Nebraska extended their makerspace program to include mobile makerspaces in support of rural libraries (Hartman, 2020). These innovations are not limited to the United States of America. In Canada, Memorial University of Newfoundland moved from a mobile makerspace to a more permanent open access location in their main library in 2017 (The Commons, 2016). A recent partnership between the Faculty of Engineering and the University Library at McMaster will see a new makerspace to promote interdisciplinary collaboration

(McMaster, 2016). These examples illustrate the space and resources universities are beginning to invest in makerspaces.

The present literature outlines significant limitations on makerspace accessibility. Some of the issues that other scholars do not commonly discuss extensively include individual department's access, whether individuals outside of faculty can use the space, and restrictions surrounding student access. Barrett et al. (2015) and Gottbrath and Charnas (2019) reported in their studies that makerspaces within universities were usually open to staff, faculty, and students with a few schools restricting access. The makerspaces that restricted access were those catering to engineering disciplines, and these made access to their spaces exclusive to only their staff, faculty, and students.

How makerspaces are staffed and administered also varies significantly among organizations. Barrett et al. (2015) noted in their study that many university makerspaces have a combination of specialized full-time staff and student staff. In addition to paid staff, some makerspaces are entirely student-driven. This is also supported by Wong and Partridge (2016), who point out that makerspaces in Australian universities are mainly operated by a combination of specialized staff, students in maker clubs and library staff.

Affordances of Makerspaces

The term affordance often appears in explanations of people's relationships with technology (Oliver, 2005). Dalgarno and Lee (2010) proposed that "the affordance of a tool is essentially an action made possible by the availability of that tool" (p. 12). The idea of affordances was first suggested by the American psychologist James Shea Gibson (1977), but gained prominence by Don Norman in his book *Design of Everyday Things* (1990) with real and perceived affordances. Norman (1990) defined affordances as “the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used” (p. 9). Norman also proposed the potential relationships between actors and objects (Wright & Parchoma, 2011). Norman (1990) used a chair to illustrate how affordance works. A chair affords support and therefore affords sitting (an *actual* property); however, it can also be carried (a *perceived* property). Affordances themselves cannot be directly responsible for the occurrence of learning; however, affordances can indirectly afford specific learning tasks that could give rise to learning (Dalgarno & Lee, 2010).

Affordance can apply within the maker context (Giannakos, Divitini, & Sejer-Iversen, 2017). According to Giannakos et al. (2017), makerspaces are equipped with many different tools and technologies with diverse making affordance abilities. In a broad sense, makerspace affordances would be its ability (perceived or actual) for students to interact within the makerspace to create and engage. This creation can lead to learning and increased engagement (Giannakos et al., 2017). In a more specific sense, the tools and software within the makerspace have their specific affordances. For example, if we use a standard tool within a makerspace, like a 3D printer, an actual affordance would be printing out a 3D object. The actors (i.e., the students) perform actions that can range from something tangible, such as printing out a toy, to something as abstract as printing out a virus replica for a biology class. Based on the variety of tools available to students within a makerspace context, these affordances are potentially only limited to the students’ ingenuity and creativity.

Libraries as Sites of Makerspaces in Higher Education

Libraries tend to be viewed as places where one accesses information. Public libraries have also had a long history of providing spaces for community purposes, such as craft activities like knitting and sewing (Slatter & Howard, 2013). Libraries also enable people to create other artifacts. For example, students use libraries to research information and create academic artifacts like reports (Fourie & Meyer, 2015; Preddy, 2013; Slatter & Howard, 2013). Libraries provide learners with the space, the material (i.e., books), and the tools (e.g., computers) to create and innovate. This mindset, combined with the resurgence of a do-it-yourself culture and the accessibility of technology, has led to a realignment in programming at public libraries (Purpur, Radniecki, Colegrove, & Klenke, 2016; Slatter & Howard, 2013). This community focus and open-access approach may be some of the phenomena contributing to the emergence of makerspace in public libraries across the globe (Halverson & Sheridan, 2014; Slatter & Howard, 2013). It is also worth noting that the connections between libraries and the makerspace movement were initially challenging to see. Slatter and Howard (2013), however, reported that the literature suggests libraries are mainly supportive of housing and promoting makerspaces.

Like public libraries, libraries serving higher education institutions can be places where innovation is fostered (Leong & Anderson, 2012). University libraries, by their very nature, are open, accessible places that foster education in many disciplines. Libraries also have a tradition of providing new technologies in a non-judgmental environment. Given this fact, along with libraries’ history of providing access (which is often free to their communities), Halverson and

Sheridan (2014) are hopeful that these institutions will promote the democratization of makerspaces.

Many university libraries across North America have an Information or Learning Commons (Allison, DeFrain, Hitt, & Tyler, 2019; Beagle, 2012; Hynes & Hynes, 2018). The popularity of a Commons is due to the academic library's changing role within higher education. Instead of collecting and warehousing physical books and other print material, libraries are now redefining these spaces to be more focused on teaching and their institutions' learning goals (Saunders, 2015). A Commons works within the university's broader academic environment, whereby it contains IT tools, resources, and support for students' academic learning. Computers, software, digital library resources, and assistive technology are often co-located within a Commons. Support for these resources is also present and tends to involve experts from various disciplines (Bennett, 2008). The very nature of a library Commons promotes sharing and creativity (Preddy, 2013) and is focused on helping students with teaching, learning and research (Saunders, 2015). They often have a digital media discipline that allows students to create digital artifacts. For example, the Digital Media Centre at Memorial University of Newfoundland provides training and access to the Adobe Suite. With this software collection, students can create and edit various media, such as video, graphics, and audio (The Commons, 2016). Another example is found at the University of Northern Iowa (2016), where green screens, video cameras, and lighting are provided so that students can create original movies.

Libraries provide spaces for students to create, collaborate and share while fostering engagement. Students who seek out purposeful educational activities and who frequent academic libraries are more engaged academically (Kuh & Gonyea, 2003). Since university libraries have a history of openness are willing to evolve, and possess an inherent potential for engaging students, it would seem logical for makerspaces to become part of postsecondary institutional library systems.

Engagement in Learning

The focus on student engagement has become more prominent in education in the last several decades (Appleton, Christenson, Kim, & Reschly, 2006; Friesen, 2010; Jacobsen, Lock, & Friesen, 2013). Throughout the literature, there are many definitions of student engagement. For example, Fredricks, Blumenfeld, and Paris (2004) and Archambault, Janosz, Fallu, and Pagani (2009) identified three dimensions of student engagement: behavioural, emotional, and cognitive; while Friesen and Willms (2013), Friesen, and Milton (2009) divided student engagement into three categories: social, academic, and intellectual. For this study, Willms' et al. (2009) three categories will be used, while incorporating other research into their defined categories.

Social engagement occurs when the student feels they are part of the activity they are participating in, such as playing a school sport (Fredricks et al., 2004; Willms et al., 2009). Willms defines two dimensions of social engagement: participation and sense of belonging. Participation is measured by how often students participate in the social aspects of school. Several factors influence social engagement, like playing on school teams and participating in school clubs, cultivating positive relationships with teachers and other students, and expectations of success (Fredricks et al., 2004; Willms et al., 2009). Fredricks et al. (2004) suggest that social activities should be considered crucial for deterring student dropouts and achieving positive academic outcomes.

Academic engagement is directly related to participating in the school's formal requirements, including academic achievement in subjects such as math and science. Formal involvement in the (mandated or required) curriculum is considered a requirement for the academic portion of the engagement (Willms et al., 2009). The more academically active students are in school, the more engaged they will usually be (Fredricks et al., 2004). Factors that influence academic engagement are teacher and parental encouragement, direct and indirect consequences, effort demonstrated by the student, a positive classroom disciplinary climate, and intellectually challenging lectures.

Intellectual engagement "requires a serious emotional and cognitive investment in learning, using higher order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge" (Willms et al., 2009, p. 7). An example of intellectual engagement would include students' interest in the schoolwork beyond what their instructor requires in class (Willms et al., 2009). Csikszentmihalyi (1990) described it as those moments when a person is completely absorbed in a challenging task. Fredricks, Blumenfeld, and Paris (2004) defined emotional aspects of engagement as the students' reactions within the classroom.

Examples of emotional aspects of engagement include boredom, happiness, or anxiety. Fredricks et al. (2004) defined the cognitive aspects of engagement as "being strategic or self-regulating" (p. 64). Intellectual engagement can also be seen as the effort a learner exerts in applying knowledge and learning strategies when working on a project or task (Zhu et al., 2009). One of the underlying themes of engagement is that it has to be deep and meaningful to student learning (Appleton et al., 2006; Csikszentmihalyi, 1990; Sawyer, 2006; Toll, Drefs, & Lock, 2016). This deeper engagement may lead to students expanding their knowledge, gaining a better mastery of the task they are learning, and, more importantly, allow for sustained cognitive engagement (Bevan et al., 2015; Sawyer, 2006).

Recent interest in engagement has been motivated by its potential for improving learning outcomes for students (Friesen, 2010; Greene & Miller, 1996; Klopfer & Resnick, 1989). Student engagement can retain student interest and can foster enjoyment while learning (Picard et al., 2004). Engagement is often a personal experience that incorporates real-life experiences and applies them to the classroom (Johnson, Levine, Smith, & Smythe, 2009). Picard et al. (2004) commented that "even a superficial eye can see that learners are more engaged when they learn principles of physics and engineering by building functioning machines" (p. 262). This comment highlights the potential efficacy of engaging students by asking them to make something related to a topic they are studying. Coates (2005) examined student engagement in the higher education context and was concerned with engagement in various activities such as learning actively, working collaboratively, and enriching educational experiences. Through these and other engagement activities, there is potential to influence learning positively.

Coates (2005) commented that engagement is often overlooked in higher education. Friesen (2013) noted that students' participation and attendance dramatically dropped when students reached grade 12, whereas it remained high during elementary school. More alarming was that intellectual engagement was measured below 60% in grade 6, declined to below 40% in junior high, and slightly increased in grade 12. Johnson et al. (2009) also noted that as students are not engaged in the K-12 school system, this results in a lack of engagement in learning. Johnson et al. (2009) stated that while technologies familiar to students, project-based learning, and mentoring are readily available, these resources may not be utilized appropriately in the school system. Friesen (2013) noted in her study that the school a student attends has a much more significant influence on the level of engagement compared to other variables, such as the student's family background.

When looking at makerspace projects in the classroom, it is essential to pick appropriate projects for students. Depending on the complexity of the project, this may impact the students' cognitive engagement. A project that is too easy may result in disengaged students while, conversely, students that find the project too complex may decide the project is too hard, give up and disengage with the maker project (Csikszentmihalyi, 1997; Sawyer, 2006; Toll et al., 2016). Sawyer (2006) pointed out that even when students appear to show greater interest in what they are working on, this interest may be only superficial. Thus, the students may not be cognitively engaged. For example, students may appear highly engaged when observing a plant's development from a seed. Superficially, they observe how the seed is transforming and note the growth rate but may miss the deeper lesson of what causes the seed to transform.

Appleton et al. (2006) argued that student cognitive engagement could improve outcomes by providing students with a more profound learning experience that will improve schoolwork quality and their commitment to education. Toll et al. (2016) pointed out that a part of the issue may be that teachers are not well versed in this concept, and, therefore, students have not yet had the exposure to cognitive engagement. Students who are engaged cognitively have better learning outcomes than disengaged students (Appleton et al., 2006; Greene & Miller, 1996; Reyes, Brackett, Rivers, White, & Salovey, 2012; Toll et al., 2016; Willms et al., 2009). Those who are not engaged, in contrast, have far worse learning outcomes and can be at risk of educational failure (Appleton et al., 2006; Toll et al., 2016).

Fredrick et al. (2004) attributed the growing interest in engagement to the idea of measuring levels of commitment or investment across all dimensions of engagement that can vary in intensity and duration. This idea suggests a qualitative difference in engagement levels based on the amount of work a student does (Fredricks, Blumenfeld, & Paris, 2004; Trowler, 2010). For example, types of social engagement can vary from following classroom rules to running a school's newspaper. Trowler (2010) categorized engagement levels as being either positive, negative, or non-engaged. For example, academic engagement can range from merely attending classes and being bored (i.e., non-engagement), to deeply appreciating the value of each class and the instructors who facilitate them (i.e., positive engagement), to disrupting lectures (i.e., negative engagement). Intellectual engagement can range from not being prepared for an exam, to studying for an exam by memorizing the material, to using various learning strategies that will give a deeper understanding of the concepts addressed in class. It is also worth noting that students may perform positively in one dimension of engagement while exhibiting negative or non-engagement in others (Fredricks et al., 2004). In addition to engagement levels being measurable based on the student's commitment or investment, some scholars believe that engagement is malleable with the potential to improve all dimensions of engagement over time (Fredricks et al., 2004; Trowler, 2010).

Reflection in Learning

Students' knowledge can grow through their active participation and reflection on projects. Active participation and reflection have been shown to play important roles when students work on maker projects. Dewey (1933) said, "We do not learn from experience. We learn from reflecting on experience" (p. 78). Dewey felt reflection is not passive; instead, it is a purposeful and an ongoing process. Schön (1984) expanded on Dewey's work by describing two distinct types of reflections, reflection-in-action and reflection-on-action. Reflection-in-action occurs during the activity when students are simultaneously working, for example, on a project and reflecting on what they are accomplishing. Reflection-in-action represents a real-time analysis of a situation, where students' thinking adapts and evolves (Ferreira, 2017). Reflection-on-action, however, occurs when students reflect after the completion of the activity.

Reflection has a positive impact on student engagement (Bransford, Brown, & Cocking, 2000). Majgaard (2014) found that when first-year engineering students combined play and reflection on their game design projects, they gained additional insights and awareness about their subject matter. Boud, Keogh, and Walker (1985) stressed the importance of reflection and identified three stages of reflection: preparation, engagement in an activity, and the processing of the experience. In the first phase, students are exploring their expectations of the event. This phase can be stressful and can cause a high level of anxiety. In the second phase, students participate in the activity; at this phase, students may initially become overwhelmed, causing them to adopt coping strategies. At this phase, students may not make connections between theory and practice. At the final phase, students have finished their projects and begin to report on their experiences and connect theory to practice. At this point, students may also recognize unanswered questions and incomplete parts of the project. Boud et al. (1985) pointed out that reflection should play a role in all three of these phases, and students should be actively encouraged to reflect on their projects at different stages of their completion.

Reflection can occur at different times, is complex and requires students to participate in the process actively (Baud et al., 1985; Dewey, 1933). Reflection, whether in-action or on-action, positively impacts student engagement. Reflection should be encouraged during all phases of a project, including preparation, engagement, and processing.

Authenticity

Authentic instruction is a strong predictor of student engagement (Fredricks et al., 2004). An authentic task needs to reflect real problems of the discipline that is being taught in the classroom. Questions should address significant problems or tasks a professional working in that specific field might encounter (Friesen & Scott, 2013), as the use of real-world, authentic questions and subsequent discussions engage students (Newmann, 1992). Blackley, Sheffield, Walker, Koul, & Maynard (2017) suggested the makerspace concept can allow students to authentically engage with other students in an academic setting. Newmann (1992) suggested that smaller class sizes, combined with an authentic question, help engage students. With fewer students in a class, teachers may have the opportunity to interact with students more meaningfully. In some cases, an experienced instructor may enable an exchange of ideas between student and instructor, influencing the teaching direction.

The types of maker projects on which students work should be considered. Maker projects need to be authentic. Engaged student learning using technology requires planning the integration of technology into student learning by the instructors**.** Student tasks need to be authentic, challenging, and multidisciplinary (Jacobsen, Clifford, & Friesen, 2002a). From a makerspace lens, having an authentic problem for students to work on not only results in more meaningful learning, but it can also increase student engagement in makerspaces. Authentic makerspace projects allow for greater participation within makerspaces, allowing students to develop additional skills and knowledge (Vossoughi & Bevan, 2014).

Learning Theories and the Maker Movement

Maker activities may play a role in improving student engagement (Martinez & Stager, 2013). To understand learning in makerspaces, we must understand the major learning theories that ground the maker movement. At a basic level, constructivism examines how children naturally learn things by doing (Duckworth, 1964). Constructionism is more focused on how children learn and how making artifacts contribute to this process (Ackermann, 2001). By using tools and other equipment types, students take ownership of their learning in a self-directed manner (Ackermann, 2001). The following section will examine each theory, connecting them to the wider maker movement.

Constructivism

The concept of constructivism is a relatively modern learning theory. Piaget is often credited with being the foundational figure by many constructivists (Phillips, 1995). Some of the theory's ideas have their origins in East-Asian antiquity. The quote, "Tell me and I forget, teach me and I may remember, involve me and I learn" is associated with the Chinese Confucian Philosopher Xun Kuang, who lived from 312 to 230 BC. This quote is still relevant, and elements are apparent in Piaget's (1980) quote: “Fifty years of experience have taught us that knowledge does not result from a mere recording of observations without a structuring activity” (p. 23). In its simplest form, constructivism can be thought of as learning by making (Papert & Harel, 1991; Resnick & Silverman, 2005). While this is an oversimplification of constructivism that does not illustrate the theory’s depth and multifaceted approaches (Papert & Harel, 1991), it can give us a general idea and a starting reference point from which to explore the theory.

Constructivism has its roots in developmental and cognitive psychology (Young & Collin, 2004). John Dewey, a psychologist and educational reformer, challenged how we saw the day's school system. Teaching often consisted of a repetitive cycle of attending class, observing, and memorizing material with each cycle more difficult than the last (Dewey, 2004). Instead, Dewey (2004) believed that students learned not by memorization, but by inquiry and discovery. It was not the result of what was learned, but rather the learning process itself; in other words, learning how to learn (Huang, 2002). Constructivism looks at learning from the perspective that we impose our meaning on our environment. While we do experience the world, we find the meaning from those interactions (Duffy & Jonassen, 1992). Constructivism suggests that we use cognitive processes to apply our experiences to how we view the world (Anderson, 2008; Young & Collin, 2004). The meanings we derive from our experiences are unique; two people may experience the same environment and form different realities. Even if two individuals have the same experience and discuss this experience, there will be some discrepancies in their perspectives (Duffy & Jonassen, 1992). Constructivists view the learning process as something internal to the individual rather than an external imposition and, as Young and Colins (2004), and Tudge and (Winterhoff, 1993) observed, constructivists often omit the significance of social interactions. Learning becomes more of an active process and less of a passive process when students are engaged in constructing knowledge rather than having it handed it to them (Anderson, 2008).

Constructionism

A learning environment that draws upon constructivist theories keeps students actively engaged in learning rather than passively listening to instruction (Mayes, 2001). It also encourages the learners to engage in problem-solving and critical thinking (Jonassen & Kwon, 2001). Zhu (2012) studied students who were required to engage in online discussions with other students regularly after a set number of lectures. As a result of these discussions, students constructed knowledge through interactions with their peers. Zhu concluded that social constructivism could enhance online activities by promoting knowledge construction. Critics of constructionism point to some research that showed there were no cognitive benefits in children who work with Papert's Logo language over a school year. Another study revealed that knowledge gained from Logo had limited transferability to other kinds of learning (Parmaxi & Zaphiris, 2014). Papert responded to these criticisms by pointing out there was a technocentric bias at work. Papert (1987) said,

> Consider for a moment some questions that are "obviously" absurd. Does wood produce good houses? If I built a house out of wood and it fell down, would this show that wood does not produce good houses? Do hammers and saws produce good furniture? These betray themselves as technocentric questions by ignoring people and the elements only people can introduce. (p. 24)

Papert was also a constructivist and worked closely in Geneva with Piaget in the late 1950s and early 1960s (Ackermann, 2001). Papert and Harel (1991) argued that there is no scientific consensus regarding which approach constitutes the most effective learning theory. To argue one way or another, choosing constructionism as the only learning theory within the maker movement, is not the point of this discussion. Instead, the purpose is to highlight constructionist views' utility as a starting point, which may subsequently offer guidance on how to approach the research question. Papert and Harel (1991) used the analogy of the painter-programmer and how they approach their work. Papert observed that one lets the work guide the decisions made during the project's progression. This bricolage allowed for more improvisation over a planned approach. The other approach followed a more formal and analytical approach that pre-plans the techniques necessary to complete the project rather than relying on instinct. These different approaches are not necessarily right or wrong, but instead are by-products of personal preference. They both, however, illustrate constructionism in that both processes foster learning through creation.

Constructionism, Constructivism and Social Constructivism

As Ackermann (2001) and Kafai (2006) pointed out, constructionists are focused on learning via creating artifacts, whereas constructivists are interested in an individual's learning process. With social constructivism, the focus is on the social process (Tudge & Winterhoff, 1993). It is interested in the social interactions within groups that allow this process to occur (Kim, 2001). Tudge and Winterhoff (1993) contrasted social constructivism and constructivism, noting that "Piaget began with the individual child who progressively becomes social, whereas for Vygotsky the child is social from the start" (p. 67).

Vygotsky social constructivism differed from Piaget constructivism in that learning cannot be separated from its social context (Tudge & Winterhoff, 1993; Vygotsky, 1983). Social constructivism is based on basic assumptions about reality, knowledge, and learning, emphasizing the importance of culture and context in understanding what occurs in society (Kim, 2001). Piaget believed that children work as individuals to make sense of their reality. At the same time, Vygotsky argued that development is a social process that involves the individual and assistance from others more knowledgeable in the skill the child is trying to learn (Tudge & Winterhoff, 1993). Vygotsky (1978) also believed that with specific support and help from more experienced learners, students would learn more than if they worked independently. This process is referred to as the zone of proximal development and will be discussed in the following section.

Vygotsky's Zone of Proximal Development and Scaffolding

Based on the different types of support models discussed, it is worth considering Vygotsky's (1978) zone of proximal development. Vygotsky proposed that differences exist when learners attempt to independently perform a task without support versus when they receive some external support. Wood and Middleton (1975) also made a similar argument following a study that observed 12 mothers and their interactions with their children as they worked towards assembling a toy. While results varied within the study, those did best when the mother helped the child when the child started to experience problems. Wood and Middleton (1975) concluded that if student success is contingent upon the instructor's ability to modify the extent of their teaching intervention, subsequent instructor/teacher interactions will require less interventions, leaving the child greater autonomy and latitude. Wood and Middleton (1975) noted, "Where it meets with failure, it is modified in the direction of greater specificity and control, thus confronting the child with less uncertainty and a greater probability of some success" (p.190). Reiser and Takak (2014) supported this view because they noted that support allowed for completion of the task and allowed students to learn from experience. This idea of *supports* that assist student's progress in their learning is often referred to as scaffolding. Wood, Bruner, and Ross (1976) proposed this term when they referred to scaffolding as a process to help learners achieve a task they would not achieve otherwise. Scaffolding refers to when an educator breaks a project into discrete sections for a learner, which allows the learner to focus on elements of the task that the learner can solve on their own. Reiser and Tabak (2014) suggested that a "central idea in scaffolding is that the work is shared between the learner and some more knowledgeable other agent" (p. 45). We can relate the concept of a zone of proximal development to the makerspace environment. In the makerspace environment, the maker staff should act as guide more than infallible expert to allow students to reach beyond what they might achieve individually. Along with the proximal development zone, scaffolding may also prove beneficial in the makerspace environment by supporting the activities within the makerspace that would allow the student to reach their learning objectives faster.

Maker learning from a constructivist and constructionist perspective

Constructivism and constructionism are interrelated in that they share the belief that learning is a product of play, inquiry, and experimentation (Halverson & Sheridan, 2014). Seymour Papert's constructionism was inspired, in part, by the work of his mentor Jean Piaget (Blikstein, 2013). Ackermann (2001) noted that "integrating both views can enrich our understanding of how people learn and grow" (p. 1). The following section will look at how both theories potentially influence maker learning.

The importance of being creative and inventive, as Piaget argued, is evident in that: "The principal goal of education in the schools should be creating [individuals] who are capable of doing new things, not simply repeating what other generations have done; [individuals] who are creative, inventive and discoverers" (Duckworth, 1964, p. 499). Kurti, Kurti, and Fleming (2014) pointed out that makerspaces allow students to engage in hands-on and more personalized learning. The student is responsible for their learning and for exploring original ideas. The teacher becomes more of a guide and less of a maker expert. This type of hands-on learning, which engages the student in learning content and process conjointly, is a type of constructionist-based learning design (Halverson & Sheridan, 2014). In this model, the learner is at the centre of learning and develops knowledge through the creation process. The teacher plays a supportive role through advising and facilitating the learner's learning process (Anderson, 2008).

Despite the teacher's supporting role, they are still crucial in a making learning environment (Colegrove, 2017). The makerspace instructor must allow students to explore on their own and not answer too many of the students' questions. If they help the students too much, they will be seen as experts in the learners' eyes. This dependency will hold the student back and may result in the student not being able to surpass the knowledge of the instructor (Kurti et al., 2014a). This dynamic between students and educators dictates a significant component of makerspace projects.

Much like the dynamic relationship between educators and students, how technology operates in the maker movement is a crucial part of learning (Gershenfeld, 2008). Papert and Harel (1991) discussed that computers play a prominent role in constructionism because they provide individuals with creative freedom. The availability of computers and access to the internet allows for almost unlimited potential with respect to gathering information on any possible project or utilizing available resources effectively. In a more general sense, "technology allows students to do things at a level of complexity and sophistication impossible without a computer" (Clifford & Friesen, 2001, p. 39). Makerspaces and those participating in maker activities today have greater interconnectedness that did not exist before the Internet (Fourie & Meyer, 2015). Early maker enthusiasts were comprised of small communities centred around a specific interest (Dougherty, 2012; Tanenbaum et al., 2013). Papert (1999) commented that we now live in a digital world, and it is as important as reading or writing to become computer literate. He also noted that it is even more critical for students to use their digital knowledge to learn about everything else. Computer literacy allows access to a digital world that would not be possible otherwise.

Conceptual Framework

This study aimed to investigate how makerspace activities impact student engagement in learning in postsecondary education. Makerspaces are places where one learns by doing. This *doing* has garnered a lot of attention in educational literature over the years. Initially, doing can be linked to Dewey's (1938) "hands-on approach to learning," Piaget's (1956) constructivist experiential learning and, most importantly, Papert's (1999) learning by making constructionist views. The purpose of this conceptual framework is to help focus my research. Bloomberg and

Volpe (2012) commented that “a conceptual framework draws essentially on theory, research and experience and as such it is the structure, heuristic device, or model that guides your research” (p. 87).

My conceptual framework for this study is informed by the theories discussed in the previous sections and my own experiences as an educator working within a makerspace environment at Memorial University of Newfoundland. While Piaget’s (1956) theory of constructivism is useful for understanding the *learning by doing*, it does not get at the heart of a maker's essence. To understand the effects both constructionist and constructivist theories have on makers, one needs to compare and contrast the two schools of thought. As Papert (1999) pointed out, constructionists are focused on creating artifacts while constructivists are interested in the individual learner's learning process. With social constructionism, as it relates to making, the focus would be more concerned with the social environment or context (i.e., the social milieu) (O’loughlin, 1992) around the creation and building of artifacts within the makerspace.

When learners are engaged in the learning process, they are willing to undertake the process because of a goal or purpose; the process does not need to be entirely fun, attractive, or easy (Jenkins, Purushotma, Weigel, Clinton, & Robison, 2009). Makerspace projects and their concomitant pedagogical approaches have the potential to engage postsecondary students. Authors such as Blikestein et al. (2017), Peppler et al. (2016b), and Martinez and Stager (2013) contended that learning within makerspaces is strongly associated with Papert’s constructionism. The relationships among engagement, constructionism, maker, making, and makerspace are visible in Figure 1. In these proposed relationships, the outer ring represents the three major components of the maker movement (Peppler et al., 2016b) within education, which allow for creative experimentation. The outer ring includes the people (i.e., makers), the places (i.e., makerspaces) and the activities (i.e., the making). The inner circle represents the interaction among the dimensions and student engagement (Willms et al., 2009). Figure 1 also illustrates the interactions between the inner and outer circle, in that maker, makerspace, and making can play roles in the different dimensions of student engagement, such as social, academic, and intellectual engagement.

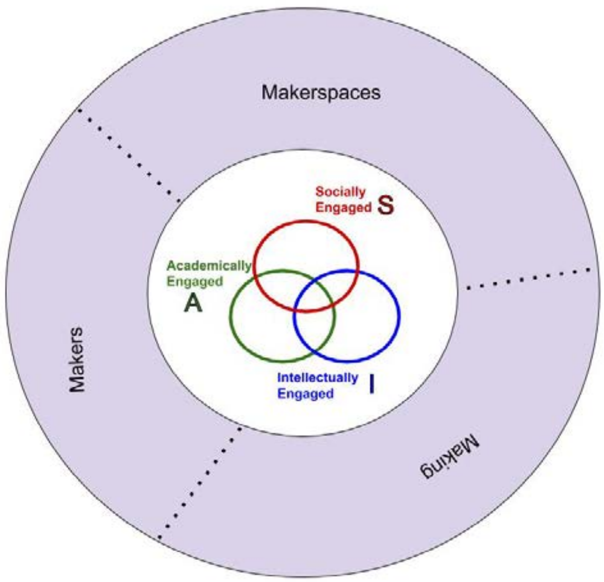

Figure 1. A conceptual framework for understanding how makers, making, and makerspaces impacted student engagement.

This framework has helped conceptualize my understanding of the existing literature and can guide and inform future research. For example, when observing students constructing artifacts for their classes within the makerspace, the framework provided me with improved insight into students' experiences and engagement levels.

Positioning the Study

There has been a growing number of researchers investigating makerspace in higher education, such as Davee, Regalla, and Chang (2015), Halverson and Sheridan (2014), and Wong and Partridge (2016). Most of the interest has focused either on innovation within the STEM disciplines (Peppler et al., 2016b; Wong & Partridge, 2016) or within the K-12 school system. Wong and Partridge (2016) suggested that the research conducted in higher education is focused mainly on American universities and does not account for other nationalities' educational systems. As higher education institutions introduce makerspaces, guidance in how to implement the movement is necessary. Martin (2015) and Wong and Partridge (2016) suggested that more research is required to understand makerspaces' roles within higher education better. Kurti et al. (2014a), Peppler et al. (2015) and reports from the California Council on Science and Technology (2016) acknowledged makerspaces' potential to engage students within higher education but provide no direct evidence linking engagement to makerspaces.

My study was designed to investigate student engagement and learning gaps when using a maker approach in higher education undergraduate courses. The study focused on three non-STEM courses at a Canadian university to identify how students learn within makerspaces. The study further determined factors that influence the nature of student engagement.

Chapter Summary

Through the literature review, I examined the concepts of maker, making, and makerspaces, including the maker movement's progression and the role of makerspaces in postsecondary education. Engagement and reflection were both defined and investigated regarding makerspace, including the impact of learning theories on the maker movement. The Chapter concluded with my proposed initial conceptual framework, developed from this literature review. In Chapter Three, I will present my research design.

CHAPTER THREE: RESEARCH DESIGN

This research study investigated how makerspaces in higher education engaged students and how making activities impacted learning outcomes in a postsecondary classroom setting. This chapter provides the rationale for using case study methodology and describes how the collected data was sampled, analyzed and presented. The study focused on three different undergraduate classes taught at a university located in Eastern Canada: two Education courses in the Faculty of Education and one Geography course in the Faculty of Arts. This chapter also includes discussions concerning ethical considerations, limitations, and delimitations of the research.

Rationale for Qualitative Research

This study was situated within the qualitative research paradigm and used a case study research methodology (Bloomberg & Volpe, 2012; Yin, 2014). Within the single case study, this dissertation references three case groups. According to Creswell (2012), "qualitative research is best suited to address a research problem in which you do not know the variables and need to explore" (p. 16). The main question that guided the research was: How do postsecondary students engage in learning through makerspace activities in non-STEM courses? The question arose from a problem and purpose, which was to better understand makerspace activities' potential to engage students. This question aligns with Creswell (2012), who stated that: "A central phenomenon is the key concept, idea or process studied in qualitative research" (p. 16). In this study, the phenomenon being studied is student learning engagement through making in undergraduate, non-STEM courses. Understanding the meaning of the phenomenon requires the researcher to ask questions to those experiencing the phenomenon and interpret meaning from those experiences (Merriam & Tisdell, 2015). Denzin and Lincoln (2011) suggested that "a qualitative researcher stresses the socially constructed nature of reality, the intimate relationship between the research and what is studied" (p. 8). Denzin and Lincoln (2011) identified that the word "qualitative implies an emphasis on the qualities of entities and on process and meaning that are not experimentally examined or measured (if measured at all) regarding quantity, amount, intensity, or frequency" (p. 9). Expressive information, such as a subject's beliefs, feelings, values, and motivations, can be captured through observations and recordings of the subject's actions rather than with numerical analysis.

According to Merriam and Tisdell (2015), the following four characteristics underpin qualitative research:

1. Qualitative research focuses on meaning and understanding (Denzin & Lincoln, 2011; Merriam & Tisdell, 2015). Merriam and Tisdell (2015) suggested that researchers are interested in how people construct their worlds and interpret and apply meaning to their experiences.
2. The researcher is the primary instrument for the collection and analysis of data. While observing and interacting with subjects, the researcher can react and respond to the stimuli they are studying (Merriam & Tisdell, 2015). Researchers can, for example, take data they just recorded and ask the subject clarifying questions.
3. An inductive process often requires that the researcher use observations, interviews and documents to build towards a theory or set of theories (Merriam & Tisdell, 2015). Denzin and Lincoln (2011) refer to qualitative researchers as bricoleur and quiltmakers in

that they must assemble individual pieces of data collected from a variety of materials in their attempts to make something whole.

4. Qualitative research often includes richly descriptive data that describes a phenomenon (Denzin & Lincoln, 2011; Merriam & Tisdell, 2015). While quantitative data is composed of numbers, qualitative data relies on words and vivid descriptions to convey the researcher's message. Qualitative research often includes quotes from participants and the researcher's field notes to support their findings (Merriam & Tisdell, 2015).

These four principles and the constructivist paradigm guided my research. As the primary instrument, I also sought to understand my research results. I did this by collecting data from interviews, surveys and observations and interpreting this rich, descriptive data. Constructivist or interpretivist paradigms attempt to gain understanding through the interpretation of the research participants' perceptions. (Denzin & Lincoln, 2011). Ontologically, I believe people build knowledge by interacting with others and through experiences. Epistemologically, I share the same viewpoint as Denzin and Lincoln (2011) that we "cannot separate ourselves from what we know" (p. 105). As Miles, Huberman, and Saldaña (2014) suggested, the researcher's role in a qualitative study is to observe and question participants over a prolonged time frame to better understand the phenomenon being studied. Thus, my role as researcher was to collect data through interacting with and observing students and analyzing the collected information to form a holistic view of the phenomenon to answer my research questions.

Case Study Methodology

In this study, I lean more towards constructivist traditions around case study; however, I have considered other authors' views in my discussion. Authors such as Merriam and Tisdell (2015) use a constructivist lens. Case studies are collected data from multiple participants, leading to multiple perspectives. The data is interpreted to be a culmination of these multiple perspectives. Conversely, Yin (2014) follows a positivist lens, believing there is one true reality. Before undertaking my research, I had experience with quantitative research in both my professional and educational backgrounds. Epistemologically, I used statistics to collect data and objectively answer questions. Ontologically, the answer I sought was dichotomous, and the results pointed to the best answer. During my doctoral studies, I began to shift my viewpoint of epistemology and ontology to more of a constructivist lens in relation to the theoretical framework of my study, while continuing to ground my research methodology in a positivist lens.

Bloomberg and Volpe (2012) "defined a methodology as the process of studying knowledge" (p. 28). While case study is considered a form of qualitative research (Denzin & Lincoln, 2011), Flyvbjerg (2011) suggested that empirical statistics and case studies have the potential to be complementary rather than on opposing ends of the methodology spectrum. Case studies are enduring, long-standing methodologies that span across social and science disciplines (Flyvbjerg, 2011). A case study is a form of qualitative research that focuses on individuals or groups. Merriam and Tisdell (2015) defined a case study as "an in-depth description and analysis of a bounded system" (p. 37). The binding refers to selecting a case for research based on criteria such as time, place, or group. Yin (2014) defined case boundaries according to "the time period, social groups, organizations, geographic locations. Or other conditions that fall within (as opposed to outside of) the case in the case study, understanding that the boundaries can be fuzzy" (p. 237).

Part of the confusion surrounding case studies is that the process of conducting a case study is conflated with both the unit of study (the case) and the product of this type of investigation. Freebody (2003) commented that case studies "focus on one particular instance of educational experience and attempt to gain theoretical and professional insights from full documentation of that instance" (p. 81). The phenomenon under review in this study is students' engagement, which will be explored within the context of makerspace learning activities across three undergraduate course settings. The phenomenon lends itself well to a case study and is an especially good choice for those researching technology and industrial education (Gomm, Hammersley, & Foster, 2000). This approach is also supported by Flyvbjerg (2011) as a good choice for a case study methodology because it focuses on the context concerning the environment being studied.

Merriam and Tisdell (2015) pointed out that case studies involve collecting data from the study over time, including collecting data from multiple sources. In my study, data was gathered from several sources, including interviews, surveys, and direct feedback from students and instructors.

One major challenge in this study was selecting appropriate undergraduate classes for analysis. Yin (2014) stressed the importance of choosing the right bounded system for one’s case (Yin, 2014). In this study, the three cases were selected from a number of undergraduate classes taught at the University. Bloomberg and Volpe (2012) stated that selecting a case (or cases) to study requires that the research establish a rationale for the purposeful sampling strategy and a clear indication of the case's boundaries. To establish adequate boundaries for this study, which is often a concern with case study methodology (p. 31), well thought out questions and well-defined boundaries were previously developed. In this study, the phenomenon being studied is student learning engagement through making in undergraduate, non-STEM courses. The learning through making was bounded in the following three ways: 1) The maker activity in the course occurred only in one semester; 2) All students were enrolled in an undergraduate non-STEM course, and 3) The study occurred on one campus in a Canadian university.

Research Settings or Context

The research focused on conducting makerspace activities in three selected undergraduate courses offered at a Canadian university. The courses that were part of the study included two Education courses in the Faculty of Education and a Geography course in the Faculty of Arts. These courses were selected as they are all non-STEM. The selected university's main campus is located within a major city in Eastern Canada.

Research Questions

The main question that guided the research was: How do postsecondary students engage in learning through makerspace activities in non-STEM courses? The following are two sub-questions designed to help inform the main inquiry question:

1. What is the nature of academic, social and intellectual student engagement when learning through making in non-stem course environments?

2. What factors influence or hinder the usage of makerspaces in non-STEM postsecondary course contexts?

Research Sample

Purposeful sampling was used to select participants for this case study. According to Palinkas et al. (2015), "purposeful sampling is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest" (p. 1). Purposeful sampling requires the researcher to select an area where they are able to observe the central phenomenon, which concerns makerspaces and student engagement in this situation. When choosing an area, one may choose a single site, a group, an individual, or several sites (Creswell, 2012). Creswell (2012) listed nine variations of purposeful sampling. Of the nine variations that Creswell (2012) listed, convenience sampling is most closely aligned to this case study. Convenience sampling is conducted when the researcher selects participants based on their willingness and availability (Creswell, 2012). Convenience sampling is a subcategory of purposeful sampling and occurs when the samples are selected based on specific parameters (for example, location, money, and availability) (Merriam & Tisdell, 2015). In this situation, selecting the cases in this study was based on the researcher's proximity to a post-secondary institution. In this study, three undergraduate courses were selected based on their availability. The main reason for choosing this university in Eastern Canada, over other, similar universities was that student and staff participants were easily accessible to me. I conducted this study in Eastern Canada as that is where I reside, and the university is the only university nearby. The city where I reside is also a considerable distance away from the next-closest university. The selection of courses within this university was dependent on the willingness and availability of professors. While I acknowledge that a random sample would be preferred, random sampling is often not a practical approach when dealing with a case study method due to population size and distribution. This challenge was due to the small number of cases associated with typical case study methods (Seawright & Gerring, 2008). Seawright and Gerring (2008) pointed out that while there is a potential for bias when not random sampling, the benefits outweigh the risks. A random sample of a petite sample size can cause problems for the researcher due to the substantially unrepresentative sample obtained. While launching studies in classes based on professor availability rather than an even distribution over departments is not an example of pure random sampling, purposive sampling goals will remain the same. The first goal was to choose a representative sample of the population, and the second was to choose based on useful variation on the dimensions of theoretical interest (Seawright & Gerring, 2008). The main criteria for this study was to select non-STEM courses taught at the undergraduate level. Due to the limited size (N= 75) of the sample population for this study, all those who filled out a consent form were chosen to participate in the study and were included in some or all of the data collection process.

Twelve instructors were identified as potential participants for the study. Learning Commons staff identified instructors who had expressed interest in working on projects with the Commons Makerspace. Like many universities, a Learning Commons is used as a learning resource for both students and faculty. The Learning Commons at this university has had a working relationship with many faculty members over the 14 years it has operated. Of those identified, there were four who agreed to participate in the study. This was reduced to three when one of the instructors withdrew before the study began. All instructors completed informed consent forms before the study began.

Data Collection Methods

The following data sources were initially chosen to inform the research question: 1) classroom observation, 2) focus group interviews, 3) individual interviews, 4) survey, and 5) documentation. The following section will include a description of the method, the strengths and weaknesses of each method, and an outline of the research plan. Multiple data collection methods, along with multiple sources, will allow for triangulation to occur, which will help validate the data (Bloomberg & Volpe, 2012; Creswell, 2012).

Classroom Observation

Observation is common in many types of research, including case studies (Merriam & Tisdell, 2015). According to Creswell (2012), "observation is the process of gathering open-ended, firsthand information by observing people and places at a research site" (p. 214). One advantage of a case study is that it occurs in a natural setting. This setting allows a researcher to directly observe the phenomenon in a real-world setting (Creswell, 2012; Yin, 2014). Observing and recording students at the makerspace allowed the researcher to see firsthand how students were engaged in the maker process. There were 22 hours of observations conducted in classrooms, labs, and at the makerspace in which maker activities took place. As the researcher, I observed students and each class's instructors for the three courses using an engagement instrument. Participants were selected from those students who completed a consent form.

I randomly selected participants using a blind random sampling procedure. All participants' names were entered into an MS Excel spreadsheet and assigned a number. Then, using the Microsoft Excel random function generator, I chose which participants to observe in each class.

I observed the selected groups while students worked on their maker activities. I took field notes while observing the students and instructors, and recorded dates and times. Initially, I planned only to observe and not directly engage with students or instructors. However, I did briefly interact with students during classes to provide context when necessary. Additionally, direct observation and the associated field notes allowed me to confirm what we later discussed in interviews (Yin, 2014).

Observing the students and their instructor in each of the three courses allowed me to see what was happening in real-time. In addition, observing participants can help contextualize the observed case (Yin, 2014). One potential problem, however, was that observations were time-intensive and selective by their very nature. Another consideration was the potential for observation bias, whereby participants tend to be on their best behaviour when they know they are being observed. For this study, I used several instruments (Daniels, Friesen, Jacobsen, & Varnhagen, 2012; National Survey of Student Engagement, 2017), and several academic professionals from my university to help inform my observation protocol. The protocol provided a means to examine student groups, their interactions, and their level of engagement. The observations focused on the classroom environment, student on and off-task activities, and instructional practices. Using this Classroom Observation Protocol (see Appendix A), I randomly selected specific groups or individuals (who provided informed ethical consent) to observe while participating in makerspace activities. Those participating in maker activities used the Commons Makerspace, located at the university's main library and in a classroom where maker activities took place. For some of the projects, groups and individuals booked the space by appointment to allow a makerspace staff member to prepare for the visit. Those selected scheduled times within the makerspace; during that period, the researcher observed and took field notes of the group or individual working on their projects. In other situations, the researcher observed students and instructors in scheduled classes, during which maker activities were conducted.

Individual interviews

According to Creswell (2012) and Yin (2014), interviews are a common observational technique used in qualitative research. Initially, the prospective interviewees were purposefully selected through using the same rationale that was employed for selecting focus group participants. Merriam and Tisdell (2015) suggested that there are no firm guidelines used to facilitate the selection of the correct number of participants. Baker, Edwards, and Doidge (2012) suggested that the number of interviews selected for a study depends not on how many, but on whether the research question can be answered. For this study, all participants who agreed to be interviewed were selected from each class. If the number of willing participants proved disproportionate among the classes, the initial plan was to consider each class and add more interviews later should they be required. I decided to interview all 17 participants as this was a reasonable number based on the resources (i.e. time and interview space availability) and my availability. Sargeant (2012) also commented that "the number of participants depends upon the number required to inform fully all-important elements of the phenomenon being studied" (p. 2). In this study, 11 students and six instructors/teaching assistants were interviewed. Interviews are commonly used in qualitative research and can provide the researcher with rich, descriptive data (Bloomberg & Volpe, 2012). A semi-structured format was used, allowing a more focused exploration of the topic (Bloomberg & Volpe, 2012). The semi-structured interviews were guided by a list of questions that offered the flexibility for interviewees to elaborate and for me to explore issues raised during the interview (Merriam & Tisdell, 2015). In qualitative research, interviews usually are set up with a participant or participants who are asked general, open-ended questions, which the researcher records. (Creswell, 2012). Asking open-ended questions is consistent with a social constructivist worldview, allowing the interviewee to create their own opinions and answer questions in their own words (Creswell, 2012).

Individual interviews were conducted with selected students and instructors from each course. There were 11 students and six faculty and staff interviewed for the study across the three courses. Interviews typically lasted for 30 minutes for students and 45 minutes for instructors and teaching assistants. All interviews (refer to Appendix B & C) except one were conducted in-person in the same conference room located in the university's main library. The remote interview was conducted via Google Hangouts with Henry, the TA for Education I. Each interview was recorded on a digital recorder with the participant’s consent. One advantage of interviewing was that it allowed the researcher to ask targeted questions, enabling the researcher to gain insight into what the interviewee said (Yin, 2014). Factors such as personal perceptions and attitudes were observable and recordable in this setting (Creswell, 2012; Yin, 2014). As the researcher, I needed to create a comfortable atmosphere for the participants when conducting an interview. Should the interviewee feel pressured, this might bias the data by way of reflexivity. Reflexivity is defined as the interviewee not answering honestly; instead, they tell the interviewer what they want to hear (Yin, 2014; Creswell, 2012).

Focus Groups

During the study, I had the opportunity to conduct 17 interviews with both instructors and students. At the start of the study, I had planned to conduct three focus group interviews, one for each class. Unfortunately, those who were individually interviewed made up most of the participants who consented to attend a focus group. At the end of their interviews, participants were asked about their availability for a focus group session. The majority declined, citing being too busy with school and questioned how much more new information they would bring to the focus group. Group interviews, or focus groups, would have allowed me to collect information from an assembly of individuals answering open-ended questions (Creswell, 2012). The motivation behind conducting focus groups alongside interviews was to enhance the findings' reliability and to ameliorate the interpretation of individual interviews from the vantage point of a group context (Lambert & Loiselle, 2008).

Survey

One advantage of a survey is that it is easy to disseminate, manage and is relatively unobtrusive to the participant (Fowler, 1993). Based on the researcher's previous experiences with surveys, it was initially estimated that students and instructors would complete a total of 20 online surveys in the three classes. The survey was anonymous; therefore, it was unknown if survey participants overlapped with interview participants. It was estimated that surveys would take 15 minutes to complete. During the study, there were 19 online surveys completed; instructors and teaching assistants completed five. Two surveys were designed, one for instructors and another for students. The surveys were sent out to all individuals who signed consent forms at the end of the semester via the email address they provided. By this time, students had received their marks and had been given feedback on their projects. Surveying participants at the end of the course allowed the researcher to collect summary data about the participant's experience as it was still unfolding (Merriam & Tisdell, 2015). For example, at this point in their classes, students had submitted their maker project and had time to reflect on their makerspace experience. In addition, this also allowed me to add any supplementary questions that arose from the interviews and during the observations. For example, during the interviews, students' views seemed to vary depending on whether they had any previous experience with the technology they were using. Therefore, a question about their previous experience, if any, was included in the student survey. Because surveys are less time-intensive to administer and complete (Fowler, 1993), all individuals who signed consent forms (n=35) in the maker project were eligible to complete the survey (refer to Appendix D & E).

As Bloomberg and Volpe (2012) pointed out, one drawback to conducting a survey is that it has limited value in discovering social relationships and is often deficient in providing the study's broader context. Creswell (2012) indicated that surveys are an acceptable method of collecting data. Creswell explained that closed-ended questions might help support specific concepts. The survey included open-ended questions, allowing the participants to share their personal feelings about their experiences making, which created greater flexibility for respondents (Bloomberg & Volpe, 2012). For example, in this study, the survey allowed me to potentially reach additional participants, have participants respond anonymously, and get participants' opinions once the semester concluded.

Documentation

Documentation is an essential method of data collection within a case study (Yin, 2014). Creswell (2005) stated that "documents consist of public and private records that a qualitative researcher obtains about a site or participants in a study" (p. 219). Yin (2014) suggested that a researcher should embark on an extensive document search before undertaking any fieldwork. In this study, lesson plans, planning documents, and rubrics related to the makerspace activities were requested from the instructors, and an assessment of the previous course evaluation forms was conducted. These course evaluation forms are made available to all students attending classes at the university. While the program's information helped provide some context, the documented classroom maker activities provided a historical record of how the students view the program.

Documentation provided a stable set of data that is specific and independent of the study. The majority of the course evaluations collected were filled out prior to the students beginning their projects and, therefore, were unobtrusive to the study participants. (Yin, 2014). Public documentation and personal records are often the most common forms of collected documentation (Merriam & Tisdell, 2015). In the study, Public CEQs (course evaluation questionnaires) were collected, and documentation specific to each course (e.g., project descriptions) was collected. Documentation can be difficult to find and may provide an incomplete record. This incomplete record may be due to selective publication. Furthermore, a researcher needs to be aware that the record may reflect the author’s bias (Yin, 2014). For example, details from minutes of a program meeting may omit relevant information that may reflect negatively on the author.

Data Collection Participation and Timeline

Student participation within each class was on a volunteer basis. Due to the university's regulations regarding research of students in a classroom setting, I was only allowed 10 minutes in each class to explain my research project. The date and time of each talk was dependent on when the making assignment was scheduled in each course and the availability of classroom time, which was at the instructor's discretion. Each presentation followed a similar format: I explained my research, handed out a consent form and then answered any questions the students had. Before I attended the classes, each instructor completed their consent form. Students could participate in observations, surveys, interviews, focus groups, or in examining their final projects. A total of 27 out of 75 students gave informed consent to participate in the study.

Data collection began at the beginning of the 2018 Fall semester and ended a few weeks into the 2019 Winter semester. Data for this study were collected sequentially. Data from observation were gathered first, followed by interviews, and finally, a survey (Figure 2). Due to the fact that data were collected sequentially, data collected later helped explain or elaborate on previously gathered data (Creswell, 2012). For example, questions may be raised during interviews that may be put forth in the survey to better understand the larger group.

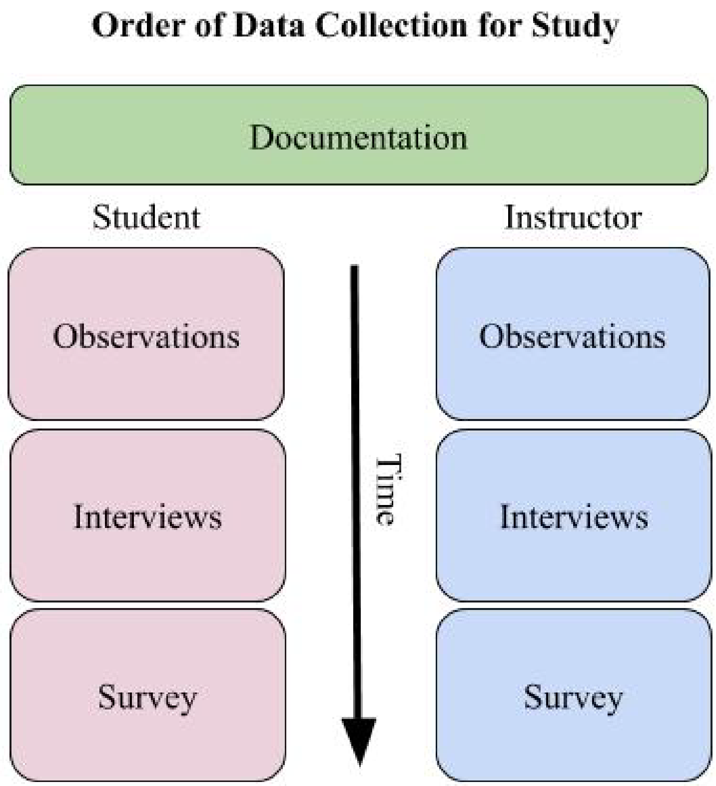

Figure 2. Order of data collection for students and instructors over one Semester

Data Analysis Methods

Thematic analysis was used to analyze the data gathered from the interviews, observations, and documentation. Boyatzis (1998) broke down thematic analysis into three steps: recognizing a pattern, classifying or encoding the pattern, and finally interpreting it. Braun and Clarke (2006) identified six thematic analysis phases: familiarizing oneself with the data, searching for themes, reviewing themes, defining and naming themes, and producing a report. In both cases, the importance of recognizing themes or patterns and interpreting them is at the forefront. The process followed in this study will retain the guidelines of both authors.

The first stage of data collection included the preparation of the extracted data. One example is taking transcripts from interviews and transcribing the information into data that can be analyzed. This process included editing to ensure the information was consistent and legible. Editing also helped organize the data to make subsequent analysis more manageable. Transcription and editing were done manually by me. Field notes from observations were transcribed similarly. The data was broken down into themes through a process called hierarchical analysis (Saldaña, 2015). For example, coding stripes and highlighting were used to associate data with research questions related to the study (Figure 3). This approach resulted in a detailed transcript for each of the study's interviews (Saldaña, 2015). This stage required reading and re-reading the data for completeness. During this stage, initial ideas and impressions were also noted (Braun & Clarke, 2006).

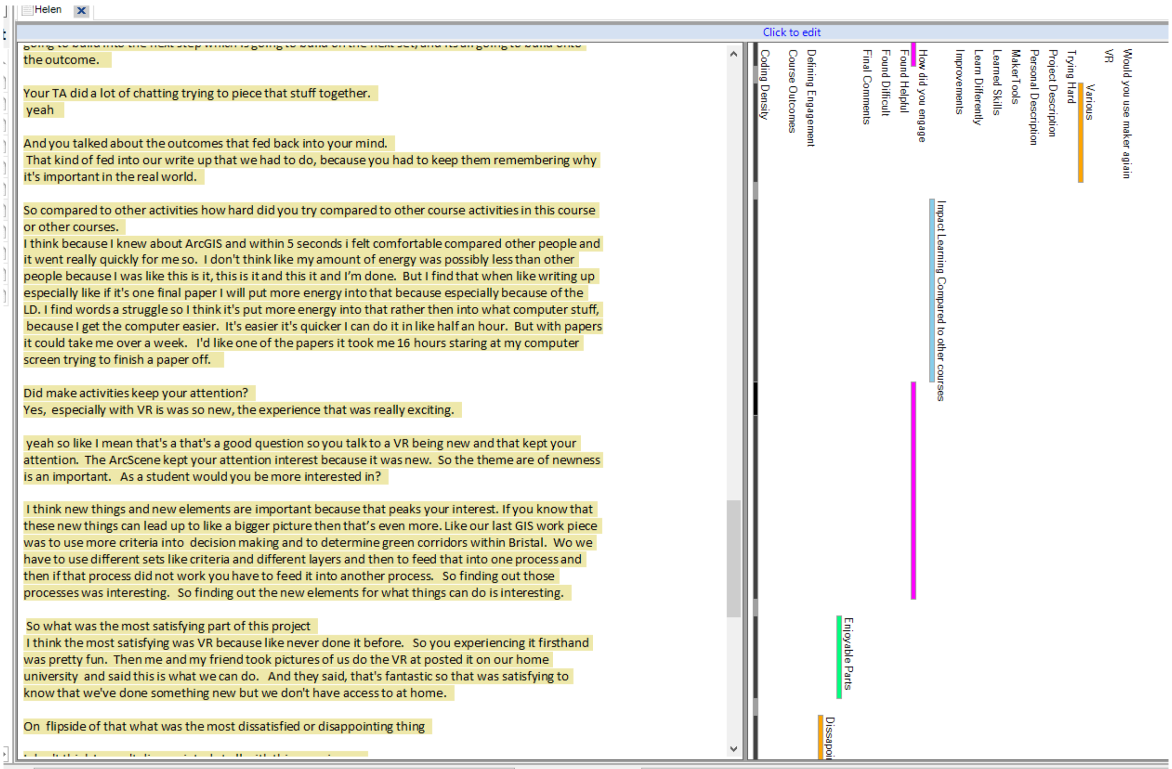

Figure 3: Example of Coding in NVivo

Qualitative data analysis software was considered and eventually adopted. Qualitative data analysis software can make the sorting of data easier and automate some of the necessary tasks (Bloomberg & Volpe, 2012). There are drawbacks to using such software, so consideration was given to the software's cost and learning curve.

Information was then entered into the NVivo software. The information was then re-coded using an iterative approach. Once the data had been reduced and was viewable, the final step was to draw conclusions based on the data, with subsequent verification of the data and the conclusion's validity. Techniques used to support this process included triangulation and inter-rater reliability.

Coding was also utilized to process qualitative data. The coding method is used to make sense of textual data by breaking it down and categorizing the data into a few themes (Creswell, 2005). Boyatzis (1998) "refers to coding as a list of themes; a complex model with themes, indicators, and qualifications that are causally related; or something in between the two forms" (p.4). The term code is defined as "labels used to describe a segment of text or image" (Creswell, 2005). In other words, codes can be words or phrases that identify to the researcher a critical attribute that was discussed in a transcribed interview. Simply put, coding is the transitional process of sorting the data that lies between data collection and more extensive data analysis (Saldaña, 2015). The process of open or first cycle coding is the first step in coding; it involves categorizing collected information (Creswell, 2012; Saldaña, 2015). This process involves taking the entire data set and breaking it down into manageable pieces for subsequent comparisons. First cycle coding involved reading the passages and adding descriptive codes. This can be achieved by simply writing descriptive words or short sentences in the margins next to each passage (Saldaña, 2015). One example of this is to take all the information from the transcripts and put that information into categories for later comparisons. Figure 3 shows the first attempts at coding in NVivo, where descriptive words were associated with specific text passages, representing questions asked during the interview. Creating categories was done iteratively, going back and updating as necessary. The final result should be a set of meaningful data that demonstrates relationships and connections among the data (Creswell, 2005).

Once open or first cycle coding was completed, and the categories were built, I needed to conduct axial or secondary coding. Creswell (2005) stated that "axial coding puts the data back together in new ways by making connections between categories. Axial coding involves identifying a single category as the central phenomenon and exploring its relationship to the other categories" (p. 423). Axial coding involves taking a second look at the original categories and searching for links and any additional themes that may arise. This axial coding created a narrative that connected the previously created categories (Creswell, 2005; Saldaña, 2015). These categories were then developed into themes or concepts that helped shape and formulate my theories (Creswell, 2012).

Saldaña (2015) discussed that one must be careful not to summarize or condense the coded data. The goal of coding is to instead reduce it to a point where it can be organized appropriately. Another key point is that the coding process is an iterative one, where it may take several iterations of coding for a complete picture to emerge from the data (Saldaña, 2015).

Once the data was sorted and coded (Figure 4), the next step was to organize and present the data in a meaningful way. Network diagrams were one method chosen for its ability to show relationships between ideas contrasted in the study. Commentary regarding the data will come later in Chapters 4 and 5.

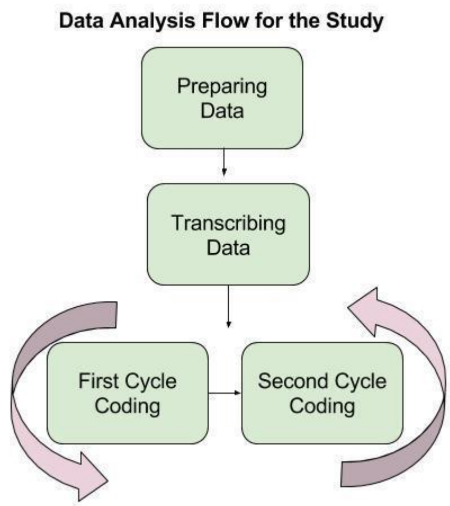

Figure 4. Data Analysis Flow for all Data Collected in the Study

In addition to thematic analysis, other forms of analysis were conducted for surveys and documentation collected during the study. For the survey, descriptive statistics were developed to help visualize the data. Examples of these statistics included the frequency of engagement level for both students and instructors who participated in the survey or the number of participants who would consider taking part in a maker style project again. For the document analysis, the type of documents I collected were course syllabi, project descriptions and course descriptions. Documents collected and read through were included within the analysis. For example, project descriptions were used to provide details on the types of projects, and class syllabuses were used to determine the times and dates of classes.

Integrity of the Study

Integrity must be maintained in all aspects of data collection and analysis of qualitative research (Bloomberg & Volpe, 2012; Creswell, 2012; Given, 2008; McKenney & Reeves, 2012).

Integrity in the researcher and their methods is characterized by transparency and honesty. Integrity rejects intentional deception. Ethical research principles demonstrate integrity by ensuring the researchers have informed consent from participants, do not harm participants and accurately represent participants' views (Given, 2008).

Integrity within qualitative research encompasses the researchers' honesty and transparency, and it is viewed as a continuum from the design stage through research collection, analysis, and reporting (Given, 2008). Through these stages of research, the researcher must be aware of potential moral implications with respect to the participants and responders and potential moral implications regarding the interpretation of their results. As qualitative research can be messy and unpredictable, researchers may not anticipate every possible outcome, including those with immoral implications (Given, 2008).

Integrity and trustworthiness are essential in ensuring that the research has repeatable findings. If done correctly, two independent researchers should be able to produce comparable observations if studying the same phenomenon (Bloomberg & Volpe, 2012). However, due to the subjective nature of qualitative data, this often does not happen. Consistent data collection methods help ensure consistent and reliable results. (Creswell, 2012). Yin (2014) suggested that the following four principles should be followed to keep data valid and dependable: using multiple sources of evidence, creating a case study database, maintaining a chain of evidence, and exercising care when using data from electronic sources.

In this study, multiple methods and sources were used to collect data from the studied cases. Interviews allowed both the researcher and the participants to ask or answer questions about the study in person. The semi-structured interviews allowed me to inquire about areas of interest and follow up for clarification. The study also included a survey that allowed participants to add additional information; these were distributed after the observations and interviews were conducted.

Once the first principle, using multiple sources of evidence, was completed, Yin's (2014) second principle was used to create a case study database. Keeping a case study database allows the researcher to separate the data collected from the case study report. A well-organized case study database allows for cross-references of evidence (Darke, Shanks, & Broadbent, 1998). A well-organized database allows other researchers to review the data or conduct a separate study involving secondary data analysis (Yin, 2014). The case database was comprised of a combination of my observations, field notes derived from my observations and interviews, as well as case study documents collected while conducting the study (Yin, 2014). Case study documents included lesson plans, rubrics, and course evaluation forms. The case study database was planned before data collection and was frequently updated throughout the study (Darke et al., 1998). In this case, the NVivo was used to store all data collected from the study.

The purpose of Yin's third principle (2014) is to maintain a chain of evidence within the study. In this study, building a chain of evidence included coding to identify patterns in work and creating casual network diagrams (Darke et al., 1998). Creating a chain of evidence allows an external observer to trace the steps they have taken to reach their conclusion (Yin, 2014). Yin (2014) suggested that "the external observer should be able to trace the steps in either direction." (p. 127). All coding was done within the program NVivo, which included transcribed interviews, field notes, surveys and documents. A series of timestamped backups of NVivo was also stored, which shows a progression in the study's coding. To help increase the research's dependability, an academic journal was maintained during the study. Noble and Smith (2015) suggested that maintaining a reflective journal can enhance qualitative research credibility. In addition, journaling can also support the study's auditability, as it offers a written record of the researcher's questions and assumptions (Bloomberg & Volpe, 2012; Creswell & Miller, 2000; Merriam & Tisdell, 2015; Noble & Smith, 2015). Bloomberg and Volpe (2012) discussed how using research strategies such as triangulation, journaling/reflexivity and auditability also contributes to the confirmability of research.

The fourth principle proposed by Yin (2014) has to do with exercising care when using data from electronic sources. Yin pointed out that the amount of information available electronically can be overwhelming. To deal with this, Yin (2014) recommended setting time limits on how long is spent investigating various sites. In this study, the number of CEQs was limited to the courses included in the research. Furthermore, CEQ review was limited to the last ten years. Yin (2014) also warned about cross-checking sources with websites and social media sites. When looking at these sites, one has to be aware of who is posting, how often they contribute to a conversation, and the incompleteness of their arguments, as a specific author can dominate conversations with their views (Yin, 2014). In this study, CEQ review was not cross-referenced with other sources, such as ratemyprofessors.com.

Another common strategy for ensuring internal validity is member checking (Bloomberg & Volpe, 2012; Merriam & Tisdell, 2015). The process of member checking involves documenting what was said during interviews and feedback sessions, and then returning to the participants to verify the documents' accuracy. The researcher can then fine-tune the documentation to reflect the event's participants' experiences (Merriam & Tisdell, 2015). This redundancy allows for the researcher to communicate to the participant and allows the participant to clarify anything that may be incorrect or misrepresented (Merriam & Tisdell, 2015).

Trustworthiness

According to Lincoln and Guba (1985), to achieve trustworthiness in qualitative research, one must establish four trustworthiness components. The four components of trustworthiness are transferability, credibility, confirmability, and dependability. In the following section, I will discuss the four components and how they impacted the study.

Transferability

Transferability refers to the ability of the conclusions and findings of a study to be transferable to other situations and contexts (Merriam & Tisdell, 2015). Merriam and Tisdell (2015) pointed out that there is some debate as to who is responsible for the transfer of data from one context to another, with some who view it as the reader's responsibility and not the researcher of the study. Due to the nature of qualitative research, transferability can prove challenging. Part of the issue is in determining how to replicate the same conditions as the original study (Bloomberg & Volpe, 2012; Miles et al., 2014). To increase the study’s transferability, detailed descriptions of the data collected is vital. Bloomberg and Volpe (2012) suggested that it is important to capture detailed descriptions from participants in the form of such things as interviews, field notes, and documents during the study. Lincoln and Guba (1985) also supported this view and suggested that thick and rich data collection will allow other researchers to assess similarities between studies. This researcher conducted extensive interviews with participants and conducted 18 hours of observations and field notes to support this.

Credibility

Credibility refers to the confidence placed in the findings of research. The research findings' credibility is based on how correctly the data was interpreted from the participants' original views (Korstjens & Moser, 2018; Lincoln & Guba, 1985). To address credibility issues, I undertook the following based on Lincoln and Guba's (1985) recommendations with respect to improving credibility. Member checking was conducted, which involved allowing participants to review the information collected on their participation (Bloomberg & Volpe, 2012). I conducted member checking with participants in the study. I reached out to students and instructors, and those who responded were shown the transcripts which corresponded with their involvement in the study so they could check for accuracy. As these were directly transcribed from audio, no significant issues were raised by the participants. Peer debriefing was also done with one of my colleagues within the university to validate transcripts and methodology.

Finally, I used triangulation. This study used multiple sources of evidence to collect data, including interviews, observations, and surveys. In qualitative research, triangulation refers to collecting and analyzing data using a multimethod approach (Given, 2008). Should multiple methods have the same conclusion when using triangulation, there is a greater likelihood of it being accurate (Denzin & Lincoln, 2011). Bloomberg and Volpe (2012) noted that triangulation is used to reduce the likelihood of misinterpreting analyzed data. To be validated, case study research should present multiple sources of evidence (Creswell, 2012). For example, this study looked at instructors and students with the idea that the evidence collected should come together in such a way as to converge (Yazan, 2015). Triangulation is also done by collecting multiple data sets through different methods, such as observations, interviews, focus groups, surveys, document reviews, and incident reports (Creswell, 2005).

Confirmability

Confirmability focuses on the study's findings and how they should not be motivated by the researcher's bias, motivations and self-interest, but instead be shaped by the participants (McKenney & Reeves, 2012). Confirmability reflects the need to ensure that the interpretations and findings match the data. That is, no claims are made that the data cannot support. Confirmability can help clarify how the researcher's interpretations were derived from the collected data (Bloomberg & Volpe, 2012), such as how major themes were derived from interviews, observations, surveys and observations. Another way to verify confirmability is through the creation of an audit trail of the research. An audit trail confirms the process and the produced results (Cohen, Manion, & Morrison, 2013). In this study, parts of the audit trail include describing the coding process and the produced results, giving examples of the coding process, and providing a rationale regarding the developed themes.

Dependability

Dependability refers to the researcher's findings and how stable they are over time. The research steps that were taken throughout the study should be transparent. This can be achieved through describing the process followed during the research study (Korstjens & Moser, 2018), which, like confirmability, maintains an audit trail of how data was collected. While confirmability is concerned with neutrality, an audit trail can demonstrate that the researcher is following best practices for a specific research design. For example, during the study transcriptions of interviews, copies of surveys and coding notes were all maintained. These records could be used to perform a dependability or confirmability audit.

Ethical Considerations

In any academic study focused on the observation of applicants, the researcher must be aware that they can harm participants. Therefore, researchers are morally obligated to research in ways that reduce the potential for negatively impacting those involved in the research process (Bloomberg & Volpe, 2012). How valid and reliable the study depends on how ethically the researcher has conducted the study (Merriam & Tisdell, 2015).

Before the study began, an ethics application was submitted to the Conjoint Faculties Research Ethics Board (CFREB) and was approved on July 31, 2018. The CFREB covers research directly related to the field of education. To apply for the CFREB, a graduate student must complete a Tri-Councils' Course on Research Ethics (CORE) (University of Calgary, 2015). This course was completed well in advance of the ethics submission. Based on the Panel on Research Ethics Consent process, participants' recruitment within the study required voluntary consent from each participant. In addition to the University of Calgary's ethics application, ethics approval was also obtained from the university where the study would take place. The ethics process was similar to the University of Calgary’s in that an ethics application needed to be submitted to the Interdisciplinary Committee on Ethics in Human Research

(ICEHR) and required the completion of the Tri-Councils' Course on Research Ethics. The university granted approval on August 16, 2018.

Delimitations

The study has three delimitations. First, the study was delimited to three undergraduate courses within the main campus at the Canadian university where the study would take place. Within the selected non-STEM classes, participants were chosen from those participating directly in makerspace projects. Second, students within this pool were delimited based on their voluntary response to be interviewed. Third, in addition to students, the instructors for each course were also interviewed. Selection of each course was based on the instructor's willingness to participate in the study. Data collection occurred primarily in the 2018-19 academic calendar year, which runs from September of 2018 to August of 2019.

Limitations

This study has four limitations. First, one of the criticisms of case studies is that the findings are not always easy to generalize (Gomm et al., 2000). In response to this, Bloomberg and Volpe (2012) pointed out that generalization is not the focus of qualitative research. Qualitative research is instead more concerned with how findings can be transferred to similar contexts or settings as those found in the initial study. Potentially, transferability allows for the findings and insights discovered during a study to be applied to other instances (Bloomberg & Volpe, 2012; McKenney & Reeves, 2012; Merriam & Tisdell, 2015; Miles, Huberman, & Saldaña, 2014). A good case study will not claim to generalize beyond what it is studying from a case study perspective. Instead, it will focus on genuinely understanding the case itself and its uniqueness (Richards & Morse, 2013). I expect the collected data and their findings to apply to other institutions working in similar environments, of which there are several.

Second, choosing the cases to be analyzed is a critical aspect of case study research. Flyvbjerg (2011) pointed out that poor selection choices may create bias through overstating or understating the relationships one is trying to study. I conducted all interviews, observation, surveys, and analysis in this study. Because the researcher is the sole instrument conducting the research in this case, it can lead to potential bias. For example, the human instrument may bias the research through how they ask the questions in an interview setting, or through nonverbal cues that may inadvertently affect the results (Merriam & Tisdell, 2015). There was no choice in the selection of cases or participants due to the limited number of available options. Instruments used for interviews, surveys, and observations were informed by other instruments and academic scholars.

Thirdly, the researcher was also aware of the potential issues related to reflexivity. Reflexivity does not only impact participants in a study, but it can also affect the researcher. From a researcher's perspective, there must be some awareness regarding the role reflexivity can play (Korstjens & Moser, 2018; Merriam & Tisdell, 2015). Probst and Berenson (2014) suggested: "reflexivity is generally understood as an awareness of the influence the researcher has on what is being studied and, simultaneously, of how the research process affects the researcher" (p. 814). To help maintain awareness throughout the study, I kept a research journal that allowed the researcher to re-read and reflect on issues such as bias during the study. This allowed me to capture my experiences, assumptions, insights and questions during the study (Bloomberg & Volpe, 2012).

Finally, another major limitation and, at the same time, a benefit that is associated with case study methodology is the amount of data available for collection. For example, in this study, I have collected data by ways of interviewing, observing and conducting surveys. With only one researcher with limited resources, the case study is limited by the amount of data that can be collected, transcribed, and analyzed (Stake, 2005). Due to the amount and the potential range of data sources, Merriam and Tisdell (2015) warn that "the case study researcher can be seriously challenged in trying to make sense out of the data" (p.233). The researcher must be aware of the limitations of a restricted project scale and must ensure that the questions asked the participants are well defined and purposeful.

Role of the Researcher

I have been involved in adult education since graduating from the University of New Brunswick in 1997. My teaching experience ranges from teaching first aid courses in the Canadian Army Reserves to facilitating software programming courses in Visual Basic for a multinational technology organization. For the last 15 years, I have been working at the university in which the study was conducted. While at the university, I have had the opportunity to observe the institution from the lens of an administrator, an instructor, and a researcher. The majority of my time at the university has been spent as an administrator of student computing. A significant aspect of my role in this capacity has been managing our university Commons, located at the Main Library. Over time, I have expanded the available services offered to students, which include Information Technology (IT) tutoring services and software application support. Recently, I led a project to expand the Commons by adding a Makerspace. This project, and my course work at the University of Calgary, ultimately pointed me in the direction of my dissertation topic related to makerspaces in a postsecondary setting. While doing my coursework, my professors frequently told me to choose a timely and exciting topic. Tracy (2010) suggested that good qualitative research is timely, interesting, significant and can be influenced not only by a theoretical perspective but also by societal or personal events. As a natural tinker, this research topic allowed me to combine one of my passions with work and research.

During our makerspace project at the university, I had the opportunity to bring makerspaces to the classrooms of three undergraduate courses. These pilot projects were conducted in the winter semester of 2017 and were in the fields of Education, Arts, and Human Kinetics. Conducting these pilot maker projects gave me insight into my study's potential progression. Merriam and Tisdell (2015) support the idea, as they suggest teachers would be reluctant to engage in new activities should they not have some level of confidence that the activity would be successful.

As a researcher, it is important to be aware of potential biases, and measures should be taken to mitigate them (Creswell, 2012; Miles et al., 2014). One example of partiality is personal bias. It has the potential to present itself in many forms, such as "the researcher's personal agenda, personal demons, or personal 'axes to grind,' which skew the ability to represent and present fieldwork and data analysis in a trustworthy manner" (Miles et al., 2014, p. 318). I recognize that conducting my study at the university, a place where I both teach and work, could engender biased analysis. To address this, chosen courses were at a different campus and in different departments from where I teach. To help with my objectivity, I selected unbiased, informed questions posed by sources such as the national survey of student engagement (NSSE).

Creswell (2012) recommended choosing an instrument that has shown to be reliable in the past. In my case, I chose triangulation, an observation instrument (Daniels et al., 2012) recommended by S. Friesen, a member of my supervisory committee. Through collecting multiple sources of evidence, triangulation is possible, which increases the validity of the data and research (Miles et al., 2014; Yin, 2014). Furthermore, complementing its capacity to reduce bias, triangulation offers the researcher a degree of inter-rater reliability. Inter-rater ability is the process of peer-review. Allowing someone else to have a second look can help reduce potential bias that the researcher may unknowingly bring to the research (Bloomberg & Volpe, 2012). In this study, a colleague within the institution was asked to review and code a student interview.

I acknowledge that choosing to conduct a case study at the university where I work has the potential to create bias in my research. However, by being aware of those biases and planning for them, I minimized the risk of allowing biases to negatively affect my research (Merriam & Tisdell, 2015). A qualitative case study can be as rigorous as quantitative research (if done correctly) (Flyvbjerg, 2006), and has the added benefit of allowing the researcher to get close to the research. As someone who works in this space, I was able to get close to the research and this intimacy informed my decisions regarding what I should study and how I should study it.

Chapter Summary

With the rise in popularity of makerspaces in higher education, more students will undoubtedly have greater exposure to learning through maker activities. In my research, I have investigated three undergraduate courses with a case study methodology to answer key questions regarding student engagement in learning within maker contexts in non-STEM course environments. In Chapter Four, I present the study's findings and investigate some of the major themes that arose from the data that was collected.

CHAPTER FOUR: FINDINGS

Three different classes provided data for this single case study. Each class was completely autonomous, and instructors had no contact with one another. Similarly, the maker activity undertaken for each class was unique. This Chapter describes each class, the students and instructors who participated in each activity, and finally the prescribed maker activities. Next, I outlined the common themes that emerged from the studied classes. Themes were supported by data collected from observations, surveys and interviews during the study. The following themes were identified by case group:

- Geography I: the novelty of the experience, and the experience of instructors/TAs.
- Education I: the experience of the instructor, groupthink, moments of inspiration and communication.
- Education II: working as individuals, the experience of the instructor and the complexity of tasks.
- Common themes across all classes: students' perceptions of how they learned, perceptions of engagement, attitudes towards learning, and experience around engagement.

Themes per class and across the case are discussed in detail in this Chapter.

Overview of the Participation in the Study

Maker activities for Education II and Geography I occurred at the university's centrally-located Learning Commons housed at the main library. Maker activities for Education I occurred in a classroom in the Faculty of Education. This Education classroom was equipped with all the necessary maker technology and material. Table 1 highlights the differences between each course in terms of time, format, and structure.

Table 1

Format of Maker Projects Per Course

	Time	Format	Structure
Education I	4x4 hour sessions	Groups of 2/3	Semi-Structured
Geography I	1x3 hour session	Individual	Highly Structured
Education II	Over the semester (13 Weeks)	Individual	Open-ended

With the data collection, two surveys were sent to students and instructors after the completion of each interview. There was a response rate of 54%, for a total of 19 responses, which were comprised of 14/28 from students and 5/7 from instructors. In this chapter, I present the results for both students and instructors/TAs separately. From September to December, approximately 18 hours of observations were conducted over that time. Additionally, a total of 17 interviews were conducted. For the 11 student interviews, four were from Education I, two from Education II, and five from Geography I. There were six instructors/TAs among the interviewed participants: two instructors from Education I one instructor from each of Education

II and Geography I. as well as two TAs who worked for the Makerspace in both the Geography I and Education II classes.

Case Group One: Geography I - Physical geography: The global perspective

Context of the Course

This course is a second-level class offered by the Geography department in the Faculty of Humanities and Social Science. According to the university's calendar, Geography I is a physical geography course from a global perspective. The course's focus is the study of form, process, and change in natural systems at and near Earth's surface.

This required course is for anyone pursuing a major, minor or concentration in Geography. The course consisted of three 50-minute classes and one 3-hour lab per week. Classes took place every Monday, Wednesday, and Friday at 9 am and included two separate lab slots during the week. The first was on Wednesday at 2 pm, the second on Thursday at 2 pm. There were 36 students enrolled in the class, of which 21 attended Wednesday's lab, and 15 attended Thursday's lab. Of the 36 students enrolled in the course, 18 students, the instructor and two teaching assistants signed consent forms to participate in the study. Of those, five students participated in interviews, and seven completed the online survey.

This maker project was explicitly designed as a lab to fit the structure of the class. The Learning Commons staff worked with the professor in the spring semester and early into the fall semester to create the project. The project's focus was a popular cove located on a town's outskirts in Newfoundland and Labrador. A few weeks before the maker lab took place, students were taken on a field trip to the area to observe the physical features of the landscape.

Initially, the lab was focused on creating a 3D printable landscape. However, the professor and Commons TA decided to include Virtual Reality (VR). For this reason, the lab was comprised of two groups. One group worked with GIS software to create a 3D object based on the cove they visited. The students' software was ArcGIS and Arc Scene developed by the Environmental Systems Research Institute (ESRI). Once the object was created, it was saved onto a USB drive, where it was printed by a 3D printer and given back to the student the following week. The second part involved using VR to view the cove they had visited during the field trip. For this part of the lab, there were two VR headsets located within the Commons. Two Commons staff members who were familiar with using VR staffed each area. Students were expected to navigate to the cove during this part of the lab from a set location. Once there, they observed the cove's physical features, including both the land and the ocean.

In terms of grading, each lab was worth 3% of the final mark. The final deliverable was a reflection paper on the takeaways from interacting with the GIS and VR technologies. While students were given the 3D printable artifact they created, it was not included as part of their grading. Furthermore, a question about the activity would also be included on the students' final exam.

Participants

Eight participants (five students, two TAs and one faculty member) consented to participate in the study. A pseudonym identifies each of the participants. A brief biography is presented for each person to understand better who they are and their place within the study.

Sam is a student enrolled in the geography course. He has a varied background; he initially attended this university but left to pursue work. During this time away from university, he travelled and worked in many places throughout the world. In 2017, Sam returned to university and enrolled in the International Bachelor of Arts (IBA) within the Faculty of Humanities and Social Sciences. Sam chose Geography 2102 as an elective for his program.

Emma is in her first semester of a one-year exchange in England and is enrolled in the Geography course. Her major focus is on physical geography. For her exchange program, Emma must enroll in five courses per semester for three semesters. Unlike the rest of the students in her class, Emma will not receive a grade on her transcript, simply a pass or fail. Emma has extensive experience with GIS software, which she acquired at her home university in England. However, she has minimal knowledge of VR.

Megan is a student enrolled in Geography I. Her major is in geography, with a focus on physical geography. She has some limited experience with GIS software from another course she completed for her program. She also has some previous experience with VR software, which she acquired in a summer employment program where she worked in a naval architecture lab.

Grace is a student enrolled in Geography I. Grace is in her first semester of a one-year exchange program from England. She is a third-year student and is studying physical geography. She has completed many courses in geography, including several focused on human geography. Grace has a lot of GIS experience, which she gained from her first two years studying in England. She has had no experience with VR but does welcome the opportunity to learn new technologies.

Madonna enrolled in Geography I and is taking this course as part of her program. Madonna is an undergraduate student completing a double major in Geography and English. She has been in university for several years and is also pursuing a public policy certificate. However, she has had no experience with GIS software or the VR software.

Tim worked with students enrolled in Geography I and Education II. Tim is a staff member at the Learning Commons located in the university's main library. He is responsible for the day-to-day operations of the makerspace and the digital media center located within the Learning Commons. Tim has extensive experience with digital multimedia technologies such as video, audio, and imaging editing. Tim was involved in creating the makerspace and has been working with makerspace technologies for the last two years. During that time, he has trained other students and has conducted workshops within the makerspace. Tim is also responsible for developing training materials and sessions for student support staff.

Rodney worked with students enrolled in Geography I and Education II. Rodney started working in the Learning Commons at the start of the semester. Rodney is a Learning Commons Co-op from the Faculty of Engineering, where he is studying electrical engineering. Rodney was hired to work in the Learning Commons to help clients. He also spends a considerable amount of time in the makerspace providing frontline support.

Furthermore, Rodney is responsible for creating and running workshops during the semester. Rodney has some experience working in Makerspace. In the last work-term, he developed and delivered makerspace type sessions in a K-12 school setting in Ontario.

Dr. Cliff was the instructor for Geography 2102. Dr. Cliff has worked at this university as a professor for many years. Dr. Cliff has published extensively in the field of Geography and has conducted research around the world. Dr. Cliff has taught many courses in the Department of Geography. Dr. Cliff is interested in the potential of using makerspaces within the course curriculum, not only for this current course but for other courses in the future. While he had been interested in working on a makerspace type project, this was his first introduction to makerspaces.

Themes

The main themes unique to the class were the experiences encountered when working on maker projects. Specifically, from a student standpoint, their engagement when interacting with something they perceived as modern and exciting. The instructors and teaching assistants (TAs)' impact on their experience with the maker project was also discussed.

The novelty of the experience. One unexpected theme that emerged was the students' attraction to new technologies. This was especially true for the VR sets and 3D printers. Madonna commented that getting to use the 3D printers helped keep her attention because this was something she had seen on Netflix. The student had watched a documentary on 3D printing and was excited about using the same technology she had seen on TV.

During the October 3 lab, students were divided equally between the two VR rooms that had one VR system running in each room. Within the VR environment, all students started the program in New York City and then had to navigate to the local cove where they conducted their field trip. Observing and overhearing the TA's conversation, it was clear that most of the students had no prior experience using VR, which was also apparent during the individual interviews. The few who were a little more familiar with VR had experiences with it that were different from this VR setup. For example, Emma experienced a VR rollercoaster at an amusement park in England. In addition, another student was overheard saying they had used VR in a game console.

The idea of experiencing something new and different was not just limited to using new technology. Several students commented that using this type of approach to learning for the first time was also very exciting and engaging. For example, Madonna talked about how she loved experiencing something new, such as this project. To her, the approach to the lab was something different than she had experienced before. At university, she had participated in many labs in subjects like chemistry, biology, and mathematics, which were somewhat similar in structure to each other. However, the approach to this lab was different.

In some cases, students were familiar with certain technologies in the lab, but the novelty of other technologies made the experience that much more engaging. For example, Grace already had significant experience with the GIS. However, she did not have any previous experience with VR. While she admitted to quickly finishing the GIS portion of the project, the course's VR portion was still engaging. Emma had over two years of experience working with GIS, but found the idea of creating a 3D object from her GIS work exciting and satisfying. She commented:

> I remember waiting for it to be printed, waiting for it, saying, "Is it in yet?" Like I said, it's normally we just printed the poster, and that's it. You look at it once or twice after you're done with that. I'm bringing mine home for Christmas.

For her, combining something with which she was familiar with something novel, like a 3D printer, was a very memorable experience.

Experience of Instructors and TA. The Geography class was unique in that students had a finite amount of time to complete their projects, and the head instructor had no experience working with makerspace technologies. I observed this lack of experience in the sessions they attended. It was observed that, over the two sessions, students' engagement increased as the instructors and TA became more comfortable with the sessions' format.

There were two parts for this lab, a GIS and a VR component. Each part was approximately two hours long. The GIS component took place in the Rotunda, a computer lab run by the University Commons, and the VR component was conducted in two VR rooms within the University Commons. The first group had nine of the 17 students attend the session with the remaining students attending the second half. This was the first time this lab was conducted, and there were several issues with the lab from the start. The number of users and the size of the data caused the computers to slow considerably. Additionally, links to instruction videos specific to the lab were not identified, confusing participants. These issues were addressed in the following hour of the lab. For the first half, students were quiet and focused on their projects. The way the lab was situated meant that students worked in groups of two. While this was an individual project, most of the students were chatting and asking one another questions. Students' experience level with respect to the GIS software seemed to vary considerably, which was evident in the progress some students made compared to others.

During the second class, 19 students attended the lab. Unlike the first lab, the group stayed together and did the lab's GIS portion first. The primary reason for this change was accidental, as one of the leading lab instructors could only commit to the first half of the lab due to another last-minute obligation. Furthermore, based on student feedback, it was decided to have everyone watch the GIS instructional video together before working with the GIS software. This synchronous viewing allowed the primary lab instructor to go over some crucial details with the group. The video and brief discussion lasted for approximately 15 minutes, and then they began to work with the software. It was observed that most students were following along with the instructor, often taking notes either on paper or on their laptops. The students were then assigned to a computer to work on their GIS projects. Overall, the session went smoother than the session before, with fewer questions about the software's usage. In this case, more questions were posed to the lab instructor about different software features (for example, experimenting with the elevation within Arcscene). In this session, all students had a 3D digital model that was 3D printable. This was a marked success compared to the first session, where only two students successfully created a 3D object. Analysis of the field notes indicated that most students spent their time on task, and asked a lot of appropriate questions to the instructor, such as queries regarding placement of contour lines and the scaling of their projects. Another process used in this session that differed from those used in the previous one was that students who finished early were permitted to go directly to one of the VR stations. This resulted in less noise and a higher instructor/student ratio for those students still working on the GIS portion of the lab.

Thus, the students still working on the GIS portion of the lab were less distracted, and could avail of spending more time with the instructors if needed.

On the second day (lab), the class approach was different in that students came up to the VR rooms once they had finished their projects. This way, all students had some experience creating a digital 3D model of the cove before viewing it in VR. This allowed them to view the cove initially from a physical viewpoint when they visited the Cove, then digitally as they used GIS software to create a 3D model, then virtually through VR, and then finally get to view the cove again as a 3D printed model physically. The setup on the second day was also impacted when the students interacted with the VR portion of the lab. From the interviews and observations, it was clear there was a wide variety in the participants' knowledge of GIS software. For example, Emma commented, "I feel like for me personally, I have done GIS courses in the past. I feel like I did this project in about 15 minutes." While Megan commented, "A lot of people in geography haven't taken any GIS." For that reason, some students finished the GIS portion much earlier than others, and some students needed additional time to work on their 3D models. Generally, this allowed students to trickle into the VR space, often only one or two students at any time. This provided time for students to observe others using the VR sets and get an idea of how it worked while also discussing their experience with the other students or the TA who was in the room. It also limited the amount of waiting time, reduced unrelated socialization and off-topic discussions observed during the first session.

Summary

Both themes discussed in this section directly related to different kinds of experiences from two different perspectives. The first was students who experienced novel technologies that helped keep them engaged in their projects. The second was from an instructor perspective, the experience they brought to the project, or lack thereof. The newness of the project forced them to learn along the way, in a continual improvement environment. This also helped improve the experience of students who participated in future activities.

Case Group Two: Education I -Teachers and Teaching

Context of the Course

Education I is a fourth-level course offered by the Faculty of Education at the university. The course was restricted to students in the education faculty who were studying primary/elementary education. Grading for the course was done on a pass or fail basis. For the project, no mark was given. Instead, each project was assigned a pass or fail. Also included in the assessment was specific feedback on each project

There were 11 students enrolled in the course. Nine students, the instructor and teaching assistant signed consent forms to participate in the study. Of those, four students participated in interviews, and seven completed the online survey. This course was taught by several different instructors who have expertise in specific areas of education. Each instructor was assigned four blocks of class time. The study focused on one of those instructors who had expertise in teaching technology. The instructor had the students work on a specified set of technologies to solve a problem. The maker project was conducted during a four-week block on Friday afternoons from 12:00 to 4:00 pm.

This course's project was completed during the four-hour classes, and students could bring their projects home. For this project, the students had to solve a real-world problem, centred around a conflict between a community and wildlife. The community experienced a problem with beavers that had moved into the area. Specifically, the beavers were damming the waterway in the community and, as a result, were causing its water to rise and the town’s main road to flood. The road was the only way in or out of the community and needed to be clear for the free flow of traffic. The task was to find a way to solve the problem without harming the beavers, using the technology that was provided by the instructor. The class was divided into groups of two or three students. The technologies provided consisted of BBC micro-bit controllers, Makey Makey controllers, Littlebits electronics, Scratch programming language, Tinkercad computer-aided design software, 3D printers, and multimedia hardware/software. Also, students were free to use any traditional craft materials and tools to help with their projects.

Participants Interviewed

In this case, there were six participants (four students, one TA and one faculty member) who consented to participate in the study. A pseudonym identifies each of the participants. A brief biography is presented for each person to help achieve a better understanding of them and their place within the study.

Nolan graduated from Business in 2013; however, he was interested in many subjects. During his time at university, he took courses in the areas of arts, business and science.

Admittedly, he had "lost his way" and decided to settle on business to complete a degree. After graduation, Nolan found employment in his field but decided to leave work and study education. Nolan is now enrolled full-time in the Faculty of Education primary/elementary program and plans to teach after he graduates.

Sandy completed a degree in Archaeology from this university and worked briefly within the archaeology field before moving to the oil and gas industry for six years. She then returned to university to study primary/elementary education. While she does not consider herself to be technical, she does enjoy getting her hands dirty during the learning process.

Simon finished a Geography degree and considered enrolling in a Master's program in Geography before deciding to pursue a primary/elementary degree. By his admission, Simon struggled with technology, and in his group often took a back seat to other group members when it came to the technology portions of the project.

Bella was enrolled in Education I, which is a required course for her program. She is studying to be a primary/elementary school teacher and intends to work in the field after graduating. Before studying to be a schoolteacher, Bella spent her first three years at university studying various subjects before studying English. Last year, she graduated with a Bachelor of Arts, majoring in French with a minor in English.

Dr. Sean is a faculty member in the Faculty of Education. Dr. Sean is a relatively new faculty member; however, he has taught as a part-time instructor at the university for many years. As a faculty member, part of his responsibilities is to oversee the technology lab in the Faculty of Education. Before becoming a professor, Dr. Sean was a junior high school teacher for 12 years, where he served as a librarian and technical education teacher. Dr. Sean is very comfortable with technology and uses it within his classroom as often as possible.

Henry was the teaching assistant (TA) for Education I. Henry is working on an Education degree with a focus on technology education. He has been a student of Dr. Sean in the past. Henry has a degree in French and English. After graduating, he spent four years as a woodworker but then decided to go back to university. While Henry has no formal background in many of the technologies he was working with, he still found playing and tinkering with these technologies enjoyable. Henry pointed out that he also learned a lot by helping the students in the class, and often had to learn the technologies with the students. Henry was in his third semester and will be graduating after the end of the Spring 2019 semester. He plans to pursue a career in teaching at the intermediate or high school level.

Themes

This case represented the largest number of participants, with nine students and two instructors/TA. Interviews, surveys, and observations produced a significant amount of data that yielded several themes. Of the themes uncovered, there were three themes unique to this case that emerged: experiences of the instructor, groupthink, and moments of inspiration.

Experience of the Instructor. During this class's observation, it was clear that the instructor was very comfortable with this class environment. This was observed in his apparent ease with the students, speaking with them on both the group and individual levels. For example, in the interview, Dr. Sean talked about his extensive technology teaching experience.

There were four observations completed for Education I, each conducted during the four sessions, which occurred over four weeks.

When Dr. Sean introduced the project the class would be working on for the next month, he stressed a few essential points. The first was not to let the technology drive the project. He wanted students to avoid choosing projects solely based on their interest in a specific technology; Dr. Sean emphasized that the chosen technology should have some purpose indirectly supporting their solutions. Dr. Sean said, "I mean, there wouldn't be a project without the tech, but the tech isn't the project. Does that make sense? It could have been any tech; it could have been the paper and scissors that you talked about." He wanted to make sure these projects were relevant to the curriculum they would potentially be teaching after graduation. He also wanted students to avoid taking an approach that was overly standardized or structured. He wanted students to be creative and pointed out that there are many ways to approach and solve the problem presented to them. Many of the students seemed uncomfortable with the open-ended approach and asked several questions for clarification, such as: How can we deal with the beavers? Is there more than one road? Dr. Sean would not go into detail. Instead, he often pushed the question back at the students and asked them what they thought. At this point, he suggested everyone form into groups and began to discuss the project and play with the technologies with which they could work.

While the students worked in their groups, Dr. Sean and his TA informally chatted with them. This was the first time Dr. Sean worked with these students, and he made a point of getting to know each student on a first-name basis. It appeared that Dr. Sean's approach to dealing with the students differed from that of the TA. For example, Dr. Sean was not quick to solve the group's problems, while the TA was more willing to jump in and help solve the problem. In his interview, Dr. Sean said:

> One of the criteria that I forced them to do is that they have to come up with multiple ideas. They can't just pick the first thing they want, but everybody wants to pick the first thing that they want. You know what they think. I actually forced them when I sat down, and they said, "Is this okay? Where are your other ideas?

Dr. Sean would ask questions or suggest they think about the problem differently. Groups were free to move around, talk, and experiment. For the first few hours, the class was very active. However, the class slowed considerably once 3 pm approached, as the students tired.

Groupthink. In the second session, each group claimed a table and diligently worked on their projects. During this session, the group began to experiment with the different technologies and then formulate solutions to the problem presented in the first class. For the first two hours, each group experimented with eight technologies provided by Dr. Sean. A little over an hour into the session, Dr. Sean addressed the class. There was much discussion and the occasional laughter, and all students were observed working on their projects. Dr. Sean commented to the class that everyone fixated on one solution, pond drainage. He noted that all the groups were headed in the same direction, primarily because everyone searched for the same thing on Google. The first few suggestions on how to deal with beavers revolved around the concept of water drainage. Rather than personally engaging with the problem to unearth answers, students turned to Google to find the solution for them. During his interview, Dr. Sean commented that he had seen this before, and it is an issue of design convergence, where everyone in the group gets the same idea. "I think the internet can help at the right time, but, in this case, I think it hurt the engagement level, okay. I really do because a lot of them thought they were done after they did their Google search." He then discussed how he had seen this in younger students, but he was not surprised that it occurred at the post-secondary level.

As an experienced instructor, Dr. Sean used this as a teachable moment and warned his students that this is very likely to happen in a classroom setting. He encouraged everyone to brainstorm ideas before searching for solutions on the internet. Once a few ideas emerged, the groups would be better positioned to do research, using the internet to help implement potential solutions. Students moved from focusing on one solution during the first week of observations, when they were searching on Google, to brainstorming ideas within their groups. For example, during class conversations, many different solutions were discussed once students put their computers away. One of the solutions discussed during the class conversation was increasing the water temperature; another was making use of a beaver scarecrow.

At the end of the team presentations, during the fourth and final class, Dr. Sean addressed the students and talked about the importance of divergent thinking, understanding technology, and not being afraid to play. His final remark was about challenging students in the classroom. He pointed out that it is essential to challenge students with complex problems. These problems should be authentic, real-world problems and not have a right or wrong solution. Dr. Sean emphasized the importance of encouraging students to think about potential solutions before narrowing their focus.

Moments of Inspiration. During an interview with Dr. Sean, he discussed breakthroughs students achieved when working on these projects. One of these breakthroughs happened when all groups worked on their projects' implementation, which necessitated learning how to use their respective technologies related to their projects. During this session, several "ah-ha" moments were observed where students had breakthroughs. One such breakthrough happened with a group trying to use their technology to sound a buzzer. When the buzzer went off in the classroom, not only did the group cheer, but other classmates also shouted encouraging words. It appeared that many students in the class were aware of the troubles they had and wanted that group to overcome their buzzer problem. At one point, a student commented, "I'm working 9 to 4 Monday to Friday, I'm exhausted". The student also commented that there is no end to his day, as he must spend many hours working on his project after school. In addition to his schoolwork, he also had a job that supported his schooling.

Communication. During the last session, the students could present their projects to their peers, instructors, and other faculty members. During their presentations, they described the process, the lessons they learned, and their reflections on the process. Generally, all presentations followed the same format: groups prepared a presentation and delivered it as a group to the class. Once the formal presentation ended, each group conducted a live demonstration of their project. Dr. Sean required each group to discuss the alternative solutions they studied and why they chose a particular solution to solve the presented problem. During the presentations, students in the audience seemed generally attentive, especially to the demonstration portion. Each group was asked many questions about their projects. It was observed that many of the questions were technical. For example, one student asked a group how they got their photosensor to work, as he had some difficulty getting his to work.

Summary

Dr. Sean was an experienced instructor who had worked in a Makerspace environment many times in the past. Here, I observed a small class of mature students working with an experienced instructor. Over the four-session period, students evolved in their approach, thinking and comfort level in taking risks when completing their beaver projects. Dr. Sean's experience contrasted with that of a relatively new TA, who was learning his craft as a teacher and learning many of the maker technologies available to the class's students.

Case Group Three: Education II Language Arts in the Primary/Elementary School I

Education II is a third-level core course offered by the School of Education. The course consists of two 1.5 hour lectures a week. The project was introduced early in the semester by the instructor and staff from the university's makerspace, giving a 30 minute presentation on the makerspace's capabilities. While students were given some time to work on their projects in class, they were expected to visit the makerspace outside of class time. They were encouraged to call ahead to book a time slot but also had the option to drop in during the day when the makerspace was open to the public.

There were 28 students enrolled in the course, and two students agreed to participate in the study. The instructor and two teaching assistants also signed consent forms to participate in the study. Of those, two students participated in interviews, and no students completed the online survey. The project for the course was based on the concept of creating a unique-themed board game out of a pizza box. The course focused on children's literature, which became the central theme for the students' project. Students were required to pick a children's book that involved a social justice message. Students presented the book and the represented theme to the instructor for approval. Once approved, the students had the freedom to create any board game; the only restriction was that they incorporate the pizza box into the design. At the end of the semester, students displayed their games during class and had the opportunity to view and sometimes play other people's board games. Students were assigned a pass or fail grade and were given feedback on their games at the end of the semester.

Participants Interviewed

In this case, there were three participants (two students, one TA and one faculty member) who consented to participate in the study. A pseudonym identifies each of the participants. A brief biography is presented to understand better each participant and their place within the study. One of the two Learning Commons TAs (Rodney), who worked with the Geography class, also assisted students in this class.

Brady is in his seventh year at university. He has completed many courses during this time, including many in the School of Human Kinetics and Biology. Brady became interested in education, and he started volunteering with Big Brothers Big Sisters. He has since been accepted into the Faculty of Education and is studying to become a primary/elementary school teacher. Brady created a pizza box board game based on the children's book *Baby Honu's Incredible Journey* by Tammy Yee.

Alex is an undergraduate student, and in her third year at the School of Education. She is in her early 20s and wants to work as a primary/elementary school teacher when she graduates from university. Like many of the other students, Alex has no experience with makerspaces; in fact, she disclosed that she did not even know that the place existed in the library, which she frequently visits. Alex worked on creating a pizza box board game based on the children's book *The Lorax* by Dr. Seuss.

Dr. Sophia is a faculty member in Education. Dr. Sophia was a primary teacher for 21 years before becoming a professor; during the 21 years, she mostly taught grade three. Dr. Sophia always uses crafts to explore education. She has many research interests that include play-based and experiential learning. Dr. Sophia has worked with the Makerspace for one of her previous courses and is somewhat familiar with Makerspace on campus. During the study, Dr. Sophia participated in her class's project and developed her own board game.

Themes

Although this class had a low number of study participants (two students, one instructor and one TA), several themes emerged. In this case, students worked independently on developing their projects and organizing the help available to them. The second theme centered around the variety of projects and the impact that had on the TA.

Working as individuals. The class had the opportunity to work on their projects for the longest duration of the three classes. Furthermore, the project was an individual one, so no group work was required. In his interview, Brady pointed out that he did not have a good idea of what his classmates were doing for their projects on an ongoing basis. Brady said, "It probably would have been a good thing to see each other's projects around midterm." While Dr. Sophia did make visiting the Commons Makerspace mandatory, she did not require students to book times with the TA assistant initially assigned to the class. As the makerspace is open to the general public, students had the opportunity to drop in during regular business hours. This configuration made it difficult to observe the two students who participated in the study. However, one of the TAs in the study did work at the makerspace, and he agreed that I could observe him if students came in for assistance with their projects. After several attempts, I had the opportunity to observe one group that came in for assistance from the class, including one student within the study.

Experience of the instructor and complexity of tasks. During one session in the makerspace, five students worked with the Commons student staff member, Rodney. Rodney was also involved in the Geography course. At this point in the project, each student had picked and acquired their themed book. However, from the questions being asked to Rodney, I could see that each student was at a different stage in their board game development. Some of the students were working on their final game pieces, while others were figuring out how to use the makerspace tools. Alex stated in her interview, "I sat there a while, doing nothing because nobody would help me." Part of the problem was in making sure all students were engaged in working on their projects. Rodney often struggled to bring the ideas out of the students. In addition, there were several times when multiple students had multiple questions that were unique to each student. These frequent questions seemed to cause a certain level of uncertainty within the space. It was clear that the students did not know Rodney very well. For most of them, this would be the first time they had met Rodney, except for a brief introduction when he first introduced Makerspace to their class. This unfamiliarity also made Rodney less effective, as he had first to understand what each student was doing, and what they needed from the Makerspace to complete their projects. At the start, it was observed that Rodney was continually moving from student to student and seemed overwhelmed. As the session progressed, the students became more comfortable with him, and the atmosphere became more relaxed. During the session, Rodney brought several of the students together, trying to develop a 3D model for their games. This seemed to work; however, this was more Rodney showing them the steps so they could do it on their own. Later in the session, it was observed that some students helped one another when Rodney was occupied with another student. Generally, this occurred when the student offering assistance had done the task or activity before. For example, one student assisted another with their CAD drawings, and a second showed a student how to use the laminator.

Summary

Education II had the fewest student participants in the study. The instructor gave students the freedom to explore in a very open-ended approach to their respective projects. Students had the freedom to choose their book and what makerspace technology they wanted to use. This complexity, combined with a more inconsistent support structure from Commons Makerspace staffing, may have caused unnecessary frustration among students.

Cross Case Group Analysis

Within the case study, there were three situations or case groups. Each of the case groups had their challenges and successes. They also shared common themes and similarities. Through observing, interviewing, and surveying faculty and staff, several commonalities between the three case groups became evident. Common themes across the three groups were: students' perceptions of how they learned, perception of engagement, attitudes towards learning, experiences with engagement, iterative learning, signs of engagement, and tools and technology.

Students' Perceptions of how They Learned

In the interviews, most students indicated that maker activities impacted their learning differently than the more traditional projects they completed in other courses in the past. Simon, a student in the Education I class, saw the group take a different approach. He noted, "Working on a normal group paper, we would have split the paper up into three even sections. For example, I'll write three pages, and you write three pages." Working on this project meant that students could not divide the tasks quickly, and many of the tasks depended on other tasks' completion. Madonna found that it differed from what she had done in the past because it allowed her to do something dissimilar from her typical approach to projects. She commented that:

> The virtual reality allowed me to do the same thing, but it was more hands-on, and from a learning perspective, we all have different ways of learning, and that was something that most people don't really get to experience very frequently. So, in a classroom, you're sitting down. I'm gonna be honest, it's super dull. You want to go to sleep. Being able to do something that gets you up, that gets you intrigued, that gets you interested, that gets you excited, I found that really beneficial to my learning experience.

Nolan and Megan both agreed that this type of activity was very different from those they completed in previous courses they took. Both referred to the emphasis on testing and listening to lectures during classes. The maker activities were different in that they allowed people to experiment, take risks, and fail in what they were doing. During the interviews, four students commented on the focus being not so much on the end project, but on the journey leading up to completing their projects.

Perception of Engagement

From the several conversations I had with participants as part of the research, it became clear that engagement can mean different things to different people. To understand how each student perceived engagement, they were asked to define the term. This was significant because it allowed me to understand better how they experienced engagement within their class. I asked all participants interviewed: "How would you define engagement," and "What does engagement mean to you?" Five of the students (n=11) referred to being engaged as getting hands-on with learning. For example, Madonna from Geography I responded with this definition, "Engagement is hands-on, enabling me to think by myself, instead of being told how to think what to do." Three of the students viewed engagement as maintaining their interest in what they were doing. For example, Emma saw engagement as maintaining someone's attention or interest. She said: "Engagement is grabbing someone's attention, being actively involved in something, too. So it's not just listening, but actually interacting with that information you're given." Three other students viewed engagement as merely being an active participant in their learning. Megan simply stated that, "What comes to mind when I think of engagement is participating in the learning that is taking place."

In general, instructors' and TAs' definitions of engagement were more elaborate, which was especially true for the instructors. The instructors were more focused on activity-driven engagement. For example, Dr. Sean talked about engagement as something that becomes your singular focus at that moment. He stated: "Engagement is when you forget everything else. When you're focused on the task, for example, engagement was those two girls trying to solve that buzzer problem." Henry echoed this idea when he said: "Well, the first thing that comes to my mind regarding engagement would just be the proportion of your time you spend devoted to the task at hand versus being distracted by other things." Refer to Table 2 for a summary of the instructors' responses.

Table 2

Categorization from Interviews of Definitions of Engagement

Meaning	Student (n=11)	Instructor/TA (n=5)
Keeping interested	3	1
Hands on learning	5	
Participating	3	4

Attitudes towards Learning

Students were interviewed to determine their attitudes towards learning in the studied courses compared to other courses taken in the past. When asked this question, many students responded that they found working on their specific projects more attractive than in other courses they had completed and often spent more time on their projects. For example, when working on her beaver project in Education I, Bella pointed out that she went out in the forest with her uncle to look at the habitat in which the beaver lived, including the dam, lodge, and surrounding forest. From this excursion, she better understood the beaver and how to approach solving her problem. Simon, who was a student in the same class, watched a documentary on beavers by Dr. David Suzuki for the same reason. In both examples, students pointed out that they would not have gone to these lengths if they were simply writing a paper.

Experience around Engagement

There were different instruction styles between the instructors and TAs, especially in the Education I class. The TAs were much more reserved and seemed less skilled at facilitation; for example, the TAs, Rodney and Tim, would be more willing to answer the questions of the students they were working with, whereas the instructor was more likely to point students in a more general direction using probing questions. For example, one group was talking about how to approach a geothermal solution with Dr. Sean. To instigate independent thought, he did not answer students' questions directly; instead, he asked a question regarding how much water a beaver needs. This query encouraged the group to think about the scale of a possible geothermal solution to the beaver problem. Dr. Sean concluded this session by saying, "You should be figuring out your projects by now; you should also know the technologies that you are going to use. By the next class, you should be comfortable with the electronics so we can do work on it during class."

Except for Dr. Sean's class, the other two classes in the study relied on the use of the makerspace. The university's Learning Commons uses a peer to peer support model to provide front line technical support to their clients. Since most supported clients are students, the Learning Commons hires students as support staff. This hiring practice results in student staff members comprising most of the makerspace front line staff, including an engineering CO-OP student, and one permanent staff member in charge of the area's overall administration. The area is usually open from 9:00 –5:00 pm during the fall and winter semesters. During that time, students typically do two- or three-hour shifts. While each staff member received basic training, each had different skill levels based on their interests, experience working with the equipment, and experience supporting clients.

The same variation of skill was present with the instructors and TAs. There were three instructors and four TAs who interacted with students in the three courses of this study. Everyone brought with them a different level of experience in facilitation and knowledge. For example, Dr. Sean has a doctorate in educational technology, has more than 15 years of experience as a teacher, and has extensive experience working with students on technology and maker type projects. In contrast, Rodney graduated from high school only a few years before this study was conducted and has limited instruction and makerspace technology experience. While he does not have a formal teaching background, Tim has ten years' experience conducting tutorials, workshops, and application sessions for students at the university. While enrolled in an education program, Dr. Sean's TA has minimal formal experience in teaching, and, by his admission, was learning as he went. Several students commented on these different experience levels during their interviews.

Each instructor brought with them a different level of knowledge with regard to implementing a makerspace project within their classrooms. Dr. Cliff, for example, had only a superficial understanding of a makerspace. During his interview, he noted this was his first time implementing this type of project into one of his classes, and the next time he attempts a project of this type, he would approach it differently. He said:

> Since we were starting, I wasn't sure what the result would be, so now I know what the result would be, and I can clearly then tailor my thinking in the way that I introduce it in class and so forth to make sure that it fits better.

During meetings with the TAs, makerspace and Dr. Cliff, many details were discussed, and a plan was put in place. However, not everything was accounted for, even with all the preparatory work completed. It would be observed, just like a maker project. An important learning component of a maker project is implementing the project and learning from the mistakes of the actual delivery of the project.

The quality of instruction may affect parts of the student experience. For example, a student in Dr. Sophia's class, while having a positive experience overall with the project, noted that her TA was not very helpful. A Geography I student also mentioned that they had a similar, negative experience with a TA. Both cases will be described in more detail later in the section.

In Dr. Sophia's class, students were encouraged to book time directly with Rodney. However, they also could drop in at any time during working hours. This availability meant that students could interact with any of the staff within the makerspace. Alex decided to drop in during the day and had a negative experience. She noted about her experience: "While the main

TA was awesome, other students were dealing with different Makerspace student staff, and that was causing some confusion." Alex went on to describe her peers' experiences when she said:

> When I spoke to other students, they more or less went in, and the two or three guys that were at the Makerspace didn't help them. So, they essentially sat there for two hours doing nothing because nobody would help them.

Alex also pointed out that her experience was completely different. She commented that dropping in unannounced could have contributed to the issue. Alex said, "I think it's because they were also showing up without letting anyone know they were just kind of coming in whenever." A similar experience was noted by a student in the Geography I class. In one of the sessions, the TA left the room and had Bella, who had just experienced VR for the first time, guided other students through the process. This approach was not well received by her or the other students. She felt that the student staff member should have been there the entire time, helping all students through their VR experience. In her interview, she commented that: "It was super frustrating, and I know my friend was upset that she didn't get to have the experience that I experienced."

Instructors were asked in the survey about how these types of spaces and activities engaged students. One instructor commented in the survey that: "This framework seems to lead to higher levels of engagement." Others noted that it provided opportunities for students to experience hands-on learning and create something unique, as reflected in one comment: "Hands-on, active learning that takes place leads directly into engagement." Instructors were then asked if they felt students were engaged in their projects.

Based on Figure 5, most of the instructors felt that students were engaged. Instructors who observed student engagement later referenced that students learned as they went through the process. For example, instructors commented that students began to see technology not as the solution, but, instead, as a vehicle through which students could reach the understanding that there was no one right solution, but many. The instructor who did not feel students were engaged observed that some students "wanted to get it done and over with."

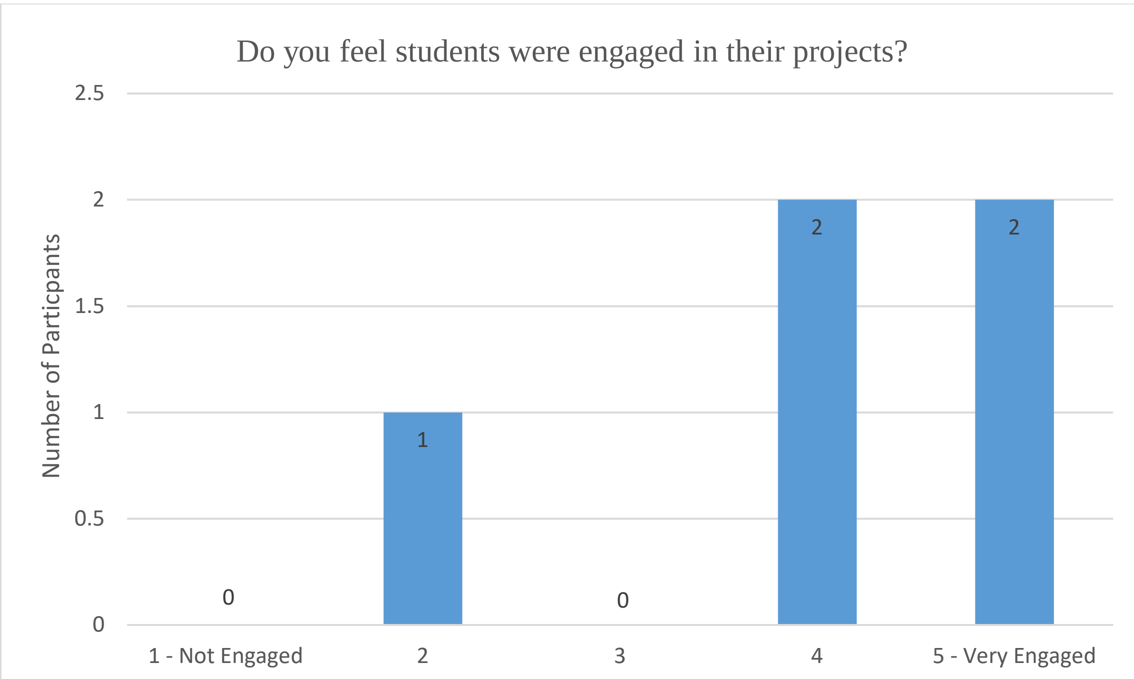

Figure 5. Survey responses from Instructors to the question, "Do you feel students were engaged in their projects?"

The skills the instructors learned during the project varied considerably. Those who had prior experience talk about how these learned skills work to refine their pedagogy, while others recognized the importance of providing students with the right amount of support at the appropriate time. For example, one instructor commented that it was like "thinking about how scaffolding can be achieved through new and exciting tools." Generally, comments were made about taking what they had learned from their experiences and applying that to their teaching going forward. All of the instructors who responded indicated that, based on their experiences, they would consider doing more of these types of projects in the future, as seen in Figure 6.

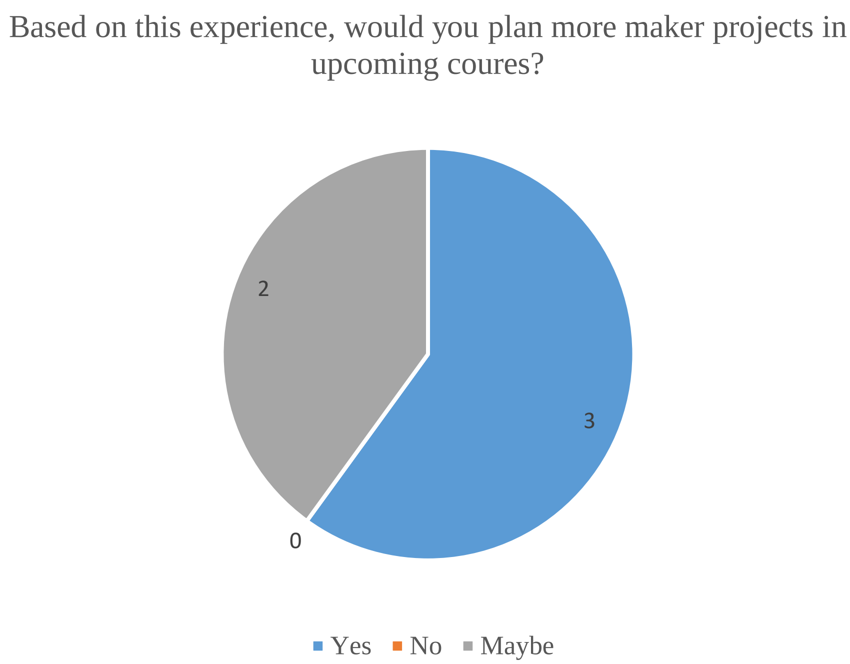

Figure 6. Survey Responses from Instructors to the Question "Based on this experience, would you plan more maker projects in upcoming courses?"

The instructors had a positive experience implementing a maker project in their course (see Table 3). The three Instructors felt that it made students get out of their comfort zones and offered a new perspective on their learning. For example, the Geography I professor saw value in getting students to see the same landscapes through three different mediums. He commented that "it made them process the similarities and differences which caused a deeper analysis and connections." Several instructors commented that the novelty of some of the technologies, like the 3D printer, helped keep students interested in their projects. One instructor pointed out that the "lure for most was the 3D printers--and making/designing something."

Table 3

Results from Instructor's Survey Question from three Case Groups

	1 Poor	**2**	**3**	**4**	**5 Excellent**	**Total Responses**
How would you rate your experience with maker projects in the classroom?	0	0	2	1	2	5

As with the instructors, students had a wide variety of experiences based on several factors such as experience level, the project, and the class they were registered for that semester. Overall, students seemed to have a positive experience. When students were asked if they would participate in another maker activity in the future (see Figure 7), 11 of 14 students responded that they would, 2 of the 14 said they would consider participating in this type of activity, while only one responded that they would not. The student who did not want to participate in maker activities again was frustrated by the experience and commented, "When I had questions, they weren't answered, but instead, the work was just done for me." Those who would participate again commented that it was a fun and enjoyable experience with one student commenting: "The activity was a fun and new way to learn and explore design challenges."

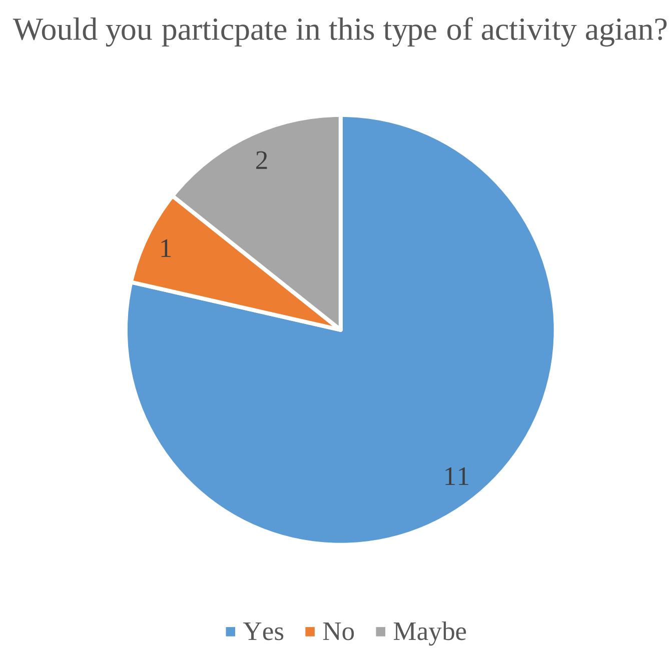

Figure 7. Student responses to the question, "Would you participate in this type of activity again?"

Generally, students who had some experience with the technology felt more could have been done to keep them engaged. Both Grace and Emma had extensive experience with GIS software and were finished within 30 minutes of starting their projects. Both agreed that the level of difficulty was appropriate for beginners, which many of the students were. A potential solution would be to add some extra optional steps at the end of the assignments that would allow them to explore the software a little more.

Iterative Learning

The level of engagement by students seemed to improve based on how well the process went. This was apparent in the Geography I case group; the instructor was new to the idea of makerspaces. Additionally, this was the first time the makerspace had attempted to convert GIS data into a 3D printable artifact and conduct a lab in VR. During the first lab on Wednesday, the group was divided into two groups: one group would work on the GIS, and the other would work on VR. After an hour, each group would switch. While several trial runs were attempted before the lab, several issues arose during the lab. Dr. Sean fundamentally understood that learning should be an iterative process centred around problem-solving, critical thinking, design, and collaboration. He stated that learning is about "going back and forth with ideas, basically proposing solutions, testing solutions and then redeveloping them again over and over again." Tim also illustrated the iterative nature of working in a maker environment when he pointed out that he has eight carved awards, each demonstrating the evolution in his fabrication ability working with a CNC router for the first time. Each successive award shows in it a little more knowledge and a little more creativity. Tim concluded that narrative by saying, "I'm not sure if that's the right way to do things but a lot of it is, you know, learning by doing and trial and error and stuff, so it's very much an iterative process."

Similarly, students associated some of their success with their ability to circle back and improve their ideas and work. Nolan commented he learned throughout the four weeks developing his project by failing and failing often. He noted in his interview:

> Honestly, there was trial and error, but it's kind of fun; it's like when you make it into a game. It's like did I solve this problem, yes or no? Well, I almost did so I can keep going this way and once I have that answer quite like that question answered did I solve this problem?

Sandy commented that it is essential to challenge yourself in these types of projects. She commented that "challenges, although they might be frustrating not being afraid of failure and not stopping because of it." The theme of learning through failure was also visible in Geography I and Dr. Sophia's Education II projects. Bella talked about how some of the technologies can seem intimidating at first, but after a little exposure and playing, one eventually overcomes that fear. Bella talked about her frustration with the Arc GIS software, but she kept working at it and eventually created the 3D model. She commented, "When I actually finished that, and I know that and mine was too small but being able to finish that process, I felt proud of myself."

Signs of Engagement

Investigating how students engage in learning through makerspace activities was the focus of this study. Students and instructors made several comments and observations that indicated students were engaged in their activities. In their interviews, many students said they were motivated to do more than if they were doing a standard project. For example, in Simon's interview, he contrasted working on his beaver project with writing a paper when he said

> I think we went above and beyond; then, if it was just like the traditional class, we probably would have only done half as about the amount of work is what we did. I think

> it kind of encouraged us, and it motivated us and engaged us to learn even more about the beaver and to explore all the different solutions that were possible that we might not have thought of yet.

Grace commented that while there were other assignments due in other classes, working on the board game was what she wanted to do because the process of creating it excited her.

One word that was often referenced in the context of engagement was “fun”. The word “fun” appeared in 9 of 11 students’ interviews. For example, Nolan talked about learning new technologies in a fun environment, while Alex viewed the project as an opportunity to have fun with the project and the technology. Alex stated, "I would rather do stuff like this like, I have roommates now who are kind of working their way to getting into the Faculty of Education, and they're sitting there doing like stats courses and stuff like that, and they're like see you get to make board games and have fun with it." Emma was having so much fun with the VR that, at one point, she lost track of time. She stated, "It's so immersive, so I really enjoyed it. I kind of lost track of time, actually. I felt like I hogged it a little bit, but I really enjoyed that as an experience. I think that was a bit fun."

There were two signs of engagement noted by Dr. Sean and Dr. Cliff. Dr. Sean observed engagement during one of the sessions. He discussed one incident during a session where a group worked on a problem and finally got the program to work. He noted in the interview:

> The group didn't give up, they didn't give in, they went back, and they checked, then they re-checked, and they finally got it to go, they got it to work. You can't teach that; I don't think you can teach that type of determination.

In a broader sense, Dr. Cliff observed that a great number of his students answered a question directly related to the assigned maker project on their final exam. On this exam, Dr. Cliff observed that 30 out of 36 students chose to answer the question specifically related to the cove that was at the center of the maker project. He also noted that, while responses to other questions on the exam were of average quality, responses to the question directly related to the maker project were incredibly well done.

While this maker activity was different from other activities instructors asked their students to execute in the past, was it different from students' experiences in other courses? In other words, was this a unique opportunity for students, and if so, how did it differ from traditional teaching? Students described a traditional learning environment as a place where the professor lectures while students take notes and listen. In a traditional learning environment, students are assessed by their performances on assignments, tests or quizzes. Students found the maker activity to be a new experience. Madonna commented, "Being able to experience something new, I love doing such things, and to me, this was a new experience, and because of that, I really enjoyed that." In addition to being introduced to a maker activity, the students were exposed to different tools to complete this activity. However, was there a difference in how they learned? Overall, students did see a difference in learning through making, compared to a more traditional format. Bella commented, "It was completely different. I can't imagine writing a paper about what I was planning to do with beavers."

It was also observed that engagement is not binary and occurred on a spectrum. For example, in Geography I, students were initially very engaged with the VR portion of their second session; however, as their wait time increased, they became less engaged. During the start of the VR session, students were exceedingly slow in putting on the headset and getting oriented. However, once these things were figured out, everything else seemed to go smoothly. Initially, while students were waiting, students were observed discussing the GIS project and the VR experience. For example, one student said that, when it was their turn, they would look at the road leading up to the cove. Nevertheless, as more time passed, students who were waiting became more restless, and their conversation began to change to more social topics (for example, what they were going to do on the weekend).

Students were asked about their engagement level during the course, and how they learned in comparison to other courses they had previously completed. Overall, students seemed to have been engaged in their projects and had a positive experience, Table 4. Students generally commented on the hands-on opportunity this type of project afforded them, with one student commenting that: "The hands-on activities made the learning experience that much more memorable."

Table 4

Student Survey Results from Three Case Groups

	1 Not at All	2	3	4	5 Very Much	Total Responses
Was this an engaging experience for you?	0	2	1	3	8	14
Did you learn more using maker compared to other course activities in the past?	0	1	2	4	7	14

Tools and Technology

When the students were asked if they had any previous knowledge of makerspace, 13 out of 14 responded that they had not. The students were asked what the most valuable skills they had learned in the course were. Generally, their responses could be reduced into two categories. The first is associated with acquiring a new skill; for example, learning VR or how to use CAD. The second is related to the application of the techniques they had learned to either finishing their project or to helping them in other areas, such as future courses.

While each of the three classes assigned a different project, each also had access to varying tools and equipment, both in kind and number. Geography I was the most limited (only using GIS software, VR, and 3D printing), Education II was provided with eight different technologies, while Education I had no real limits placed.

Students responded that learning about new technology was very beneficial to them. This positive reception could be based on their gaining exposure to a new type of technology for the first time, like VR, or learning different features of an already-familiar, existing technology. Some students made a point of showing appreciation for the skills they acquired during the process of working on their projects. For example, they noted as beneficial the learning of different approaches to integrating different subject areas, and learning the importance of project design in completing a successful project.

Time and Tools

Time seemed to be an issue among the students interviewed. In Geography I, many students wanted more time to play and experiment with the software or VR headsets. While in

Dr. Sean's Geography I class, several students commented on the time commitment the completion of the maker project necessitated. Students who were new to any of the tools experienced some learning curve associated with learning any new technology. Simon felt that, alongside learning the technology itself, it was important to ensure the technologies were used correctly. He commented, "My challenge was to think about how can technology aid cohabitation and do minimal damage to the environment at the same time."

In the Geography I class, both Grace and Emma commented that they completed the task very quickly. They then went on to play with some of the additional features, but that was done purely from an interest standpoint. Both students were very comfortable with GIS and had more than two years of experience in GIS. Grace and Emma felt that should they have been asked to complete an additional non-marked portion of the assignment, this would have helped maintain their interest throughout the remainder of the class. Grace commented that a lack of familiarity with some of the key features caused unnecessary problems for some students, such as their projects moving very slowly and sometimes crashing. Grace commented about this issue when she said

> I know that other students, if they were new to ArcGIS, had some problems. I knew ArcGIS, and I know the geoprocessing and the background geoprocessing settings. I've noticed over here that people don't do that. That's a rule at homes, to turn that off and wait because you increase the risk of ArcGIS crashing.

The instructors might have also prevented this if they had more experience working with GIS in a large group environment. Issues such as the bottleneck from the internet and slow process speed may have been addressed before they became problems should the instructors have been more familiar with this environment. During the second lab time slot, the GIS files' size was reduced, which resulted in more successful 3D printable images that the GIS software rendered. This bottleneck brings the issue of resourcing such a project to the fore.

A few students noted a difference in their perceptions of time while working on their projects. For example, there were several examples where students felt as if time was moving quickly, such as when Bella went with her uncle to view a beaver dam in the forest.

> It's hard to say; it kinda sounds like, it kind of seems like you want to say it was less because it was like you weren't sitting down at a computer typing away for hours and hours on end and that drags on; it makes time so slow. But if you're working on something and you're hands-on doing it, it doesn't seem like it's that long because I spent probably four to five hours looking at those beavers with my uncle, but like that wasn't time that I was like four or five hours sitting down at a computer, which is completely different. So it's hard to say it probably was the same amount of time but definitely more engaging and fun.

Bella acknowledged that while she spent the same amount of time doing a traditional activity (for example, writing a paper), she felt the time she spent doing hands-on research for her maker project seemed to go faster because she was enjoying what she was doing.

Common Challenges Associated with Makerspace Projects

As there were common themes found across the three case groups, instructors faced common challenges within their classes. This section examines the challenges that impacted their projects. From an instructor's perspective, there were three challenges in conducting makerspace projects in a classroom environment. These challenges included: issues with the internet, seeing the potential of the experience and communication. Each of these challenges will be discussed in the following section.

Issues with the Internet

Both Dr. Sophia and Dr. Sean intended their projects to allow students to be creative and think outside the box. When interviewed, both highlight how being connected to the internet caused students to be less creative. In Dr. Sean's class, students seemed to develop tunnel vision as they looked to Google for solutions right away. In the interview, he commented:

> There's something we called design convergence, and it's when everybody in a group converges on the same idea. I saw it happen in this project the fastest I've ever seen it happen, and I should have put a note down that said you shouldn't use Google, put your phones away for the first hour.

This unexpected complication demonstrated that even an instructor with extensive makerspace experience could overlook small details that could potentially have ramifications on the project. In her interview, Dr. Sophia commented that many students think they are being innovative, but are merely copying another idea. For example, she talked about how many students rely on social media sites such as Pinterest, searching through thousands of images and models for inspiration. Unfortunately, this often results in the student emulating the model they are observing.

Seeing the potential of the experience

Dr. Sean discussed how often a learning curve is associated with technology that is new to a student. He commented that while he had 16 hours to work with students, in reality, he needed 32. When developing these types of activities, attention needs to be given to how the students will achieve a base level of knowledge to help them solve their problem. He suggested that the appropriate amount of supports are necessary to achieve this objective.

Instructors were asked in the survey if they thought there was more work associated with Makerspace activities. Three responded that there was roughly the same amount of work, and two instructors responded that there was slightly more work in preparing maker activities for their classes. While instructors and TAs thought maker activities were generally suitable, they also realized that creating these learning experiences for students comes at the cost of more time.

Communication

Dr. Cliff's and Dr. Sophia's classes were partnered with the Makerspace, which meant there were more areas where communication could fail. For example, there was communication between the instructors and the TA at the Commons Makerspace. Also, there was the issue of communicating with the students, which may have been improved. For example, Madonna commented that it might have been helpful if the students knew the maker project's details before they went out in the field to view the cove. Other students felt clearer communication in the form of feedback was needed in Dr. Sean's class when their final projects were assessed. Bella, for example, intimated that she put in a significant amount of work and felt she needed more validation with respect to her project.

The way TAs and students interacted could have also been streamlined to improve communication. The fact that students from Dr. Sophia's Education II class were allowed to drop in at the makerspace meant that they could talk with anyone who was staffing the makerspace whenever it suited them. Alex observed that "while the main TA was awesome, other students were dealing with different Makerspace student staff and that what was causing some confusion." A Geography I student also had a negative experience with a student staff member when working with the assignment's VR portion.

Chapter Summary

Each case group was unique and had their own successes and challenges. Over the three case groups, however, common themes emerged that related to: how students perceived engagement, the impact an experienced instructor can have, and the challenges associated with makerspace in a classroom environment. What differed was the level of expertise among instructors, the maker activities' formats, and the technology used.

In Chapter Five, research questions are addressed by drawing on the data in discussion and relevant literature.

CHAPTER FIVE: DISCUSSION

In this chapter, I discuss the findings in response to the questions that guided the research. The Chapter begins by revisiting the assumptions I had at the start of the research. Students' perceptions of engagement, the novelty of the technology, and the role of organizes will then be discussed in response to the questions that guided the study. Following these discussions, I provide a response to my research question. The Chapter concludes with a discussion about the conceptual framework and its relation to the study's observations.

Assumptions Revisited

My experience working with makerspaces has influenced my assumptions about learning and student engagement in learning over the last five years. In this section, I revisit four assumptions that influenced how I understand learning within maker learning environments. My first assumption was that makerspace projects at the undergraduate level are relatively uncommon. This prediction proved accurate because of the difficulty of finding instructors among non-STEM disciplines willing to work with me.

Second, as these instructors were challenging to find, the instructors who volunteered for inclusion in my research project may not represent instructors overall. At the university, I had the opportunity to work with many instructors. Instructors generally came to me for support, so my initial assumption was that I would have no issues attracting them for my study. As is turned out, I had to reach out to the wider university community in order to attract instructors to the study. The instructors who agreed to participate seemed to be more outgoing than their peers and more willing to attempt something new.

Third, as someone involved with the university Commons Makerspace, I understand the variety of skill levels represented by the people who work in the Commons. While a permanent staff member is in charge, the day-to-day operations of the makerspace tend to fall on student staff, whose facilitation ability and technical expertise can vary considerably. This variability meant that the amount and quality of support the study participants would get from the makerspace would vary as well. For example, an experienced staff member skilled in facilitation and technology could potentially interact better with students than a less-experienced staff member. These interactions could shape the participant's perception of their maker projects.

Fourth, as I progressed through my study, I appreciated the complexity of teaching and learning more than at the project's inception. Observing the student/teacher interactions and the maker activities' initial planning reminded me that both teaching and learning can follow non-linear paths.

Discussion of Findings

I used the research questions noted in Chapter Three as my starting point for each of the following sections' discussions.

Nature of Engagement

The first question that guided my study was concerned with the characteristics or natures of academic, social, and intellectual student engagement when learning through making in non-stem course environments. From my data, it became evident that the nature of engagement is not always straightforward and can differ among participants. Some factors observed that impacted student engagement were the perceptions of engagement by students and instructors and displays of engagement within a particular project's maker context.

Perceptions of Engagement. There has been a considerable amount of research conducted on student engagement (Parsons & Taylor, 2011). Simply observing students and determining if they were engaged is not always helpful; typically, students who are not engaged still attend class and complete their work (Newmann, 1992). To better understand, I needed to ask students how they viewed engagement and if they considered themselves engaged in the learning activities. It was clear that students' interpretations of engagement varied. I investigated both students and instructors with respect to their perceptions of engagement.

Students' responses concerning their perceptions of engagement often fell into three categories: maintaining interest, hands-on learning, and participation in the activity. For example, Henry viewed being fully engaged as "having your undivided attention to the task at hand." Emma described that engagement is interacting with the task at hand, while Nolan viewed engagement as "actively working with your group towards a common goal." Student participants did not directly discuss the social, intellectual or academic types of engagement. They do mention these types of engagement, however, in their interviews.

Within the study, instructors generally viewed engagement as students' active participation in the activity. Dr. Sean gave an example of intellectual engagement of a class that was so engaged in an activity they kept their heads down, working diligently for almost three hours on their project. Dr. Cliff viewed engagement in terms of paying attention and how well students perform on their assignments. He said, "My TA told me that they actually did get engaged in the lab and that their answers did indicate that they had been paying attention and that they had gained some new insights and new perspectives." This exchange with the TA seemed to indicate to Dr. Cliff that not only did participating students pay attention, but the activities they were asked to perform may have added more to their experience.

From these results, it is evident that there are a variety of opinions on what engagement means. Views concerning engagement differed not only between instructors and students but even between students themselves. These findings align with various conceptualizations of engagement found within the literature (Parsons & Taylor, 2011; Redmond, Heffernan, Abawi, Brown, & Henderson, 2018), affirming the point that instructors designing projects need to be aware that students perceive engagement differently.

Displays of Engagement. During the study, I had the opportunity to observe students as they worked on their projects and came to understand their views more deeply by conducting interviews. Based on the collected data, I will explore the displays of engagement throughout the study from an intellectual, academic, and social standpoint.

As Willms et al. (2009) noted, intellectual engagement requires a serious emotional and intellectual commitment (for example, being interested in completing schoolwork in class). I observed this pattern several times during Dr. Sean's and Dr. Cliff's sessions. In Dr. Cliff's session, most of the students actively worked on computers with GIS software and asked both the TA and other students questions directly related to their assignments. In Dr. Sean's class, we observed groups working on their beaver tasks. All members of group one experimented with different technologies: one member worked on micro bits, another tinkered with the breadboard, and a third read a reference book on micro bits and discussed how to integrate them into the project. In all three of these classes, students demonstrated an emotional and intellectual commitment to these projects. While different in scope and content, the projects allowed students to work on an authentic task and relate this to what they were learning in class.

Factors that influenced academic engagement included: student effort, providing an intellectually challenging classroom environment, and teacher encouragement (Fredricks et al., 2004). In an interview, one of the students reflected on her level of engagement in the project, which was marked by her willingness to visit a beaver dam on the weekend with her uncle; another decided to bring in actual mud and twigs to make a more authentic beaver dam. In another class, Dr. Sophia wanted to challenge each student intellectually and wanted students to create high-quality artifacts they could use when teaching. She told the students, “Don't use cheesy construction paper and just put packing tape on it. Get it done right, and then you've got something that'll last you through your teaching career.” This statement demonstrated how students could be encouraged to go beyond what they might have previously thought was “good enough,” and offered students the opportunity to construct durable teaching aids for their future. When I interviewed Brady, one of Dr. Sophia’s students, he appreciated what she was trying to achieve by stating:

> I found it really engaging; it would have been very easy for her to just give us the same old boring ‘write me an essay on this, that or the other thing,’ but this really allowed me to open up my mind and figure out what I wanted to do.

In these examples, both students and instructors demonstrated deep engagement with making. Students were willing to exceed typical coursework expectations, whereas instructors willingly adopted unique teaching methods via the maker projects.

When students feel they are making significant contributions to an activity, this is considered social engagement (Fredricks et al., 2004; Willms et al., 2009). During the study, there were many examples of how students contributed to their projects in meaningful ways. Several students said they enjoyed the collaborative aspects of the projects. Sandy felt the group worked together well because there was a fair exchange of ideas among the group's members. Sandy also took the lead on some of the technical portions of the project. However, making a significant contribution did not have to come from sharing one's familiarity with the technology used. While Simon did not contribute to the project's technical portion, he focused on conducting a literature search for his group. Simon felt that "the most satisfying was to just work collaboratively and to be able to work in a less serious type of learning environment." He noted that it was a rewarding learning experience because the group was allowed to be creative in solving their beaver problem. Both Simon and Sandy contributed to their groups in different ways. Even when projects were highly technical, students like Simon with less technological expertise were engaged with other parts of their projects.

Examples of intellectual, academic, and social engagement are apparent in the maker projects within the study. As discussed, each instructor viewed engagement differently, but the study indicated engagement occurred while students worked on their maker projects. More instructors would promote engagement if they were aware of the importance and identification of engagement. Fredricks et al. (2004) discussed how teachers view student persistence or helplessness as indicators of students' engagement levels. For example, engaged students will seem interested, ask questions and work well in teams. If students are not engaged, instructors need to reach out to try and understand why. Students may not be engaged because of a lack of interest, lack of challenge, or a lack of active participation. Going forward, understanding how to promote and identify engagement when students are making will give instructors insight into what is working and what should be improved.

Factors that Influence and Hinder Learning through Making

The second question guiding the study was related to exploring the factors influencing or hindering the use of makerspaces in non-STEM post-secondary courses, in the context of supporting student learning. I have identified the following four factors from the data: 1) Communication among participants; 2) Infrastructure for the projects; 3) Novelty of the technology, and 4) Complexity of makerspaces.

Communication Among Participants. Peppler et al. (2015) and Preddy (2013) pointed out that makerspaces can bring people together, as these projects often require a certain level of communication and collaboration among participants. The level of communication between students and instructors varied between classes. For example, Dr. Sean had direct in-class interactions with students when they worked on their maker project. While in the Geography I class, Dr. Cliff had his TA attend the sessions. Communication was a significant issue, as noted by Dr. Cliff, who discussed the importance of keeping communication open throughout the project. In Dr. Cliff's situation, there were several groups involved in the project and keeping everyone on the same page was necessary. The Geography I class had several more staff involved, starting with the instructor, Dr. Cliff, who initially worked with the Commons Staff to plan the maker activities. Dr. Cliff was not present during the sessions, and the implementation of the project became the responsibility of the TA and the Commons staff who did not take part in the planning stage. This hands-off approach meant that the TA and Commons staff during the session had to, at times, interpret and improvise when issues arose. As the TA and Commons staff became more comfortable with the project, and with each other, issues began to decrease. Tim commented, "I was able to adapt my instruction and so that by the end of the last, it had become a lot smoother than the initial day." A key to this improvement was how he communicated his approach to VR to the students, for example, simplifying the instructions that he gave to students at the start of the session. Dr. Sean and the Geography I class had the benefit of in-class interactions. While instructor-student interaction seemed to go more smoothly in Dr. Sean's class, initially, communication between students and staff in Geography I improved as they became more comfortable with the approach and provided materials.

Students not only communicated within the course but referenced outside sources for their projects. Technology is ubiquitous, and therefore it is easy for students to turn to technology to find solutions for the problems presented to them. Without careful planning, students will seek out the assistance of tools like search engines. As observed in Dr. Sean's class, many of the students found the same beaver solution, which also happened to be the first solution suggested by Google's search engine. As Willms et al. (2009) pointed out, students need emotional and cognitive investment to be intellectually engaged. How can the instructor help students be critical consumers of information, rather than take the first available solution? Dr. Sean's solution was to reset the class and brainstorm without the use of technology. In Dr.

Cliffs' case, he did not inform the class of the GIS and VR components until they had finished the field portion of the course. This omission helped avoid distraction by not looking too far ahead. In both examples, instructors attempted to ensure that students did not rely too much on outside sources like Google. A problem with readily-available solutions is easily searched (i.e. Googleable), but it is possible to construct challenging non-Googleable problems. McIntosh (2012) said that many topics have some Googleable content, which should be limited in learning activities. Instead, the focus should be on higher-order thinking unavailable in textbooks or through search engines. Therefore, a balance is possible to ensure students can still use technology for assistance without technology solving the problem outright.

Infrastructure for the Project Makerspaces. Infrastructure played an essential role as it provided the technology, tools, and space for students to learn through making. Choosing the technologies to support a makerspace required careful consideration of the activities and how the faculty used these technologies in their classes (Johnson et al., 2015). Each class had access to many different types of equipment. For example, the Geography I class had access to VR and GIS software; Education I used Micro Bits and breadboards; Education II used laminators and 3D printing. Each class was also unique in subject matter: Geography I focused on physical geography, Education I revolved around primary/elementary instruction, and Education II emphasized children's literature. The courses also differed in how they used their space. Geography used a computer lab and VR room; Education I used a classroom with tables where students could sit and collaborate; while Education II had the option of visiting the makerspace located in the Learning Commons at their convenience.

The perception of the space may also contribute to how comfortable it feels for those using it. Dr. Sophia commented that messy places are often more inviting. She said:

> My critique of this place it's very tidy, and it's scary, it's so tidy. So the carpet it’s very creepy to me. The art room in education that’s a dream to me, storage space, no carpets where you can be messy. This does not quite do it for me. If I wanted to use a glue gun, I want it out on a little cookie sheet clearly right there where it's ready to be plugged in. In the makerspace, you have to go get it.

An inviting space where students feel safe to participate and not break anything is appealing to some (Brahms et al., 2013). In contrast, Fox, Ulgado, and Rosner (2015) found that while some found messy spaces inviting, others found them uninviting and intimidating. Some makerspace members found chaotic environments, such as a garage aesthetic, were associated with a masculine DIY culture. Moreover, some scholars observed that messy spaces appeared more intimidating, especially to those not directly related to the field of engineering (Hynes & Hynes, 2018). Kurti et al. (2014a) found that sometimes a low-key space, such as a small maker table, could put students at ease, especially if they are new to the makerspace concept. While there may be no one size fits all space, an awareness of how students perceive space is important.

It is possible to overstate the usefulness and the transformative nature of technology (Oliver, 2011). Using technology for the wrong reason has the potential to create more issues than it solves. While practitioners may view technology as an important tool in teaching and learning, its usage should not be considered the end objective (Okojie et al., 2006). The key is the purposeful or intentional use of technology integrated into the learning (Jacobsen et al., 2002b). In Dr. Sean's class, he purposely limited the amount and complexity of the technology used. Dr. Sean selected eight technologies that were easy to learn, so students focused primarily on their beaver projects. As Dr. Sean points out, "The main challenges are always the same, people's perceptions. Some people think technology is a problem to overcome." To help overcome potential negative perceptions of the available technologies, Dr. Sean took the time to discuss the technologies and answer questions students had. In addition, Dr. Sean gave students agency, by allowing them to pick the technologies they would use for their project.

Struggling with technology was observed during the Geography I session, as some students were unfamiliar with the GIS software and had to spend a considerable amount of time asking for help. Madonna, a student, observed in the GIS session that her friend was not comfortable with computers and struggled with that part of the project. Madonna also suggested that working together could be beneficial, having noted that "in a group of four people, there is someone that's pretty decent with a computer." This insight is supported by Peppler et al. (2015) and Preddy (2013), who argued that those working on maker projects often do not work alone. Often, projects require collaboration, communication, and valuable skills that are brought in by their group members. Instructors should consider the potentially wide range of experience and skills among students working on maker projects. Instructors could then assign students to particular groups after they are familiar with their students' skill sets (as they pertain to the project). This assessment of skill sets could be made possible by having students share their experience with relevant technologies during class.

As Bauer and Kenton (2005), Friedman (1997), and Gorder (2008) suggested, we need to have a good understanding of the integration of technology into fostering meaningful student learning. This was illustrated in Dr. Cliff's interview when he discussed the initial planning of the project. Dr. Cliff, who had a limited understanding of makerspaces, did see it as an opportunity to enhance his class. Initially, the project was to include only GIS and 3D printing (VR's inclusion was a later development). When it was understood that VR could be used to view the field site from various visual perspectives, this provided Dr. Cliff with additional options regarding potential sites to be visited during the field trip. On reflection, Dr. Cliff felt he could further improve the student experience in upcoming courses. He stated:

> Since we were starting, I wasn't sure what the result would be, so now I know what the result would be, and I can clearly then tailor my thinking in the way that I introduce it in class and so forth to make sure that it fits better.

Even when makerspaces have a solid infrastructure (e.g., access to various resources and materials), their capabilities may not be apparent to instructors. They may not understand or have the experience needed to see the potential of the various tools and resources for their project. Furthermore, instructors' limited experience with learning and teaching through making may result in a limited scope with respect to the breadth and depth of the infrastructure used in their maker classrooms. A suggestion may be to use an iterative approach to maker projects that allows instructors to become familiar with the infrastructure and its capability.

Novelty of the Technology. A recurring theme in all three classes was that the projects piqued students' interest due to the technology's perceived newness. Several students interviewed indicated that new technologies, such as 3D printers and Virtual Reality, kept their interest in the project. This apparent interest in new technologies is supported by Giannakos et al. (2017), who suggested that the novelty of maker technologies can help attract students to these types of activities and can help engage students in learning. Madonna, a student, commented that she found the 3D printers "super fun and super cool" and was excited to see the 3D print result. She said, "to be honest, I'm kind of childish, so knowing that I was gonna get this (the 3D print) at the end of the project made me giddy." Tim, a TA, commented that students seemed to be attracted to the 3D printers. He stated: "There's something about 3D printing that just captures people's imagination; it seems like something out of the future". Megan commented that she liked the project's novelty and stated, "This isn't something that you use every day. You're not using 3D printers in typical everyday activities. I like being in this type of environment and even seeing other people use virtual reality; it's so cool." Brady also commented that, a few weeks before, he watched a Netflix series called *The Art Of* on 3D printing then found out that he was going to get the chance to use one. He said, "Watching the show was my first exposure to it and then once we were told we had to do this I was pretty excited about it." At least in the short term, several students demonstrated that the technologies' newness helped motivate and engage them while working on maker projects.

While technologies such as 3D printing and VR can motivate students, they also have the potential to intimidate. For example, Simon, a student, chose to let the other group members work on the technical parts and regretted this when reflecting on the project. New technology may attract the interest of some students, but it may also discourage others. Some students may even show signs of technophobia. A study by Anthony et al. (2000) found that while 50% of university students did not show any fear of technology, 33% demonstrated a moderate to high fear of using technology. To alleviate these fears, it could be beneficial for instructors to find ways to lower the level of intimidation. Dr. Sean, when interviewed, made the following comment:

> The technology I used was designed for kids, they're basically just a step above toys, right, but I take that attitude about almost anything. If you could break it down, there are two types of people, people who are attracted to shiny things and there's another group that runs away from shiny things. I don't see technology being a problem. I think once you expose people to it, once you give them enough comfort, most people are smart enough to realize oh, this is not that bad, right.

This comment was consistent with his communication to the classes about the technology he used. In this case, he framed the technology as a potential tool for the students' future teaching careers.

While students in all classes used many maker technology types, Learning Commons maker equipment, such as 3D printing, was the most popular, mainly due to the technology's novelty. There was diversity, however, with respect to the equipment used in the three classes. This variety is aligned with previous observations found in the literature by Barrett et al. (2015). They surveyed 51 makerspaces and reported that while there were some commonalities, there was a diverse collection of equipment among the 51 makerspaces, the majority of which provided 3D printing capability. Even though 3D printing equipment is standard within makerspaces, it is relatively uncommon within the general population (Dickinson, 2018). As students still consider 3D printing novel, there was a certain level of excitement felt by those who had limited or no experience using this type of technology.

Technology, by itself, will not improve teaching and learning initiatives within the classroom (Fourie & Meyer, 2015; Vossoughi & Bevan, 2014). As Clifford and Friesen (2001) stated, “New technologies should never be about pouring old wine into new bottles” (p. 39). Technologies allow students to undertake more complex tasks, which would not be possible otherwise (Clifford & Friesen, 2001). The challenge is for instructors to design the learning task for which students are purposefully and intentionally using the technology to support their learning. For instructors and students to use the technology, they may need to learn how to use it first, requiring demonstrations or workshops. It may create a collaborative opportunity where students can learn with and from each other. Careful consideration needs to be given by the instructor on how to best support technology’s utility in learning. However, authors such as Giannakos et al. (2017) and Martin (2015) have suggested that technology can increase student engagement.

Complexity of Makerspaces. There is the potential for makerspaces to be intimidating to students and instructors when they first encounter this type of environment (Lewis, 2019; Purpur et al., 2016). The intimidation may be the result of the number of tools available which can potentially be daunting. For example, Henry commented that he did not interact with the maker tools, partly because he did not consider himself technically sound. Instead, he left that task to other group members while he focused on research.

The types of technologies used varied considerably across the three classes. Dr. Sean purposely chose to limit the amount of technology available to his students, while Dr. Cliff gave his class no choice, as the students used the technology specifically designed for their project, which was GIS software, VR headsets, and 3D printers. In Dr. Sophia's class, the students were permitted to use any technology that was available in the makerspace. The university's Learning Commons webpage lists equipment ranging from basic tools, like a sewing machine, to something as advanced as a laser cutter. The overabundance of choice could pose a significant barrier to students, especially those who do not consider themselves technically inclined or handy. Instructors could be encouraged to create an environment where students do not feel overwhelmed with the tools and technology they potentially have at their disposal.

There are ways to help mitigate the feeling of being overwhelmed by the maker experience. First, instructors could conduct an introductory workshop focusing on the tools and technologies that will be made available to students. An introductory workshop would allow students to learn about makerspaces and discover their interests around the specific technologies being used (Lewis, 2019). The second would be to pair novice users with those who are more familiar with makerspaces. Also, novice users need to be encouraged to interact with the technologies. Finally, the instructor needs to set reasonable expectations for projects. Lewis (2019) suggested setting clear expectations for beginners. For example, we would not expect a total novice programmer to write an elaborate application in 16 hours. Considerations around introducing the Makerspace concept at the planning stages of projects can lower the level of intimidation for students.

Selecting and using technology needs to be considered purposeful in supporting learning (Friesen & Scott, 2013; Jacobsen et al., 2002a). Access to specific technologies that could be dangerous may require operational and safety training (Sheridan et al., 2014). With other technologies, the students may require learning how to use it. Instructors need to factor these issues into their projects: What supports are required to use the technology and who can support students in learning it. Training can be more formalized where students have to complete training, or training can be more informal where staff or experts assist less experienced students in a “just in time” environment. (Sheridan et al., 2014).

How Students Engage in Learning Through Making

The overarching research question that guided my study was: “How do post-secondary students engage in learning through makerspace activities in non-STEM courses?” Throughout this study, it was evident that students engaged in many ways. While many of the students became engaged in learning while working on their projects, others were engaged in more traditional methods (for example, when Simon went to the library and researched beavers for his group).

Most students interviewed expressed an awareness that the maker approach to learning was different than what they expected. Many of the students were used to either writing exams or papers to demonstrate what they learned, and these tasks usually accounted for a large portion of their final grade in the courses they completed. Traditional lectures, where the instructor would present information and the students would take it in, still comprised most in-class activities. This view is supported by Kafai et al. (2014) who suggested maker activities have the potential to differentiate themselves from traditional learning by providing new ways of approaching learning, yet also share the common goal of mastery of the presented concepts to the students. In the following section, I discuss the following three primary influences of student engagement in learning: 1) Engaging through play, 2) Using an authentic problem, and 3) The role of reflection in engagement.

Engaging through Play. Research points to students learning through the act of play in higher education (Kafai, 2006; Martin, 2015; Wohlwend & Peppler, 2015). Students interviewed often used the word ‘play’ to describe their experience, referring to play as taking risks in their learning approach, including creating a board game, developing a beaver dam, or constructing a 3D model. While students in this study were university-aged, many expressed the value of having the freedom to play and experiment. One example of this freedom is found in Grace’s opportunity to play with the GIS software. Bella expressed that she was far more engaged in her project precisely because she had the chance to play instead of being told what to do. Both Grace and Bella understood the importance of play and appreciated having the opportunity to engage in some play while completing their projects.

Playing was not just limited to the students. Instructors and TAs also enjoyed learning while participating in maker projects. Tim, a TA at the Learning Commons, felt that he and many participating students were playing and learning. He said,

> I always enjoy making and creating things, so being in the makerspace, it's not even like work half of the time; it is just like playing and problem-solving. For me, that ends up being really engaging. I almost feel bad I'm taking a paycheck half the time.

Having this freedom to play allowed Tim to be cognitively engaged and feel he was not working. This enjoyment and positivity can also help contribute to engagement within the classroom by promoting a positive social and emotional environment for students (Reyes et al., 2012).

Dr. Sophia was very aware of the value of play and generally feels that many adults have forgotten how to play. Cross (2002) supports this idea in their observation that adults passively absorb information at museums, while children want to interact with the environment. Dr. Sophia felt it was essential to challenge her students to play. Dr. Sophia gave the example of a birdhouse workshop. She said:

> Instead of following instructions, you tell students to play around with those pieces for a few minutes; let's see if you can figure out how they go together, how fun would that be. So what if it doesn't quite go together the way the perfect birdhouse does. That shuts down any chance of trying it out and that is problem-solving at its best.

Dr. Sophia discussed that students are intent on seeing examples for the same reason, so it is important to force students to play with ideas and learn by trial and error. Bevan (2017) pointed out that education is often too focused on learning and problem solving, while the act of making can produce a sense of playfulness in those participating. By incorporating learning objectives within a maker context, a more profound learning experience is possible through play (Wohlwend & Peppler, 2015).

Using an Authentic Problem. The act of engaging students partly involves creating a problem worth solving. Students' projects should be meaningful; they need to be relevant, authentic and challenging (Friesen, 2010). Oliver (2016) suggested that makerspace projects are more successful when the experience's authenticity allows for a personal investment. Dr. Sean stressed this point in his interview. He said:

> I really think it's the authentic problem that is key, finding something authentic to work on that's meaningful. Authentic doesn't mean that they're going to go out and showcase their solution to Hibernia or Nalcor, and it's going to be adopted just that it's authentic and connected to the real world.

Barrett et al. (2015) supported the idea of having a project linked to real-world problems. Students can also benefit when their projects connect to what they are learning (Horvath and Cameron, 2015). Real-world or authentic problems, such as a community issue, can engage students and bring a sense of purpose to what they are learning (Parsons & Taylor, 2011). This need for authenticity was also apparent in Dr. Cliff's class when they worked on their GIS project. They were doing the work based on a real cove they visited just a few weeks before. What they created was an actual 3D print of the landscape they observed. This simple piece of plastic was tangible and related directly to what they observed in the field. Generally, students demonstrated that they valued the project's real-world connection that maker projects afforded them.

Not all students who participated in the study were engaged in learning. Many factors may have contributed to their lack of engagement, such as how they viewed their given problem's authenticity. Some students may have felt they had no connection or saw no relevance in the problem. This disconnect was apparent in the Geography I class, where some students may not have perceived their assignment, in full or partially, as authentic. One of the students interviewed in the Geography I class, Sam, did not complete all three parts of the project. Part of the reason for this could have been the degree to which he viewed the problem authentic. Sam was not a Geography major and said: “I feel that if I were to do geography as my major, I would value it (the 3D printed wedge) far more.” In Sam's case, this was an elective, and he may not have had the technical background or general interest in the project to make it meaningful for him. As such, instructors should design learning projects through the use of authentic or real-world problems, which foster students’ connection to the course’s content. Problems must not just be merely authentic, but they also need to provide a challenge and should be multidisciplinary (Jacobsen et al., 2002b). To achieve a sense of authenticity, instructors might take additional time at the start of the project to talk about the issues and challenges related to the project topic and how it relates to the local area, society, and the students themselves. Making a connection to the topic is a critical element of student engagement.

The Role of Reflection in Engagement. While not an initial focus of the study, one common thread that weaved through each of the classes was the reflection component presented within each class. Dewey (1933) said, “We do not learn from experience. We learn from reflecting on experience” (p. 78). While not planned as a component of this study, it was observed that all three classes had some form of reflection built into their projects. Dewey’s (1910) view on reflection alluded to revisiting a problem from different perspectives by stating, “Reflection is turning a topic over in various aspects and in various lights so that nothing significant about it shall be overlooked” (p. 57). He then likens reflection to inspecting a stone, by stating that reflecting is like how “one might turn a stone over to see what its hidden side is like or what is covered by it" (p. 57). This analogy is relevant to my study, as students were often encouraged to reflect on their projects.

Students reflected while completing their projects as well as once their projects were completed, though more formal reflection occurred once students finished their projects. In Geography I, each student had to answer questions once their project was completed. In Education I, students presented their work to the group, while students in Education II submitted a final write up. Reflecting was like turning over a stone, as students and instructors can potentially use what you find to enhance the project.

In-project reflection, also called in-action reflection, is defined as the reflection that occurs as the activity unfolds (Schön, 1984). An example of this occurred in Dr. Sean's class when he went from group to group, asking questions related to why students believed the technology they were using was the most appropriate for the objective of their project and ways of looking at the problem. Student self-reflection was also apparent during the class when the instructor and other students were raising questions. Reflection-on-action refers to reflecting on an activity that an individual has already experienced or completed (Schön, 1984). For example, in Dr. Sophia's class, students were asked to write a small reflective paper upon the completion of their project. Boud et al. (1985) pointed out that instructors often overlook this learning stage, perhaps assuming that students reflect intuitively. Reflection at the end of an activity can positively impact engagement; its implementation should be considered during the planning stages of maker projects.

While reflection-on-action was explicitly discussed and assigned to the students, reflection-in-action was not. Boud et al. (1985) suggested the act of reflection is so familiar to instructors, that it is often overlooked in formal learning settings. The structure of the courses may provide some insight into action-reflection. For example, in Geography I, there was a very compressed schedule with strict timelines. The students had a set time at which to finish the GIS portion of their projects. Generally, students had little time to do anything else but complete their projects.

On the other hand, in Dr. Sean's education class, students worked in groups and completed their projects in four sessions, each lasting four hours in duration. Discussion was encouraged, and it was observed that, as students discussed their ideas, their projects evolved. In Dr. Sophia's education class, groups worked independently and individually, and, therefore, it was challenging to observe this behaviour. The amount of reflection-on-action varied. No instructor formally discussed it when observed or interviewed.

Each class was unique, and this extended to the approaches in implementing reflection in their maker projects. However, one approach they all had in common was that students were required to do some reflection when concluding their projects. How the instructors implemented the reflection differed among classes. Dr. Sophia had students write a small paper and put some time aside so students could play each other's games. Dr. Sean required the group to write up a reflection paper on what they had done. He also required students to present their projects, which included specific questions that made them look back at their work. Dr. Cliff asked students to do a small write-up on what they learned, and posed questions that encouraged students to relate their project to the subject they were studying, physical geography. Dr. Cliff also included an option on the final exam, where students could select one of three questions. Dr. Cliff observed that the majority of the students attempted the maker questions compared to other exam questions. He also noted that, overall, the quality of students' responses to the maker questions were superior to the other questions' responses.

When considering a maker project, instructors should be purposeful in their approaches to reflection. Meaningful reflection can help direct what students are learning (Boud et al., 1985; Majgaard, 2014). When designing a maker project, consideration should be given not only to reflection-on-action, but reflecting on the completed work. A paper or presentation might serve this kind of reflection well. Reflection tasks should also be considered in-action, for example, asking students to reflect while working on their maker projects. Incorporating reflection within a maker project should always be considered, along with the authenticity of the problem presented and the utilized technology types.

Complexity of Engagement. Through observing and interviewing both instructors and students, it became evident that students engage in many ways. Student engagement is complex (Archambault et al., 2009), and measuring and observing it can be equally challenging (Newmann, 1992). The complexity of engagement in making does not just stop at students and projects. All three instructors who participated in this study appeared to share some common traits. For example, the instructors were motivated, valued reflection, and wanted to construct an authentic problem for students to solve. However, they also differed in their approaches used to motivate students. For example, Dr. Sophia favoured open-ended questions with students working individually, while Dr. Cliff had a closed approach where students worked individually. Dr. Sean fell somewhere in the middle, asking his students to work in groups of two. How each instructor perceived engagement was also different. Dr. Sean looked more to time on task and the final presentation, Dr. Cliff associated the project's quality with the student's level of engagement, and Dr. Sophia valued reflection and how the pizza box games were displayed. When instructors plan maker projects for their students, they must be aware that measuring engagement is an involved process because it is difficult to gauge, and there is no one best way to proceed.

Conceptual Framework

My initial framework in Chapter Two was developed by drawing on relevant literature, which allowed me to organize and focus my study. From reading Bloomberg and Volpe (2012) and Merriam and Tisdell (2015), I expected my conceptual framework to evolve as I worked through the study.

My final conceptual framework recognized that engagement components are not easily qualified, as a result I looked at the concept of engagement through a wider lens. The framework illustrated in Figure 8 reveals the interconnectivity among instructors, makers, making, makerspaces, and students, leading to the outcome of student engagement. The instructors teach the students knowledge and skills. As noted by Koehler and Punya (2009), consideration needs to be given to the importance of knowing how technology can be used in the classroom. As illustrated in my study, the use of technology can be determined by the instructor, student, or other sources, such as staff in the Learning Commons. The instructor may not be an expert in making, but they need to be open to working with other people who are knowledgeable in using various technologies to support student learning through making. Both the instructor and students can learn from each other as they interact in the making process within a makerspace. This interaction leads to the outcome of student engagement.

Instructor

The role of the instructor is to design the learning through making with intention. This begins with the use of an authentic problem, which is then followed with facilitating and supporting the hands-on learning experience. The instructor is a content expert and needs to consider this when creating the authentic problem, as an authentic problem fosters more engagement from the students (Fredricks et al., 2004). After considering the content of the topic and creating an authentic problem, the next step for the instructor is to design and scaffold how to solve the problem. In addition to designing and facilitating the learning through making using an authentic problem, the instructor should also consider the importance of reflection-in-action and on-action (Schön, 1984). The instructor, throughout the learning process, needs to create opportunities for students to reflect on their learning which promotes further engagement in the learning process within the maker environment.

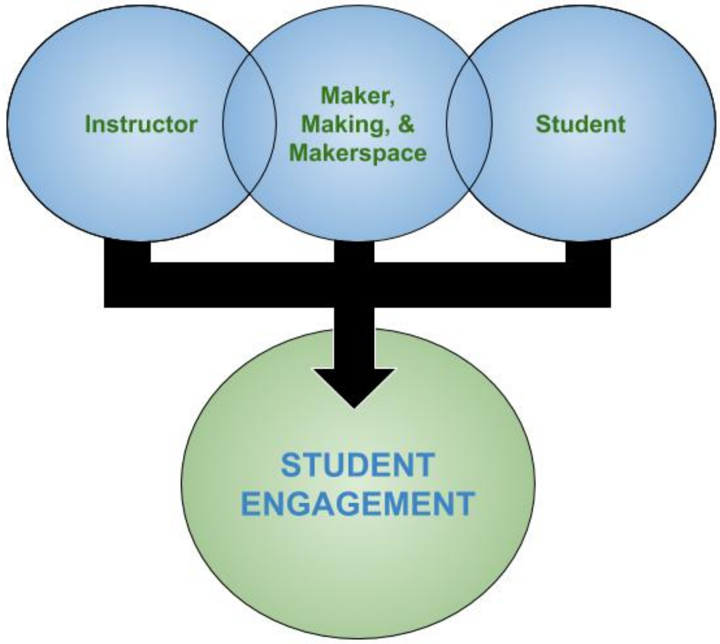

Figure 8. A conceptual framework for the creation of an engaging maker project.

Maker, Making, and Makerspaces

Makers encompass any person participating in making who has an interest in creating (Peepler et al.,2016a). This includes the instructor, the students, and individuals such as those with technological expertise, such as Learning Commons staff. When learning within a maker context, communication plays a major role among the various stakeholders as it facilitates the transfer of ideas. The students learn from each other, and this supports making while promoting student engagement in learning. As learning through making is a different than a traditional, didactic approach, makers should be encouraged to be active learners with an openness that promotes reflection, communication, and engagement.

The making process encourages collaboration with peers, as well as with those who have more expertise in content and technology. The authentic problem, which is the focus of the learning task, is grounded in the real-world context and challenges students to find suitable solutions. As students work through such an iterative process, reflection is integral in terms of reflection-in-action and reflection-on-action (Schön, 1984). Reflection helps to promote engagement with the making process, resulting in more in-depth learning.

Makerspaces can vary widely and take on many forms (California Council on Science and Technology, 2016). They can range from a mobile makerspace on wheels to a dedicated space residing in a Learning Commons. It is important to consider the tools and space available to instructors and students within a makerspace. If a makerspace has minimal infrastructure, this may impact the nature of the design of the learning tasks, as well as what students can do in creating possible solutions to the authentic problems. However, having novel tools can help foster engagement within the learning process, for example having access to technology, such as 3D printers, in a Learning Commons. Makerspace allows for students and instructors to access technology and technical support. These supports do not need to be in their classroom space. The makerspace offers an array of resources, along with possible expertise that can be accessed by both students and the instructor as they engage in the process of learning through making.

Student

As the learner, a student engaging in making within a makerspace needs to be open to inquiry, play and experimentation (Halverson & Sheridan, 2014). As the students engage in the making process, they may need to access various resources and technology in creating their unique solution to the authentic problem presented in the learning task. Students may not know how to use the technology associated with the makerspace, however, the scaffolding provided by the instructor and/or other experts (e.g., Learning Commons staff) offers an opportunity for students to learn and develop competence in using the technology to support this hands-on learning.

An important component of learning through making involves students communicating with their peers and their instructor, which enables idea sharing and problem solving. Students are encouraged to learn from each other as they work to create and test solutions to the authentic problem. Further, engaging in reflection throughout the process provides opportunities for students to explore what is working, what is not, and what the next steps are.

Student Engagement

Student engagement is a major outcome of the interactions and interconnectivity among instructor, makers, making, makerspaces, and students. This interconnectivity is demonstrated in the following ways. The instructor designs the learning and develops a scaffold to support this hands-on approach to learning. Maker, making, and makerspaces help enable the acquisition and application of learning. The instructor creates the learning task based on an authentic problem. The student, as the maker, engages in a process of finding or creating solutions in addressing the authentic problem. These learning tasks are created within the infrastructure afforded by the makerspace.

What was evident from the study is that it is difficult to separate academic, social and/or intellectual forms of engagement. Rather, it is the amalgamation of the three that is identified as student engagement.

Academic engagement has been defined as “the participation in the formal requirements of schooling” (Willms et al., 2009, p. 7). When learning through making, academic engagement is present as the students are required, as part of the course, to participate in the project to meet the assessment requirements developed by the instructor.

Intellectual engagement is defined as “an emotional and cognitive investment in learning, using higher order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge” (Willms et al., 2009, p. 7). Intellectual engagement occurs when students begin to demonstrate an emotional investment in their learning, which increases their understanding and the potential for the construction of new knowledge.

Social engagement is defined as a “sense of belonging and participation in school life” (Willms et al., 2009, p. 7). During the delivery of content and the making process, the students were socially engaged. They collaborated with each other and with their instructor to understand and then solve the authentic problem.

Within this framework, student engagement is viewed as an amalgamation of academic, intellectual, and social engagement. What was observed is that more experienced students may require more challenging projects to maintain engagement. Conversely, students with less experience with making may become disinterested and disengaged if the problem is too complicated. The key is to have the balance between experience and challenge, that results in student engagement. In this optimal balance, students become immersed in their work and are intrinsically interested in what they are working on (Csikszentmihalyi, 1997; Willms et al., 2009). Although it is difficult to measure student engagement, the conceptual framework illustrates the interconnectivity between instructors, makers, making, makerspaces, and students, leading to the outcome of student engagement.

Chapter Summary

This chapter set out to answer the three research questions by drawing on the findings and relevant academic literature. What proved critical in the study was the importance of: student and instructor engagement; understanding how engagement may differ among individuals; having the infrastructure and expertise for makerspace; and allowing students to focus and reflect on an authentic problem.

The chapter concluded with a revised conceptual framework that highlights some of the factors contributing to creating maker projects that students will view as engaging, such as: having a novel infrastructure for a makerspace; having expertise and authenticity in making; and having makers who reflect and communicate well with each other.

In the final chapter, I will discuss the study's successes and challenges, its limitations, implications for practice and policy, and direction for future research.

CHAPTER SIX: CONCLUSION

This chapter summarizes the dissertation and discusses the key research findings, limitations, practical implications of the study, and the research process. I conclude the chapter with recommendations for further research and some thoughts on engagement and makerspaces in postsecondary institutions.

Research Study Summary

My main research question asks: How do postsecondary students engage in learning through makerspace activities in non-STEM courses? I designed a qualitative case study involving three undergraduate classes that used maker projects within their classrooms. Key findings of the study included the importance of support for instructors, student engagement, reflection, and the potential of makerspaces to foster engagement. Firstly, for makerspaces to play an increased role in the classroom, instructors need support and encouragement. While instructors have subject matter knowledge, most instructors have no prior experience with makerspaces and their classroom implementation. Secondly, students' perceptions of engagement differed. To become engaged, students needed to work on an authentic problem that challenged them. For many students, maker projects offered an opportunity to engage, often through play, so maker projects may be considered another tool to promote student engagement in the classroom. Thirdly, students must reflect while engaging with their maker projects (in-action reflection) as well as following the completion of their projects (on-action reflection) to allow them to benefit from this type of hands-on learning. Finally, makerspaces can engage postsecondary students in the classroom and could support formal learning directly.

In addition to these four key findings, I developed a conceptual framework based on the study's themes. The framework illustrates how makers, making and makerspaces work together to create an engaging experience for post-secondary students. The framework attempts to illustrate the complicated relationship between instructors, makers, maker projects, makerspace, and student engagement. Multiple elements within maker, making and makerspace can contribute to student engagement. For example, the maker who is reflective, who communicates and perceives the project's importance will show more engagement. For the making process, expertise, authenticity, and reflection are crucial to engagement. Finally, the makerspace infrastructure, novelty and complexity contribute to student engagement.

My study's significant contribution to the discipline demonstrates the important relationships among student engagement, instructor engagement, and learning. The use of makerspaces in postsecondary non-STEM courses can enhance learning through engagement. To be a successful learning tool, makerspaces must help solve an authentic problem. To do so, experienced staff and adequate infrastructure are required to allow students to reflect on their problems effectively.

Reflection on the Research Process

Two elements of the study were very successful. The first relates to combining my work and education. The fact that I had already created a makerspace at my university helped me with my research, especially the contacts I made during its operations. In particular, one of these contacts helped me secure an instructor for my study.

Second was the collection of data from both students and instructors. Students and instructors had many competing priorities; however, they found the time in their busy schedules to be interviewed. I found both students and instructors to be very forthcoming when interviewed. I was very impressed by how articulate each student and instructor was, and how willing they were to open up, sharing, at times, very personal details to me. Those who were willing to participate were very generous with their time. This enthusiasm resulted in detailed descriptions of their experiences, which aided my analysis.

There were three challenges in conducting the study. First, I conducted the study in the Fall semester at a single university. The criteria I used were contingent on the participant's willingness to participate in the study. This sampling limits the confidence placed in the notion that those selected for the study adequately represented the studied population (Creswell, 2012). Furthermore, one of the study's classes had a low participation rate; only two students and the instructor from said class participated. This low number restricted the amount of available data compared to the other two classes that participated in the study. This low result may have impacted the findings and may not have been representative of the class. To ensure that I procured sufficient descriptions of the studied phenomenon, I collected detailed information from interviews, observations, and focus groups. The results of this study are reflective of the thick, descriptive data collected throughout the study.

Second, as a novice researcher, I have a new appreciation for those who volunteer to participate in research. As someone who works and studies at a university, I see countless posters and emails looking for study participants. It is easy to ignore these requests and assume someone else will come forward and volunteer. While I feel enough data was collected, I underestimated the difficulty I would encounter getting both instructors and students to participate in my research. Due to this experience, I participated in several studies while completing my dissertation and will continue to do so going forward.

Third, a major challenge was dealing with the logistics of organizing the study during an academic semester. Students and instructors have many demands placed on them throughout a semester, making it challenging to collect data for the study. For example, while the students in my study were very accommodating, finding time for interviews outside their busy schedules was difficult. This challenge meant I had to take a step back and create a more fluid schedule that resulted in a slightly longer data collection period.

Implications for Practice

This study contributes to the field of student engagement through observing the use of makers, making and makerspaces to deepen the knowledge attained in post-secondary education. Careful consideration in implementing these tools is necessary to further engage students in post-secondary studies.

My research's practical implications can be viewed from the following four different levels: 1) instructor, 2) Learning Commons, 3) department or administrative leadership, and 4) education development. In this section, I share the implications for practice per each of the four levels.

At the instructor level, instructors need to be encouraged and supported when undertaking a maker project. Maker projects require expertise, resources and space to be successful. While some instructors may have the expertise, resources, and space, most higher education instructors who want their students to engage in learning through making may not. Individual instructors have content expertise but often lack the resources or maker expertise needed to develop a successful maker project. Instructors should be made aware of the potential of learning through maker projects within their classrooms and the available supports within their institutional contexts. These opportunities may encourage instructors to consider the facilitation of learning through making in their classrooms. However, there may be implications for the nature and type of educational development needed for instructors.

At the Learning Commons level, existing maker facilities may increase utilization by allowing their makerspaces to facilitate teaching and learning. In addition to providing space and equipment, makerspaces can play a pedagogical role in improving both instructors' and students' skills and confidence in using makerspaces. Encouraging students and instructors to utilize the Learning Commons for makerspace projects may further improve engagement with learning. Future studies may explore this concept. Makerspace staff could help instructors further by training instructors on the implications of their proposed maker project. Makerspace staff can also conduct pre-workshops, allowing students to become familiar with technologies before starting their projects. Regarding technology, the Learning Commons may offer prospective instructors workshops concerning specific applications and digital literacy. Working in tandem with instructors, Learning Commons staff may provide additional assistance to students working on their projects (e.g., demonstrating possibilities when working with 3D printers). A critical element is the need for instructors and Learning Commons staff to engage in conversation to determine the level of support and expertise required for implementing the learning through making initiatives.

At the department/administrative leadership level, the leaders play a role in encouraging innovative teaching practices by engaging students in learning through making. Department leaders need to acknowledge that, while this form of learning may be beneficial, it may require additional time and energy from the instructor. Material and other resources required to complete such projects will need to be resourced to support the learning. Like makers, instructors need to feel they have the latitude to experiment with such innovative projects in their courses. Maker project success should be celebrated, not only to encourage, but also to promote awareness to other instructors of these projects' potential. Further, encouragement and promotion at the departmental level will inform instructors about the work and may support others who wish to adopt maker pedagogy in their teaching.

At the education development level, the role maker practices play in student engagement and the nature of the support for teaching and learning centres needs to be explored. To improve their capacity to design and facilitate learning through making, educational developers should advocate for consensus regarding this topic. Subsequent work with the experts from Learning Commons (e.g., technical specialists) can provide pedagogical support and ensure instructors' technical support and expertise. Supporting instructors in developing and facilitating maker projects will allow them to focus on the course content and not become overwhelmed or frustrated when learning the technology. Department leadership also has a role to play in this collaborative approach in terms of time and resource availability.

Recommendations for Future Research

While my study primarily looked at non-STEM students' potential, many other students could benefit from learning through making. Future researchers could consider repeating my case study in first-year university classes to document students' dropout rates in those using maker projects compared to those using more traditional pedagogical practices. This study would follow my outlined methodology; however, the result would be the proportion of students who pass the courses.

Success at post-secondary institutions requires that makerspaces have support at various levels (e.g., instructor, Learning Commons, department or administrative leadership, and education development). One potential further study could explore the extent to which individuals are aware of makerspaces at the department and educational development levels. In addition, such a study could investigate the degree to which individuals are proponents of makerspaces at the postsecondary level. This could be achieved by conducting a case study that gathers data from focus groups and interviews with faculty and staff regarding their awareness of the services available. Answering this question may also shed light on the long-term potential of makerspaces and their ability to be used in the classroom.

Thirdly, studies will need to be conducted at different universities and in different disciplines (e.g., Anthropology, Folklore or English). Studying these areas may provide more insight into maker projects' potential and the nature of support and resources required by students, faculty, and staff. Additional studies are viable for STEM courses that may not currently use labs (for example, mathematics).

Finally, I was writing this dissertation during a global pandemic, which was due to the Novel Coronavirus (COVID-19). During this time, most post-secondary institutions had to transfer their curriculum to an exclusively online format. Learning through making opens the door to learning opportunities that can be realized either online or through using a blended learning approach. Further studies could investigate students’ engagement in learning through making within online learning environments. Exploring what is needed to create a virtual making environment from both the student's and instructor's perspectives is an additional area of study that could be entertained.

Conclusion

Post-secondary students demonstrate engagement in non-STEM courses when using makerspaces. To maximize this engagement, instructors require technological support. Students must also work on a challenging, authentic problem, and must reflect while completing their projects as well as after their projects are completed.

When I moved from the private sector to higher education more than 15 years ago, I did so because I wanted to work directly with students and contribute positively to their post-secondary learning experience. As someone who has overseen the development of a makerspace in a university context, I have been in a unique position to witness student learning potential. Students can create many unique artifacts in a maker learning environment through purposeful design, tinkering and play, which provide opportunities to apply theory to practice and to learn through experimentation and iteration.

In contemporary post-secondary education, there is an emphasis on creating and supporting various learning opportunities. Most recently, there is a focus on experiential learning. As reported in my study, many students understand the importance of engaged learning and doing things differently, so they might learn more effectively compared to the ways in which they learned in the past. The importance of inquiry and hands-on learning provided students an opportunity to enhance their learning experience. What emerged from my study is that the maker community creates more than a space within which students can participate in the learning experience. Instead, the maker community creates an environment that encourages learning through making, which engages students in deep and robust investigation.

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Appendix A: Classroom Observation Instrument

Level of Student Engagement

Characterize the level of student engagement in the maker session.

Disengagement would include inattention, attending to an alternative activity, off-topic conversation, or misbehaviour.

Ritualistic Compliance is identified as working on assigned activities without enthusiasm or personal investment. Going through the motions of completing work to avoid conflict or unpleasant consequences.

Academic engagement is identified by on-task behaviours that signal a serious engagement in class work; these include attentiveness, doing the assigned work, and showing enthusiasm for this work by taking the initiative to raise questions, contribute to group activities and help peers.

Intellectual Engagement refers to an absorbing, creatively energizing focus requiring contemplation, interpretation, understanding, meaning-making, and critique which results in a deep, personal commitment to explore and investigate an idea, issue, problem or question for a sustained period.

Level of Engagement (LoE) Scale:
1 = disengaged 2 = ritualistic compliance 3 = academic engagement 4 = intellectual engagement

	Brief description of Activity	# of Students	# of instructors
Make Session **Start Time:** **End Time:**			

Student	**LoE #1**	**LoE#2**	**Description**
A			
B			
C			
D			

Things to consider when writing field notes

Environment:

- What is the noise level like?
- How many students are there?
- How many instructors and TA are there?
- What equipment are they using?
- What does the site look like (Take a Photo)?

Engagement:

- Are they on task, off-task, in the seat, out of seat or room etc...?
- What are they saying to each other?

- What are people doing?
- What are they trying to accomplish?
- What is happening now
- Are they focused, or not (e.g. talking about the task, or talking about other things)?

Other Considerations:

- Are my observations having an effect on students?
- How is the instructor interacting with students, how many questions are being asked?

Appendix B: Student Interview Questions

Introductory Script:

I would like to thank you for volunteering your time today to conduct this interview with me. The purpose of the interview group is to get a better understanding of makerspace in the classroom. In terms of format, I have some questions that I will ask. After each question you will have the chance to answer. At any time if there is something you would like to bring up about the topic feel free. Before we start, I would like to point out that your participation is completely voluntary and your identity to anyone other than me will be restricted. I will be creating an audio recording of the interview group that will be transcribed by me after the session group ended. Recording and transcription of the interview group will allow me to accurately reflect what was said.

Questions for Students

1. What did you make?
2. Why did you choose to make this?
3. List 3 makerspace tools you used for your project and how you used them.
4. What skills did you use while making your project?
5. How did you achieve the course outcomes through the maker activity?
6. In comparison to other courses, by using this maker activity how did it impact your learning?
7. What did you notice about how you learned?
8. How did you engaged in the learning?
9. When working on your project, what things did you find difficult about the makerspace?
10. What parts of the makerspace helped you in your learning?
11. What make this a successful learning experience?
12. What other comments about your maker experience would you like to share?

Appendix C: Instructor Interview Questions

Introductory Script:

I would like to thank you for volunteering your time today to conduct this interview with me. The purpose of the interview group is to get a better understanding of makerspace in the classroom. In terms of format, I have some questions that I will ask. After each question you will have the chance to answer. At any time if there is something you would like to bring up about the topic feel free. Before we start, I would like to point out that your participation is completely voluntary and your identity to anyone other than me will be restricted. I will be creating an audio recording of the interview group that will be transcribed by me after the session group ended. Recording and transcription of the interview group will allow me to accurately reflect what was said.

Questions for Instructors

1. What are the learning goals and outcomes you want to achieve using makerspace?
2. Did you provide students a set curriculum or more open-ended projects?
3. How will you assess the students on their projects?
4. How did working on a maker project help with what you were teaching in your course?
5. Did you find the students were more engaged working on maker projects?
6. What make this a successful learning experience?
7. What other comments about your maker experience would you like to share?

Appendix D: Student Survey Questionnaire

Introductory Script:

Hello, my name is Shawn Pendergast, I am a doctoral student at the University of Calgary and am studying the impact Maker activities have on the engagement of students in undergraduate classes at the university. Thank you for agreeing to take part in this survey. This survey asks questions about makerspace activities within undergraduate classes. Your responses are voluntary and will be kept confidential from your professor and your peers. The survey will take less than 10 minutes, and your answers will be in the strictest confidence. In a few weeks, you may be contacted to volunteer to participate in focus groups and interviews on this topic. If you have any concerns, you can contact me directly at 864-6713 or shawn@mun.ca

Questions for Students

Which course are you taking

- Education I - Beaver Project
- Education II - Board Game
- Geography - GIS, 3D Print & VR of Middle Cove

Briefly describe your project

Did you know anything about maker before you started the course? (Yes/No)

How often did you feel bored working on your maker project? (1 to 5)

What do you feel was the most valuable skill you learned at the makerspace?

What did you find most challenging with the project?

Was this an engaging experience for you? (1 to 5)

Did you learn more using maker compared to other course activities in the past? (1 to 5)

Explain your answer to the previous question.

Would you participate in this type activity again?

Compared to other courses how much interaction did you have with your peers? (1 to 5)

What was the nature of your interactions?

What other comments about your experience would you like to share?

Appendix E: Instructor Survey Questionnaire

Introductory Script

This survey asks questions about makerspace activities within undergraduate classes. Your responses are voluntary and will be kept confidential. The survey will take less than 10 minutes, and your answers will be in the strictest confidence. If you have any concerns, you can contact me directly at 778-0602 or shawn@mun.ca

Questions

Which course were you involved in?

- Education I - Beaver Project
- Education II - Board Game
- Geography - GIS, 3D Print & VR of Middle Cove

In terms of effort, how much work did it take to prepare your activity compared to other activities you have done in the past? (1 to 5)

What do you feel was the most valuable attribute is about the makerspace?

Do you feel students were engaged in their projects? (1 to 5)

Based on your answer in the last question please explain

Based on this experience would you plan more maker projects in upcoming courses (Yes/No)?

What do you feel was the most valuable skill you learned doing the project?

How would you rate your experience with making in the classroom? (1 to 5)

What other comments about your maker experience would you like to share?

- What do you feel was the most valuable skill or thing you learned at the makerspace?
- How would you rate your experience with making in the classroom?
- What other comments about your maker experience would you like to share?