2017

Tinkering in K-12: an exploratory mixed methods study of makerspaces in schools as an application of constructivist learning

Ashley Cross

Pepperdine University

Graduate School of Education and Psychology

TINKERING IN K-12: AN EXPLORATORY MIXED METHODS STUDY OF MAKERSPACES IN SCHOOLS AS AN APPLICATION OF CONSTRUCTIVIST LEARNING

A dissertation submitted in partial satisfaction

of the requirements for the degree of

Doctor of Education in Learning Technologies

by

Ashley Cross

April, 2017

Linda Polin, Ph.D. – Dissertation Chairperson

This dissertation, written by

Elizabeth Ashley Cross

under the guidance of a Faculty Committee and approved by its members, has been submitted to and accepted by the Graduate Faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION

Doctoral Committee:

Linda Polin, Ph.D., Chairperson

Judi Fusco, Ph.D.

Bill Moseley, Ph.D.

TABLE OF CONTENTS

LIST OF TABLES

VITA

EDUCATION

Pepperdine University 2013-2017 Malibu, CA

Doctor of Education | Major: Learning Technologies
GPA: 3.96

Graduate Assistant

- Compiled data on international projects from educators in Finland and Africa titled "Collaborative Research: A cyber-ensemble of inversion, immersion, collaborative workspaces, query and media-making in mathematics classrooms"
- Analyzed and coded specific sets of variables in data sets

The University of Southern Mississippi 2009-2011 Hattiesburg, MS
Master of Education | Major: Special Education, Mild to Moderate Disabilities
GPA: 4.0

The University of Southern Mississippi 2004-2009 Hattiesburg, MS
Bachelor of Science | Major: Elementary Education | Minor: Reading

RELEVANT EXPERIENCE

- Experience teaching adult learners, including current educators
- Extensive knowledge and application of innovate media and technology tools
- Doctoral level training in learning technologies and Google Certified Innovator
- Passion for higher education and advancing student learning through media and technology
- Experience leading interdisciplinary projects with adult learners

LEARNING TECHNOLOGIES

Director of Technology (Promoted) 2015 – Current Miami, FL

St. Stephen's Episcopal Day School

- Provide vision and leadership in educational programming
- Design and execute differentiated professional development for a diverse faculty of learners
- Cultivate reflective portfolios & a professional online presence for faculty and administration through training and workshops
- Lead Innovation Team, managing 4 employees
- Understand the educational environment, including the instructional focus, team building, and stakeholder focus
- Oversee social media marketing and branding efforts
- Plan logistics for Miami Device, an international biennial learning event

Assistant Director of Technology 2014 Miami, FL

St. Stephen's Episcopal Day School

- Delivered training for adult learners
- Implemented a Minecraft club
- Led our faculty and students in trainings to become a Common Sense Media Digital

Citizenship Certified school site

- Managed technology and support resources: information technology management, communications systems management, business management, and data management
- Experienced project manager: redesigned website, including video production
- Developed and executed strategic marketing strategies, goals, social media outreach, and other electronic communications
- Served on Strategic Planning Leadership Committee

Instructional Technology Specialist 2012-2014
Nashville, TN

Rutherford County Schools

- Created and presented professional development for teachers
- Supervised Professional Learning Community meetings
- Co-developed school strategic plan with long and short term goals
- Worked directly with youth implementing STEM projects
- Oversaw technology budget
- Co-taught lessons with teachers while modeling technology best practices
- Cultivated teamwork through positive reinforcement
- Oversaw administration of website and electronic communications
- Specialized in Adobe Creative Suite including Dreamweaver & Fireworks

TEACHING EXPERIENCE

Third Grade Teacher 2011-2012 White House, TN

Sumner County Schools

- Implemented research-based strategies in guided reading lessons to model questioning; developed higher order thinking skills and problem solving techniques
- Used behavior modification techniques as a motivator for improving conduct and encouraging participation
- Utilized hands-on activities to engage learners and improve knowledge retention

First Grade Teacher 2009-2011 White House, TN

Sumner County Schools

- Taught the inclusion class focusing on students with special needs
- Taught reading and foundational literacy skills
- Specialized in matching students with appropriate books
- Lead literacy & writing workshops for other educators

Disney Cast Member 2006-2009 Lake Buena Vista, FL

Walt Disney World Resort

- Delivered educational programming in an informal learning environment
- Represented the Walt Disney Corporation at Career Fairs
- Taught classes as an Instructor at the Animation Academy

ABSTRACT

Makerspaces have experienced a surge in popularity in recent years, resulting in an influx of Maker education in K-12 settings. While Makerspaces have been studied abundantly in museums, libraries, and in after-school programs, little research has been conducted inside the K-12 school day. The goal of this study is to discover insights of established Makerspaces inside the K-12 school environment. In this exploratory mixed methods study, educators were survived, examining school and participant demographics, Makerspace setup, as well as intersections of technology, content and pedagogy. Next the researcher conducted a follow-up interview with selected participants based on diversity in the following key demographic areas: teacher gender, professional background, and school environment. In order to better understand K-12 implementation of Makerspaces, the study examines seven characteristics of Makerspaces: setting, computational thinking, participant structures, teacher training, gender and racial issues, assessment, and sustainability. The data was examined through TPACK framework with a constructivist approach.

Makerspaces can empower students to invent, prototype, and tinker with low-cost technology tools such as microcircuits and fabrication tools such as 3d printers. The goal of this study is to add to the body of literature regarding the role and potential value of Makerspaces in school environments. This exploration of Makerspaces in K-12 setting could be generalized to serve as a guide for teachers who want to establish their own Makerspace.

Chapter One: Study Introduction

> Makers and builders and doers -- of all ages and backgrounds -- have pushed our country forward, developing creative solutions to important challenges and proving that ordinary Americans are capable of achieving the extraordinary when they have access to the resources they need. Let us renew our resolve to harness the potential of our time -- the technology, opportunity, and talent of our people -- and empower all of today's thinkers, makers, and dreamers.
>
> Obama, 2016
> Presidential Proclamation: National Week of Making

Education Crisis in the Information Age

Since the invention of basic building materials, children have been able to create models. Legos, Lincoln logs, Tinkertoys, and K'nex have long captured the imagination of children, allowing them to build from their imagination. Educational theorists have long espoused that playing and building with interesting materials can promote learning in children (Montessori, 1912). In recent years, technology has revolutionized the relationship between children and their building materials. With the ever-increasing affordability and widespread availability of micro-controllers and digital fabrication tools (such as 3-D printers and laser cutters), previously untapped potential is now within reach. Laymen no longer are restricted to building models of objects; students can now materialize a low-cost working prototype of any invention they devise. Learning communities support co-constructing knowledge as new members contribute back to the greater understanding. The need for a different type of worker is emerging from this technological evolution; factories are being outsourced while innovation, creativity, and collaboration are highly prized (Cohen, 2011; Vockley, 2008).

Modern workers are valued if they can solve problems in multiple ways and collaborate with a team to devise innovative solutions. Humans work with the resources available to them, and the evolution of tools has defined history: the Stone Age, the Iron Age, and the Industrial Revolution. The technology of the Information Age empowers students to be more innovative than ever before. While they are still in school, they may develop a patent or help contribute solutions to the world's greatest problems. One example of this comes from a high school innovation class in Indiana were a student created a transparent solar panel- and obtained a patent- all before graduating with a high school diploma (Kelly, 2016). As a result of increased access to technology and tools, students are now more equipped than ever to share their ideas with a broader community. They have the chance to make a meaningful impact on the world around them. Even if a student doesn't come up with the next world-changing invention, they still engage in unique knowledge building that comes from working in this type of environment. A 2007 study found that 99% of U.S. voters polled said teaching 21st century skills were vital to our country's continued economic success, (Lang, 2007). However, this type of setup is foreign and antithetical to the formal school setting. To bring this type of space into the school day requires a shift in pedagogy and an understanding of the learning theory for this distinctive setup. From this point on, 21st century skills will be referred to as 'soft-skills' and include: creativity, innovation, communication, collaboration, and problem-solving (Peppler, Maltese, Keune, Change, & Regalla, 2015a). Schools cannot teach soft-skills in the same manner that students were taught 100 years ago; the learning environment is evolving. With increased accessibility to sophisticated technology tools, everything from libraries to vocational classes are experiencing a renaissance. Shop class and technical education is no longer solely a vocational trade; libraries are no longer static places to consume information.

A growing "maker" movement, which involves creativity, tinkering, and problem solving, has grown outside of education in the hobbyist community. Interestingly, this movement aligns with the constructionist approach and is gaining momentum from educators to create opportunities to apply soft-skills within the formal education setting. The hobbyist community is influencing how antiquated learning spaces are perceived and how they can assume a new identity in education moving forward: a Makerspace.

Makerspaces can be defined as a space where students create self-directed passion projects, prototype inventions, and learn new skills based on their interests through collaboration and tinkering. Makerspaces are dedicated areas were soft-skills can be cultivated. Educational evolution may be facilitated in Makerspaces, which have also gained curricular validity with the development of the *Framework for K-12 Science Education* as well as the Next Generation Science Standards (National Research Council, 2011). For the first time Engineering is integrated into K-12 curriculum, which provides more legitimacy in Makerspace activities and design challenges (Quinn & Bell, 2013). Makerspaces vary in intent from woodshops due to the freedom students have to create their own self-directed projects, often with a technology component. The goal of a Makerspace project is commonly to fill a need, or rapidly prototype an idea. Digital fabrication technology is frequently found in Makerspaces, ranging from microcircuits to 3D printers, yet the maker mindset is the focus of the space, not the tools. Makerspaces allow students to be playful while grappling with complex concepts, providing students the opportunity for productive failure, identity development (as designers, scientists, mathematicians, and makers), the de-mystification of advanced technology (Martin, 2015).

Lastly, claims have been made about the potential of the Maker Movement to serve as a catalyst for a societal and economic shift that could alter manufacturing through access to open source files, connected communities, and factories for hire (Anderson, 2016). While this claim may seem outlandish, technology does possess disruptive capacity; reflect for a moment on the impact that the personal computer (which started with hobbyist) brought to the global economy

(Martin, 2015). If the Maker Movement is capable of the same potential, it is worth empowering our students to drive the change (Martin, 2015).

Problem Statement

Even without a body of research to supporting Makerspaces' value in the formal learning environment, the spaces have gained immense popularity in education. President Obama has shown support for the Maker Movement in education by hosting a White House Maker Faire competition for students and calling for a 'Nation of Makers'. Additionally, President Obama's *Educate to Innovate* initiative has dedicated $700 million dollars to the cause. At many national education conferences for 2016, Makerspaces were one of the top five most popular topics (ISTE Connects, 2016). While Makerspaces have been well researched in informal learning environments such as museums and libraries, little is known about their impact on formal learning environments such as K-12 schools. Constructivist learning theory, which Makerspaces ideals are built upon, is so diametrically opposed to the concept of school that teachers and students are acclimated to that it may provide a challenge for both (Mackey & Evans, 2011). Learning outcomes such as computational thinking skills are ill-defined by the research community, and can be difficult to measure.

Purpose Statement

The purpose of this exploratory mixed-methods study is to learn more about the impact of Makerspaces on K-12 educational environments. As scant research has been conducted in this domain, very little is known about how Makerspaces fit into the school day, and no one has identified intended outcomes inside a formal learning environment. Nevertheless, Makerspaces are a trending buzzword in education.

Makerspaces may have the potential to promote positive STEM dispositions, particularly in women and minorities; in a Makerspace students may develop computational thinking skills;

and they offer teachers a unique role to facilitate students' building knowledge structures through a constructivist learning approach (Peppler et al., 2015a).

With the implementation of Makerspaces in K-12 education, the dominant culture of 'sage on the stage' pedagogy shifts to a culture of creation and discovery. The constructivist approach bolsters STEM programming already popular with educators and funding agencies. Through TPACK framework, educators can apply the constructivist methodology and leverage advanced technology to enhance their curriculum.

The need for practical technological learning is steadily increasing in order to yield 21^{st} century ready workers and productive citizens. Makerspaces have the potential to revolutionize contemporary education with robust, hands-on, creative technological education, empowering students to invent, prototype, and tinker with low-cost technology tools such as microcircuits and fabrication tools such as 3-D printers within a community environment. Unfortunately no best practices guide is readily available for educators wanting to implement a Makerspace, without which valuable time and resources can be wasted on expensive equipment that lacks a sound pedagogical foundation. This exploratory mixed methods study explores the successes and challenges of established K-12 Makerspaces in order to help other educators develop successful, effective Makerspaces in their schools.

The Role of Makerspaces in K-12 Education

The next sections will discuss other important facets of Makerspaces in K-12 education, such as the inclusiveness of *all* students in Maker Education (including women and minorities), the role of STEM and computational thinking, shifts in pedagogy, and learning tools.

Reaching Women & Minorities Through Makerspaces

In a 2015 sampling survey of 51 Makerspaces across the country, researchers found the following demographics among participants: 42% White, 20% Black, 18% Latino, 14% Asian, 0.3% Native American; this diversity is greater than the current US population based on Census data (Peppler et al., 2015b). Additionally, over 8% of the populations served were students with disabilities (Peppler et al., 2015b). Makerspaces have the potential to serve all students, inclusive regardless of race, gender, ethnicity, and disability. Students are interested in Makerspaces, and there is an opportunity to provide services to the vast populace, exposing them to potential future careers and empowering them to endeavor to solve the world's greatest challenges. The ideal environment would be a Makerspace in every school, and Makerspace ideals embraced by in classrooms.

Other developed countries are outpacing the United States on international assessments; these international assessments are not emphasizing rote skills like many of the state standardized tests the United States currently utilizes, but rather applied thinking and reasoning skills. In 2012, fifteen year olds from the United States ranked 21st out of 34 developed countries in science on the Programme for International Student Assessment, commonly referred to as PISA (2012). Additionally, the results of the 2012 PISA test in mathematics indicated that U.S. students experienced difficulty with "performing mathematics tasks with higher cognitive demands, such as taking real-world situations, translating them into mathematical terms, and interpreting mathematical aspects in real-world problems" (p. 10) and only 50% of students stated they were interested in learning mathematics. Despite constant education reform, the U.S. PISA results shows no significant change over time.

To prepare *all* of our students to be successful, they will need to learn heuristic thinking skills, which may be supplemented in a Makerspace environment. The Department of Commerce's *Women in STEM: A Gender Gap to Innovation* (August 2011) showed that women earn on average 33% more when they choose to work in a STEM field. However, the same study found that women only make up 24% of the jobs in this industry. The Department of Education's *Hispanic and STEM Education Fact Sheet* (March, 2014) stated that the disparity is even more evident in the Hispanic community; they make up 16% of the population, yet they only account for 8% of STEM degrees. Makerspaces are unique in that all ability levels and student demographics are welcomed. Involvement in Makerspaces expose student to career opportunities not previously considered. Whereas a traditional formal learning environment is often limited by the sole identity of a 'student', a Makerspace offers the opportunity for pupils to perceive themselves as scientists or mathematicians (Tate, 2012).

Why STEM Alone Isn't the Solution

Science, technology, engineering and mathematics (STEM) is a very broad concept; each strand represented has its own domain and subsets. A closer examination into *science* reveals three main branches- natural, social and formal- each of which has subdomains such as chemistry, biology, physics, botany, and geology. However, computational thinking is found in each branch of STEM. Grover and Pea (2013) defined computational thinking as "the process of recognizing aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes" (p. 29).

The lack of computational thinking (CT) skills missing from formal schooling may be surmounted with Makerspaces that allows students to engage in self-directed passion projects. These flexible learning spaces afford students the opportunity to explore complex concepts in a fun environment. Additionally, Makerspaces provide opportunities for cross-curricular projects. Art and science, reading and math, physics and music and more can all bolster together during a project; it is not limited to four mere disciplines. For Makerspace projects that utilize microcontrollers, coding is required, and the process of debugging develops the analytical problem-solving approach inherent to computational thinking. Additionally, working with digital fabrication tools like 3D printers, laser cutters or vinyl cutters leads students to rapid prototyping and iteration, going beyond the narrow parameters of STEM to fostering computational thinking skills.

In May of 2012, President Obama enacted the Maker Education Initiative ("Maker Education Initiative," 2014). This program features resources for educators and communities to support both formal and informal learning experiences for students, and has increased the popularity of Makerspaces to address STEM. A venerated example of a club attempting to fill the STEM gap is United States For Inspiration and Recognition of Science and Technology (U.S. FIRST), a multinational club that hosts robotics competitions with over 18,000 students involved. However, this club still struggles with equalizing participation by females in the more traditionally masculine garage-like workspaces. Additionally, the tools limit student access and involvement. A student must be physically present in the robotic workspace in order to participate; it is not something he/she can take home and do on his/her own. An alternative solution is a school Makerspace, offering a social space to explore passion projects in which children may develop the thinking skills valued in STEM education. Many of the Makerspace artifacts are portable, thus making it possible for the students to work on them beyond their time in the lab. Additionally, components of the space can include crafting items, which make the space more inclusive and approachable by all, including female students.

Utilizing advanced technology in Makerspaces, students will take on the roles of scientists, engineers, computer programmers, etc., which also translates to an elevated worldview. More career options, previously not considered, become possibilities. Women and minority students have an equal opportunity to these experiences when they are implemented in Makerspaces. However, for these new spaces to function an educational setting, this special classroom will require a different type of teaching.

Need for a New Pedagogy

Technological advancements have impacted how people learn in recent decades. In the age of the Internet, students have access to the wealth of human knowledge in their handheld devices. Daily tasks and communication are impacted heavily due to the access of information. In addition to preparing modern youth for vocation, educational institutions are responsible for instilling principles of how to excel in the new knowledge economy. This is a new mindset with distinctive from antiquated models of thinking, separated from the regurgitation of rote facts learned from a didactic scholar. With exposure to Makerspaces, students can view the world in terms of problems to solve. Failing is antithetical the education system, but it is imperative for innovation (Stewart, 2014). Productive failure can help students become better problem solvers through a deeper understanding of the parameters a challenge offers, including constraints and structure of problems (Kapur, 2008). Learning to have productive failures in which students learn from their mistakes in a safe environment is a benefit of Makerspaces.

Additionally, this change in mindset validates the learning that students do outside of school and the digital literacy practices that they can contribute in a formal learning environment. Maker education differs drastically from the traditional classroom model. An anecdote of students from Brooklyn International school exhibits how embracing technology and passion projects enhanced their social skills, self confidence, and unlocked opportunities by giving them hands-on experience (Cohen, 2004). The students at Brooklyn International School hail from 50 different countries, and they speak over 35 distinct languages. If these students would have been placed in a typical classroom and expected to learn from textbooks, they would have been set up for failure. Instead, they experienced a nurturing environment with hands-on learning, contributing to a larger community of peers. Despite the language barrier, the students flourished when exposed to coding, artistry and personal projects. The teachers at this school have a deep understanding of how to leverage technology at the proper time, coupled with a constructivist approach and curricular understanding. The intersection of pedagogy, technology and curriculum are the main components of TPACK framework. In a Makerspace environment, educators must possess a deep understanding of how and when to wield all of these elements, just as the educators at Brooklyn International School are doing.

While the scope of this work is to promote more Makerspaces in K-12 schools, the maker mindset can permeate into classroom teaching as well. High Tech High provides an example of a freshman history assignment, in which the class creates a six foot geared wheel to theorize how populations rose to power and fell based on research on the Mayan, Roman and Greek civilizations (Stewart, 2014). The abstract concepts were physically manifested in the mechanisms of the wheel, an art installation piece that demonstrates their learning.

Even as Makerspaces are on the rise in community spaces, libraries, and museums, they are still sparse in the K-12 educational setting. In a 2013 study, the University of Maryland found that now 17% of public libraries had Makerspaces, proving the increasing popularity of the learning environment (Bertot et al., 2014). With the falling cost of tools, there is an opportunity for more Makerspaces to be implemented in a K-12 educational setting.

Tools for Learning

High tech tools have become more accessible in recent years as prices drop and more innovative products are developed. While working as a researcher at The Massachusetts Institute of Technology (MIT), Dr. Leah Buechley designed a microcontroller that can be sewn into cloth via conductive thread, thus eliminating the cumbersome process of soldering wires (Buechley &

Eisenberg, 2008). This technological advancement appeals to girls who are generally more inclined to crafting, as well as younger students (Peppler, 2013). Even though the tools are more available, rapid adoption has been slow. Regarding electronic textiles, educators are widely unaware of their existence, and the text-based programming component can be perceived as too difficult and intimidating to educators (Baafi, Buechley, Dubow, & Qiu, 2013). This is changing as Makerspaces receive more publicity, ranging from the President himself to Maker Faires across the world. Maker Faires have experienced explosive growth from the hobbyist community in the last ten years. In 2015, the flagship Maker Faire Bay Area drew over 145,000 attendees; the World Maker Faire New York followed with 90,000 attendees (2015).

Tools that enjoy great popularity in the hobbyist community are now making the transition to educational settings. Software tools are becoming more user-friendly. Scratch, the block format of programming from MIT, has become widely used in education. New drag and drop applications that mimic the format of Scratch are being developed for myriad applications.

While a masculine garage-style setup may be off-putting to females, new tools are tapping into their roots in crafting. One such tool is the Arduino Lilypad, an electronic textile (or e-textile) that can be incorporated into clothing. This tiny sensor requires no soldering, but instead uses conductive thread, offering a low barrier of entry to an extremely powerful tool. The microcircuit can receive input from sensors, which trigger a reaction. For example, a dress can light up in response to sounds of its environment. By identifying the best practices of educators running Makerspaces and wielding these learning tools effectively, a roadmap of implementation practices can be presented to those just embarking on the journey.

Need for Research

> The real power of any technology is not in the technique itself or in the allure it generates, but in the new ways of personal expression it enables, the new forms of human interaction it facilitates, and the powerful ideas it makes accessible to children (p. 18).
>
> —Blikstein, 2013
>
> Digital Fabrication and 'Making' in Education:
>
> The Democratization of Invention

While Constructivism has been widely studied in recent decades, the body of literature on Makerspaces, particularly in an educational setting, is lacking. In *Harvard Educational Review*, researchers note that in a Makerspace students serve as teachers, often exhibiting their projects and skills with a wider audience; additionally, students revised ideas, created models, and shared knowledge with peers (Sheridan et al., 2014). The researchers were intrigued by the multidisciplinary approach that Makerspaces embodied, and they called for more research to broadly conceptualize the scope of work, focus on learning environments (Sheridan et al., 2014). Additionally, these same researchers called for pedagogical support for proper implementation of resources (Berry et al., 2010). An examination into Open Portfolios as a reflective tool in documenting learning in Makerspaces was one approach taken; future research into open sharing and documentation by students in a Makerspace was encouraged (Peppler et al., 2015b). One study called for future research to define an introductory activity for students when first introduced to the Makerspace and its vast array of tools (Litts, 2015). Future research is needed to determine best practices from educators who have already successfully established their own Makerspace in an educational setting.

Why Exploratory Mixed Methods?

As Makerspaces are a relatively new concept, there are only a small minority of educators that have experienced setting up a Makerspace in educational setting and sustaining it for multiple years. This study aims to capture the best practices of establishing a space in an educational setting by asking these educators to reflect back on their process. This exploratory mixed methods study examines Makerspaces in a K-12 setting through the eyes of educators, culling the essence of their successes and failures to create advice for others that wish to pursue a Makerspace in a formal setting.

Purpose of the Study

According to Roger's (2003) Diffusion of Innovation theory, the participants of this study are the early adopters. The goal of this study is to provide insights and perspective for the early and late majority of educators as well as the laggards who will adopt Makerspaces in the future. This study hopes to be a roadmap of best practices, tips and tricks to establishing a vibrant Makerspace in a school setting. The intent of this study is to assist educators looking to create their own unique Maker culture while learning valuable lessons from those that have done it before them.

Need for this Study

International Society of Technology Educators (ISTE), the National Association of Independent Schools (NAIS), International Literacy Association and many more have all listed Makerspaces as a new trend in education, and dedicated time for Maker-related sessions at their respective conferences. However, the research for educational Makerspaces is lacking. While there have been a handful of National Science Foundation funded projects, these isolated events do not capture the long-term experience of Makerspaces in schools. Also, these research projects have dedicated funding and staffing to assist the work, yet educators do not have these luxuries. Makerspaces are a trending topic in education, yet their outcomes go un-assessed. Often, the very purpose for Makerspaces is undefined by those instituting them; Makerspaces are simply added because they are the popular trend to have in school at this time. Even worse, tools may be purchased without a plan for implementation (such as a 3D printers) because it is the latest educational fad.

The constructivist principles, which underlie Makerspaces, are difficult for educators who are not specifically trained in this area. Additionally, it takes a sophisticated understanding of TPACK framework to know how and when to leverage appropriate technology to match the curriculum goals. For Makerspaces, computational thinking skills and soft-skills such as creativity, collaboration and problem-solving skills are often desired outcomes. However, has been no research done to evaluate if those skills are being fostered in unassisted K-12 Makerspaces.

The impact of these spaces on students and whether the spaces are achieving their purpose is unclear. In order for Makerspaces to be successful and not fall by the wayside of educational trends, it must prove its longevity. Studies like this are needed to evaluate the state of the field, and provide guidance for educators moving forward.

Significance of the Study

The purpose of this exploratory mixed methods study is to develop best practices that could be used to inform educators that wish to implement a constructionist approach to their educational setting through Maker initiatives. If this study and others like it are not done, fewer educators may chose to implement Makerspaces due to a dearth of research and advocacy to substantiate the value of a school Makerspace. Additional consequences includes: a lack of understanding regarding the potential of Makerspaces, void in assessment of computational thinking and soft-skills, and a lack of gender and minority diversity in this STEM Makerspace. Without educators reclaiming the domain of their classrooms, standardized testing will continue to permeate every aspect of school. The students that emerge from the pipeline of the modern

American education system will not possess resilience, ingenuity, or an innovative spirit that is the critical to continued success and development of the American economy.

Theoretical Focus

While basic definitions of theory will be defined in this section, chapter two delves into more detailed examination of the theories. The underpinning theoretical framework for this study is the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2009). By examining constraints and interplay of framework components, educators may acquire an innovative pedagogical strategy.

Research Questions

The research questions that will be addressed in this study are:

- How are educators utilizing Makerspaces in K-12 schools?
- What are teachers' experiences of Makerspaces inside the school day?

The research questions provide overarching direction for the survey and interview questions. The research questions will be discussed at length in chapter three.

Assumptions

Numerous assumptions are critical for this study. This study assumes that participants gave an accurate representation of their best practices, and that they were not solicited in any way to present a particular response. The rapport developed with the researcher and anonymity provided gives participants assurance that they were not exploited. Additionally, the intent of the body of research for helping other educators should reassure participants that their work is valid and their contributions are important to promoting the greater body of knowledge.

Limitations and Delimitations

Due to time constrains and resources, this study is limited in scope. Participants were selected based on their work in K-12 Makerspace settings. Small sample size is another limitation of this study. While best practices will be garnered from this research, the findings may be limited to only certain education populations.

A delimitation is the focus on K-12 Makerspaces, leaving out practitioners in higher education, public libraries, and museums, in addition to for-profit and non-profit entities.

Chapter Summary

Unfortunately, there are very few guidelines on where to begin when educators want to establish their own Makerspaces. This study aims to research best practices of educators that run successful Makerspaces across the country, which could be generalized to serve as a guide for teachers attempting to set up a site. Makerspaces can empower students to invent, prototype, and tinker with low-cost technology tools such as microcircuits and fabrication tools such as 3d printers.

Chapter Two: Review of the Literature

> We must conceive of work in wood and metal, of weaving, sewing… as methods of living and learning, not as distinct studies. We must conceive of them in their social significance, as types of the processes by which society keeps itself going… as in ways which these needs have been met by the growing insight and ingenuity of man; in short, as instrumentalities through which the school itself shall be made a genuine form of active community life, instead of a place set apart in which to learn lessons. (p. 10)

—Dewey, 1976

The School and Society

Overview

This study examines best practices of Makerspace directors in a K-12 setting over a number of different sites. The successes, failures, and lessons gleaned from the educators that run established Makerspaces are the object of this research. From their forged path, other educators may learn from their successes and mistakes to champion new Makerspaces in educational settings, while saving valuable time and expensive resources.

While Makerspaces are somewhat akin to the pioneer frontier, only operations that are over a year old are included in this study. TPACK framework was used to examine the decisions and planning methods of educators running Makerspaces. Constructionist theories of learning heavily influence the pedagogy of a Makerspace, including the culture, roles, and identities explored. The classroom dynamic is flipped from a traditional model to a student-centered approach, which provided unique challenges for the educator.

This literature review explores the background of Makerspaces, theories, and pedagogy to derive a constructivism classroom. Next, it delves into seven dimensions of K-12

Makerspaces: setting, computational thinking, participant structures, teacher training, gender and racial issues, assessment, and sustainability. The intended outcome of this literature review is to provide a background of related literature to the Makerspace implementation in education, supporting future educators to learn from experience of their peers and glean wisdom from their journeys.

Maker Movement

The maker movement is on the rise, such as the increasingly popular robotics and coding clubs. In a broad sense, "making" is willingness to tinker or fiddle. The Maker Movement is characterized by an attitude of ingenuity has roots in the do-it-yourself (DIY) culture. DIY culture illustrates that anyone could perform an assortment of jobs himself/herself rather than depending on compensated specialists. The maker culture has evolved this idea by including a technology component. There is a heavy emphasis on engineering-oriented pursuits such as: 3-D printing, metalworking, electronics, robotics, and traditional arts and crafts. Tinkers adopted the nomenclature "makers" after *Make* magazine in 2005, and the subsequent Maker Faire, which followed in 2006 (Dougherty, 2012).

The San Francisco origin site of Maker movement was seeped in deep historical roots. The city was no stranger to innovation; in March of 1855 the Mechanics Institute was organized to distribute knowledge: merging libraries, laboratories and lecture halls (Holman, 2015). Industrial art fairs were hosted to showcase inventions to the public. Thomas Edison and Alexander Bell both valued the concept of collaboration and a well-equipped workspace, creating over 350 research labs. Inventions from these labs pioneered discoveries that would revolutionize the 20th century.

Today, Maker Fairs serve as a social gathering for makers to congregate, exhibit their ideas, and engage in dialogue with other makers. Outrageous projects are shown off at Maker Faires, ranging from low-cost brain monitoring systems to hybrid instruments to clothes that react to the environment (Casebeer, 2013).

Background: Makerspaces in School

There is a nomenclature to identifying variations of Makerspaces based on intent. The genesis of *FabLabs* came from a course at MIT entitled "How to make (almost) anything" and is a nonprofit entity. *TechShop* is a commercial franchise version focused on access to expensive tools and resources, and may lack the community organically found in a Makerspace. While *Hackerspace* is one of the oldest names for a Maker environment, it has fallen out of popularity due to the negative connotation of hacking as malicious activity and security breaches. As cited in *The New Shop Class*, one of the most complete definitions of a hacker is "one who enjoys the intellectual challenge of creatively overcoming or circumventing limitations" (p. 47). All of these spaces share common communities of learners who come together to assist one another. Often digital fabrication is the hallmark of the programs, with 3d printers, design software, microcontrollers and laser cutters being common elements found in these spaces. Some spaces have large machinery, such as band saws, while others house sewing equipment or digital circuitry. Educational Makerspaces may also be called innovation labs, Fablabs, design labs or idea labs, but they all share the core characteristics of designing and making. For the purposes of this study, the definition of a school Makerspace is space where students create self-directed passion projects, prototype inventions, and learn new skills based on their interests through collaboration and tinkering. Educational Makerspaces may be very low tech or extremely high tech, but regardless of the tools a similar purpose exists: to make.

Rise of Maker Culture

The scale of the maker movement continues to gain momentum. Makers around the world are making headlines with their inventions; they are gaining momentum and possess the potential to disrupt industries. One student 3d printed his own braces at school for less than sixty dollars by making custom molds for his teeth- and it worked (King, 2016). Coral reefs haven been supplemented with 3d printed sandstone models (Millsaps, 2016). Houses and cars can be manufactured in record-breaking time and for a fraction of the cost thanks to 3D printing (Nguyen, 2016). The open-source cars are made of recyclable material and boost only 50 individual parts- down from 30,000 on traditional models (Chhabra, 2016). In the event of an accident, damaged parts could be printed on demand.

Tenants of the Maker movement have deep roots in the history of learning theories. The next section examines why Makerspaces can make a valuable contribution to education through the lens of learning theories.

Learning Theories Behind Maker Spaces In Education

Many philosophers have contributed directly to the innovative approach to education that can be found in the Maker movement. Rousseau (1763) posited that education should be cultivated from lived experiences instead of relying on knowledge from books. Meaning should be made through observations, inferences, and utilizing the senses. In Switzerland, Johann Pestalozzi applied's concepts in a school setting. Due to his innovative approaches, illiteracy in 18^{th}-century Switzerland was drastically reduced by 1830. One of Pestalozzi's students, Friedrich Fröbel, continued his legacy. Fröbel is the inventor of Kindergarten, and he is also known as the *Playmaster*. Proponents of Frobel's theories claim that his work is applicable from nursery school to the University setting (Willis, 2009). Frobel valued playful instead of prescriptive learning; he accomplished this through play materials known as *gifts* as well as activities, which he called ‘occupations.’

Frobel’s approach to learning materials served as a predecessor to Maria Montessori’s work with preschoolers. Montessori was an Italian physician who developed a new approach to educating children. The Montessori Method encourages students to make discoveries by preparing the right environment to cultivate this free play and exploration.

Learning Theory: Constructivism

Constructivism can be complex, evoking many connotations based on the perspective of the individual. As a learning theory, constructivism dates back many decades. Resnick (1998) defines the theory of constructivism as individuals creating their knowledge based on interactions between new ideas and their current schema.

However, a new identity has emerged in the form of constructivist teaching as a theory and practice. Constructivism is a progressive pedagogy based in social science and psychology research (Council, 2010). New teaching paradigms are emerging from constructivism: students co-creating knowledge with educators, bolstering a community of pupils, “acting as a conceptual change agent and mentoring apprentices through the zone of proximal development” (Windschitl, 2002, p. 135).

Two camps of constructivist thinking divide scholars: social constructivists, proponents of learning through exchanges in social settings, and cognitive constructivists, supporters of mental models perpetuated through tools, information resources, and contributions from other people (Wilson, 1996). This study takes a hybrid stance, in which “knowledge is personally constructed and socially mediated” (Windschitl, 2002, p. 137).

Constructivism versus Constructionism

While Jean Piaget (1973) is considered the father of constructivism, there have been other theories derived from his work. One important theory is constructionism, attributed to Seymour Papert. It bears mentioning that Seymour Papert studied under Jean Piaget. Piaget (1973) developed cognitive development stages; Papert explores a more situated approach, and external ‘objects to think with’ play an important role. Papert criticizes contemporary educators’ obsession with abstraction (Papert, 1993). Instead, Papert flips the model, prescribing to ascend to the concrete. In his seminal book, The Children’s Machine, Papert describes the objective of constructionism as teaching in a manner that generates the most knowledge with the least amount of instruction (Papert, 1994). Papert (1994) echoed the wisdom of John Dewey in the sentiment: “The kind of knowledge children need is the knowledge that will help them get more knowledge” (p. 140). Papert reminds readers that children are excellent learners, even going a step further and suggesting that adults should emulate them.

Constructionism takes constructivism’s view of learning as creating ‘knowledge structures’ but with the addition of the concept that external object. These ‘objects-to-think with’ are the basis for constructionism. While constructionism is an important method of the constructivist approach, this paper focuses on constructivist aspect. The next section will examine constructivist approaches in regard to K-12 Makerspaces.

Concerns for Constructivist Methods in the Classroom

As constructivist methods involve deep knowledge of a specific discipline, one would hope that student test scores would reflect this. However, the kind of profound understanding of reasoning is not what is being assessed on standardized assessments!

The biggest factor in success for a constructivist classroom is the teacher's understanding of constructivism (Windschitl, 2002). As constructivism is a learning theory as a opposed to a teaching theory, it can be problematic in application. An educators' own schema of how a classroom should operate is perpetuated from their own experience, which differs wildly from the radical approaches of constructivist teaching. Even if the teachers are able to develop hands-on engaging activities, they must follow through with discourse and reflection by the learners to solidify the larger ideas.

Additionally, students must undergo a shift in order to be successful in a constructivist classroom. Students are well versed in how to win at the game of "school." There is a dichotomy between traditional classroom culture and an open constructivist approach. It can be difficult for students and teachers to adjust to the new classroom structure; a constructivist classroom usurps the traditional school culture. Lampert (1989) evokes the metaphor of the teacher as a dance instructor who must provide rehearsals in addition to instruction. As the language mediates learning, the teacher must be fluent in the discipline-specific jargon, such as math talk. This arrangement defies the state quo that students must be quietly seated in rows. In this classroom, there is not one correct answer, and divergent thinking is valued. Both students and teachers must overcome their own inhibitions and rigid mental models. In one example, Windschitl (2002) observed that students were unwilling to draft electric circuit design plans out of fear of failure. After a working artifact was produced, the students retroactively completed design drawings, averting any strenuous cognitive exercise that could result in failure.

Despite challenges associated with implementing a constructivist classroom, change is possible. Typically educators were not allotted power to make curricular decisions, as policy makers and administrators dictated those choices. However, with the emergence of technology in schools, Makerspaces can offer an opportunity to empower educators in a constructivist classroom. Makerspace classrooms are the perfect venue for constructivism. Policies are often made that stifle the forward momentum of education. Educators are asked to teach deeper understanding, which constructivism supports; paradoxically, the students are assessed on shallow rote knowledge. Introducing a constructivist approach into a school culture has the potential to start a groundswell movement, spreading to more traditional classes. For a constructivist class to be successful, it must have administrative backing. Administrators must be educated that this type of teaching serves the mission of their school. Educators must be unwavering in their commitment: community members unused to a new approach may attempt to shake their resolve. This may be daunting for educators. However, observing students learn without directly being taught by a teacher is a powerful lesson for educators, and one that they will recognize in a constructivist Makerspace. Lastly, constructivist methods has the power to reach every individual, all encompassing of the intricacies of race, class, gender and sexual orientation. The next section examines the ontology of this study, and how it applies to the landscapes of schools.

Ontological Considerations of Being

During the tumultuous era of increasing standardized tests and international competition, scholars are still ruminating and debating over diverse approaches to human learning. Epistemology has taken prominence in the debate, as it focuses on the theory of knowing: what is truth and when knowledge is valid. While epistemology accentuates social participation, relationships, settings, and historical situation, constructivism stresses interaction with the world to construct knowledge (Packer & Goicoechea, 2010).

Another consideration is often overlooked- ontological considerations of being. This has important implications for the field of education as learning develops identity and alters the state of being. Educating the whole child is essential in creating a well-rounded contributing member of society. Students can develop (or lose) their passion during their school experience. Students' views toward school and learning can be influenced through educators' deeper understanding of ontology. Perry and Weinstein (1998) note that positive relationships between the teacher and student can develop a student's internalization of values and attitudes towards school, while the absence of an advisor can have a negative impact on achievement and overall welfare. In a supported environment, students can develop both the "pragmatic and contextual aspects" of cognitive development that influence the individuals blossoming into their unique sense of self (Ferrari & Mahalingam, 1998). Makerspaces afford unique settings that operate outside of the strictly regimented high-stakes classroom; Makerspaces can offer refuge for positive student-teacher relationships to flourish. A Makerspace has the opportunity for the teacher to engage in a mentor-mentee relationship to bolster students to achieve their optimum learning potential as well as developing their distinctive identity.

Ontology can be the missing factor to unify multiple perspectives of learning. Packer and Goicoechea (2010) posit non-dualist ontology leads to a cohesive relationship between sociocultural and constructivist approaches. Sociocultural and constructivist approaches to learning are not merely differing perspectives of the same phenomenon because of their different ontological assumptions. There are drawbacks to each approach when viewed in isolation: constructivism can overlook cultural and historical basis, while sociocultural perspective appears to favor conformity, not valuing diverse interactions with a complex community. Participation in community promotes identity development, resulting in a transformation of both the learner and the community, or ontological change.

By being cognizant about the potential for the student's identity development in Makerspaces, educators can harness the space for deeper learning interactions. The next section outlines the background of schools in a constructivist context.

Landscape of Schools

Antiquated methods of learning involve a transfer of knowledge bequeathed from an all-knowing teacher to a static recipient. Newer methods of learning-by-doing are replacing the outdated model of knowledge transmission by a 'sage on the stage', pioneered by the work of Jean Piaget. During the past five decades, a groundswell of active learning has ignited exploration, experimentation, and expression in schools (Resnick, 1998).

The benefits of a constructivist classroom are deep knowledge that unifies information by situating it into a broader understanding. Social constructivism evolves through participation in communities. Access to technology in schools provides additional resources that serve as tools for organization, visualization, and computation. Tools can be influential mediators of learning. These tools can include language, computers, charts, or anything else that can facilitate the co-creation of knowledge between students (Roth, 1992). These conditions provide an optimal environment for a constructivist approach to teaching. The educational landscape is also dramatically different from years past with an influx of college-bound students. Employers of college students are interested in employees with creativity and problem-solving skills, outcomes of a constructivist approach. Paradoxically, higher percentages of college bound students reinforce standardized testing for college-entry. Modern reforms, such as the next generation science standards, are moving toward multi-faceted learning, but are is still dependent on testing.

Human knowledge of our world in every discipline is dynamic, as opposed to the static version often thrust on students. In order for change, there must first be a shift in epistemology. The next section outlines how play can bring about this change.

The Role of Play in Learning Environments

Childhood is synonymous with play. Piaget's mantra *to understand is to invent* molded how American educators taught (Piaget, 1973). Yet in recent decades, rigid dependency on high-stakes has overrun the American education system; play has all but disappeared as busy teachers prepare children for ever-increasing tests.

The value of play is well documented; Vygotsky (1978) theorized that children derived the practical meaning of concepts through play. Additionally, Vygotsky states that play is not merely a indicator of childhood, but rather a crucial factor in development. Makerspace is one example of an expanse that children can use as a valuable learning space.

Jenkins (2009) posits:

> School-based and afterschool programs serve distinct but complementary functions… Afterschool programs should be a site of experimentation and innovation, a place where educators catch up with the changing culture and teach new subjects that expand children's understanding of the world. (p. 59) The greatest opportunity for change is currently found in afterschool programs and informal learning opportunities. (p. 4)

In Seymour Papert's (1993) seminal book, Mindstorms, he describes the "child as a builder" (p. 19). His tenets of constructionism focus on actively building intellectual structures. Makerspace can serve as a sandbox that when properly leveraged, can build knowledge structures that help people learn *how* to think. It can transform the process of learning into an active, self-directed process. Makerspaces also allows children to explore identity. Whether it is the identity of a mathematician, explorer, architect, historian or physicist, Makerspaces allows children the freedom to try on different personas without negative repercussions. In these risk-free scenarios the students can explore and experiment in a deeper way. Vygotsky (1978) posited that play was an essential part of learning: children experimenting with identities displayed levels of computation and performance beyond what is expected of their age. Children and adult both can experience play through a Maker Movement that is sweeping the nation. The following section diverge from learning theories and shifts the focus to characteristics of Makerspaces that can be compared across case studies.

The Seven Dimensions of K-12 Makerspaces

This study examines Makerspaces across a variety of settings to extract the best practices and lessons that can be learned and applied to other situations. As Makerspaces are a relatively new phenomenon, there is a need to define commonalities to compare across case studies. In order to better understand K-12 implementation of Makerspaces, the study examines seven characteristics of Makerspaces: setting, computational thinking, participant structures, teacher training, gender and racial issues, assessment, and sustainability. Each of these characteristics provides critical insights to that may be leveraged in order to replicate thriving K-12 Makerspaces.

In schools, there are common elements found in Makerspaces. Educational Makerspaces foster play and experimentation, include cross-disciplinary elements, and lastly, they transform students into producers instead of consumers (Krueger, 2014). There is a very open-ended interpretation of how those concepts are applied, resulting in drastically different applications all being called ‘Makerspaces’.

Each of the seven dimensions was picked for a specific reason; the rationales are provided here. Setting is an important aspect to examine because the implementations are extremely diverse from school to school. It is therefore crucial for analysis that the data provides insights to the physical setup and operating procedures of each unique space. Assessment is vital to reporting and funding in K-12 education; it is an indicator of a program's success. Analyzing participant structures allows for determinations to be made about student ownership in their learning and overall impact of the program. Teacher training provides a metric to gauge how well teachers understand the complexities of a constructivist approach to teaching and how well their schools are supporting them. TPACK framework was used in the analysis of planning and decisions regarding Makerspace activities and tools. Computational thinking is a lens in which we can view the constructivist approach with tangible products and outcomes. Sustainability deals with long term planning, securing funds and support for the continual operation and expansion of the Makerspace. Gender and racial issues are an important topic in STEM education and should also be addressed in Makerspaces; this study examines how participants are purposefully designing activities and spaces to provide inclusivity for females and minorities to promote long-term interest in STEM careers. Makerspace implementations in schools across the nation are very diverse; the next section speaks to the logistical aspects of a Makerspace in a formal learning environment.

Unique Settings: Variations of Educational Makerspaces

Makerspaces vary in their size, resources, audience, availability and a plethora of additional factors. This section examines three main facets of Makerspace settings: tools/offerings, spaces and scheduling.

Tools and Offerings

The first major difference in educational Makerspaces is the implementation of tools. Depending on funding and focus, a Makerspace may take very different approaches (Baldwin, 2013). A design-focused space may incorporate 3d printers and laser cutters. Another space may have a large assortment of power tools. Robotics and microcircuits may be used, and computer coding could be incorporated. Low-tech offerings may incorporate paper circuits and other cost effective tools. E-textiles and wearables are yet another variation of a Makerspace. An educational Makerspace may include any or all of these individual components, making them diverse spaces but with one unified goal of sparking the imagination of students.

Spaces

The physical setup of the Makerspace in a school setting is very important. Just as the tools for each Makerspace were widely diverse, the same goes for the setting. Some schools opt for a Mobile Makerspace, often housed on a cart. This Makerspace to go can be utilized by different departments around the building, one of the main benefits of this approach. However, supplies may be limited by the small mobile space. Another problem is training on how to properly use the equipment. If a Makerspace is in a dedicated area, teachers and students can develop expertise as they learn. Imagine if a teacher uses the cart for an isolated 3d printer activity how it could lead to frustration if they are unfamiliar with the equipment and how to troubleshoot it.

Another popular alternative is the evolution of the library into a learning commons complete with a Makerspace (Plemmons, 2014). This dedicated area serves as a hub for innovation accessible to the entire school. Library staff could become experts in assisting the students and identifying student leaders that have developed areas of expertise within the

Makerspace. A limitation of libraries is space- typically schools don't have room to store the supplies for hundreds of students working on (potential large) long-term projects.

A third option is a class Makerspace. While this option gives students dedicated time and space to work on extended projects, scheduling may prohibit all students at the school from the opportunity to participate.

Scheduling

As mentioned above, another challenge is scheduling time in the Makerspace. The school must decide if the Makerspace will be a new elective that all students will visit or only smaller dedicated classes. Additionally, different spaces cater to different age groups with more appropriate tools and resources. Schools may have more than one Makerspace with completely different resources if they serve diverse groups. One such example is St. Stephen's Episcopal Day School in Miami. The school has a Jr. FabLab focused on hands-on exploration and short-term projects for Preschool through Grade 2. At the same campus, they have a FabLab for Grades 3-5 that allows for long-term, more complex projects for the older students. A middle or high school Makerspace might look completely different, yet they all have the same underlying goals.

An afterschool Makerspace or Makerspace club may be a viable solution for some schools. A combination of drop-in time could also be coupled with a permanent space. For example, a library Makerspace may be open during lunch, before school and recess time. The scheduling is an important factor, because it determines the weight placed on the Makerspace. If it is introduced as a required class, then schools must consider reporting outcomes to the parents and other stakeholders. If the Makerspace is perceived as a more casual implementation, it may not be a priority and lose long-term sustainability.

Participant Structures

As previously discussed, Makerspaces can be difficult to define because of the wide interpretation on what the space may entail. Another one of the characteristics of Makerspaces that vary widely is the participant structure. The literature shows the diverse implementation of Makerspaces and the varying perspectives of what participant structure looks like from site to site. In a case study of Makerspaces, researchers acknowledge that despite increasing interest in Makerspaces, little is known about "the content and processes of learning in Makerspaces" (Sheridan et al., 2015, p. 503). However, this study focused on community Makerspaces, still leaving a void of knowledge about the content happening in K-12 Makerspace environments. The literature focuses on targeted making outcomes via controlled activities such as circuitry or Scratch (Peppler, 2013; Resnick, 1998).

Age levels of participants (and multiage participatory grouping) are an aspect of making that overlaps both setting and participant structures. Outside of schools, makers of different age groups and expertise levels come together to share resources and ideas. Schools are often silos, not only by grade level, but also by subject. A Makerspace has the potential to break down these silos for a multidisciplinary approach that spans the grade levels.

One objective of this study is to determine how directed Makerspace activities are in K-12 settings. In some Makerspaces, directed activities to discover specific skill sets are rigged for students to interact with. Others offer a more exploratory approach, offering students the chance to come up with their own question and allow them to solve it, often in the form of passion projects. Passion projects coming to life is a byproduct of making. Students are empowered to solve real world problems in their communities and across the globe. While the main focus is not to profit, entrepreneurial students are able to create their own businesses or make a larger impact on the world around them. In a case study published in Harvard Education Review, a commonality found across Makerspaces was the potential for it to be used as a small business incubator (Sheridan et al., 2015). Solving problems, having ideas with tangible manifestations and entrepreneurial spirit espoused by the makers all lead to passion projects.

One example of this is Noblesville High School's Innovation class, where one student successfully affected environmental policy change, while another gained patents for his advancements to solar panel technology (Kelly, 2016). Even young students can make valuable contributions to society, and they may even be able to create jobs for themselves!

Outside of Makerspaces, this concept has been in education in the form of 'genius hour' or '20% time' (Juliani, 2015). One difference is the tools and resources available to students in a Makerspace setting. The advanced technology provides students the opportunity for rapid prototyping or manifestation of an abstract idea into the physical realm.

However, before students can use the tools, the teachers must be comfortable facilitating learning with advanced technology. The next section examines teacher skills and dispositions that can lead to successful Makerspace management.

Teacher Training: TPACK framework to examine educator experiences

Shulman (1986) introduced the construct of pedagogical content knowledge, or PCK, the knowledge need for an educator to be an effective instructor. Mishra and Koehler (2009) build on PCK, adding a technology component to the framework to create TPACK. It was later renamed TPACK (pronounced: "tee-pack") to give the framework a more comprehensive overview of the three knowledge domains within the acronym, as well as ease of remembrance (Thompson & Mishra, 2007). The strength of the framework lies in analyzing the interactions between and amid the knowledge bodies. TPACK serves as a framework for establishing what knowledge teachers must possess to successfully integrate technology into their teaching practices, and how teachers may develop that knowledge (Schmidt et al., 2009). While analog technologies such as pencils are viewed as archaic tools of school, the more protean digital technologies are often perceived with more reservations than ready acceptance as a tool. Educators must also understand the unique propensities and constraints technology lends to effectively wield it in the classroom. Another barrier to successful technology integration comes from educators understanding *when* technology is appropriate as an instructional tool; this is often overlooked in training that focuses solely on the *how* and *why* (Polin & Moe, 2015).

The domain of content knowledge refers to teachers' understanding of subject matter, going beyond facts and transcending to comprehending the structure of the subject matter (Shulman, 1986). A teacher not only needs to understand the concept as well as peers working in the discipline, but also must be able to explain why it is so. Additionally, a teacher must be able to explain the basis for the concept, and under what circumstances the concept may be refuted. Nature of inquire varies by discipline, yet educators should be able to convey the knowledge fundamentals within their field (Koehler & Mishra, 2009). A teacher has a much deeper charge than contemporaries in the same field that only require knowledge of the facts and figures; a teacher must discern the truths and be able to explain them to others. A teacher who lacks deep content knowledge can be detrimental to students' learning; if a teacher does not fully understand the principle and situated context themselves, how will they be able spread knowledge to others?

The next domain is Pedagogical Knowledge, or PK. Pedagogical knowledge refers to an educators' profound understanding of the approaches of teaching and learning. An educator with good pedagogical knowledge knows how learners construct knowledge, inspiring students to foster positive dispositions toward learning (Koehler & Mishra, 2009). Cognitive, social and developmental theories all come into play with pedagogical knowledge.

Where pedagogical knowledge overlaps with content knowledge is a subdomain known as PCK, or pedagogical content knowledge. Subject matter is transformed for teaching as the teacher tailors the material to the needs of his or her students. The content is adapted to meet the students' prior knowledge and presented in multiple ways. The teacher is aware of common misconceptions and helps guide the students through an analysis of the material, forging connections and exploring the problem from multiple angles. A deep understanding of both content knowledge and strong pedagogical understanding is required for PCK to come into fruition.

The third knowledge domain in the TPACK framework is technology knowledge, or TK. While difficult to define due to the ever-evolving nature of technology tools, technology knowledge evaluates when it is appropriate to use technology, how to best utilize it, and recognizing when technology can assist or impede a task (Koehler & Mishra, 2009).

Technology content knowledge (TCK) can assist us in understanding the world around us, from providing new modeling and simulation techniques to providing metaphors for understanding systems (i.e. viewing the heart as a pump). While technology choices can inhibit or liberate the content being conveyed, technology can also offer additional flexibility in navigating representations (Koehler & Mishra, 2009).

The interactions between the three knowledge domains (technology, pedagogy, and content) create TPACK, an emergent form of knowledge and the basis for impactful instruction utilizing technology (Koehler & Mishra, 2009). Unique from the individual domains, TPACK requires a skilled educator to masterfully wield all of the domains together. The introduction of new technology tools forces the teacher to re-evaluate their content representation and pedagogical strategies through the lens of TPACK framework.

Seven distinct constructs emerge in TPACK framework, including the three main knowledge domains (content knowledge, pedagogical knowledge, technical knowledge), the three subdomains of pedagogical content knowledge, technical content knowledge, technological pedagogical knowledge, and the combined TPACK (Graham, 2011).

Technological pedagogical knowledge (TPK) is harnessing the power of technology to impact teaching and learning, understanding the constraints and affordances of the technology medium. To reach the full potential of TPK, educators must reimagine technology to fit the needs of pedagogical purposes, rethinking how technology may best serve their own intents.

TPACK framework was used in this study in the analysis of the complexities of teaching in a Makerspace environment. As the newest wave of digital fabrication tools permeate the school landscape, Seymour Papert's (1996) words still ring true: people and culture should be the primary focus of learning; it is wise to be cautious of technology tool overshadowing learning. Learning can often mistakenly be about the tool instead of *with* or *through* the technology; tools must be supplemented by a sharp theory of learning (Brennan, 2015). Using the tool must be done in a purposeful manner, and can be difficult to do in a constructivist way. Blikstein (2013) describes a workshop in which participates are introduced to a simple assignment of creating a custom keychain as an introductory assignment. Instead of progressing to more complex builds, students created a factory by mass-producing the keychaings, which Blikstein coined as "keychain syndrome." The participants lacked any computational challenges, and teachers can also fall into this trap quite easily without a deeper understanding of TPACK.

A danger of trending technology is to introduce it into the schools for the sake of having the latest tool. Without a sophisticated understanding of TPACK, educators are at risk of not knowing how to best utilize the tool within the Makerspace to support learning. The intersection of technology, pedagogy and content is the optimal area for educators to be operating within. Inside a Makerspace, tools should be thoughtfully chosen based on a teacher's deep pedagogical understanding of how to best leverage a particular tool when it will enhance the content or curriculum. Applying intersecting concepts of TPACK to the Makerspace requires a sophisticated understanding and plan. Projects must be of a reasonable size and scope based on pedagogy to meet the goals of the curriculum. TPACK as well as a constructivist lens should inform Makerspace decisions.

This study examines the rationale behind the choices educators make to determine if they were influenced by TPACK framework. TPACK can assist in answering questions such as 'to what extent is computational thinking evoked in Makerspaces?' The next section looks deeper into another aspect of the learning theory constructivism: computational thinking.

Developing Computational Thinking

With STEM education gaining popularity, coding and computational thinking are also on the rise. There are many definitions of computational thinking in circulation, which makes the topic even more ambiguous as researchers and educators grapple with different approaches to implementation. While coding and computational thinking (CT) are often used without distinction, the concepts are not synonymous. Coding is the physical act of writing lines of code to instruct a program on what to do; computational thinking is much harder to define. The National Research Council (*Report of a Workshop on the Scope and Nature of Computational Thinking*, 2010) spent 26 pages defining and discussing what CT entails. The first major appearance of computational thinking in the context of K-12 education can be attributed to Seymour Papert (1996). Jeannette Wing's article acted as a catalyst for computational thinking, which gained more notoriety in conjunction with K-12 education (2006). However, Wing's article was criticized for being too vague in defining computational thinking and not distinguishing it from other problem solving approaches (Jones, 2011). Grover and Pea (2013) emphasize computational thinking as a perspective frame for working in many areas.

The International Society for Technology Educators and the Computer Science Teachers Association created an operational definition of computational thinking with the input of hundreds of educators, researchers and industry leaders. These groups describe CT as a problem-solving process with many distinguishing characteristics. First, the user can articulate a problem in a way that enables a computer or other tools to assist in solving. Data is logically arranged so that it can be analyzed; data is abstracted through models and simulations. A series of ordered steps, or algorithmic thinking, is used to automate solutions. Consolidating steps and resources to improve efficiency are key. The problem can be generalized, and transfer can occur across additional problems. Moreover, they defined dispositions associated with CT: poise while working with complexity, perseverance when faced with hard problems, lenience when dealing with ambiguity, aptitude when facing open-ended problems, and the capability to work with others to attain a common goal (Barr & Stephenson, 2011). Computational thinking is not regulated to dealing with computers, but rather the principles and approaches of analytical problem solving that derive from computer science (Wing, 2006). While all do not embrace Wing's all-encompassing definition of computational thinking, CT is still esteemed as a skill required for succeeding in the Information Age (Grover & Pea, 2013). This study seeks to learn to what extend is computational thinking actually evoked in K-12 Makerspaces. Here is an example of evaluating computational thinking and applying the previous section on TPACK frameworks. A teacher wants to introduce technology into the teaching of decomposition, a computational thinking skill. In designing a large project, there are many nuanced parts that compose the whole. When applying the TPACK framework, a teacher would plan a reasonable size and scope of a project to engage students in the concept of decomposition through technology. The teacher may encourage students to explore the concept of decomposition through a 3D modeling and 3D printing project in which the smaller pieces will have to be thoughtfully designed to assemble the whole product. In this purposefully designed activity, the teacher is melding TPACK frameworks, a constructivist approach and the proper technology to accomplish her goals. This study examines current K-12 Makerspaces to evaluate the thought-process behind the activities and tools utilized. The following section examines often-overlooked soft-skills in Makerspaces.

Promoting Soft-Skills

Important soft skills, sometimes referred to as 21st century skills, are another potential outcome of Makerspaces. Soft skills can include: creativity, innovation, communication, collaboration, and problem-solving (Peppler, Maltese, Keune, Change, & Regalla, 2015). Additionally, these soft skills also align with the Next Generation Science Standards (NGSS). This is helpful for educators seeking validation for adding a Makerspace into the formal education environment; the national standards add an element of validity to Makerspaces in regards to curriculum.

Researchers emphasize the importance of “soft” skills cultivated within Makerspaces, including: “creativity, innovation, communication and collaboration, critical thinking and problem-solving, adaptability” (Peppler et al., 2015b, p. 4). Without defining outcomes of

Makerspaces, they make not be perceived as a legitimate in the K-12 education setting. There are concrete outcomes for making that can be defined and assessed. Examples of this include: planning, iterating, recognizing errors, and metacognition. Design journals coupled with the overall product could also be evaluated. Also, in a school setting, there must be accountability for the individual student. Survey questions highlight how individual assessment of Makerspace performance is communicated to stakeholders.

Assessment & Makerspaces

Makerspaces in the educational realm are a new phenomenon. In 2015 survey of Makerspaces for the Maker Ed Open Portfolio Project, researchers found that the majority of respondents had maker programming for less than two years. (Peppler et al., 2015a). With Makerspaces infiltrating schools, each space may take on very unique forms depending on the resources available, age of students serviced, scheduling, and intended outcomes.

There are many potential outcomes of a Makerspace, and schools may add a Makerspace to obtain any one of these results. A few of the most common anticipated outcomes from Makerspaces are: promote an interest in STEM careers, cater to under-represented groups such as minorities and women, develop computational thinking, or cultivate soft-skills (creativity, innovation, communication, collaboration, problem-solving). An afterschool Makerspace or a library Makerspace may take on a completely different feel than a dedicated STEM-focused scheduled class. From casual tinkering during free time to dedicated on-going class projects, there is a stark contrast in the differences of Makerspaces implemented in schools, and the assessments that accompany it.

Challenges of Assessment in Makerspaces

One thing that all school Makerspaces have in common is a degree of accountability. Whenever programming is added to the school day, there must be a way to evaluate results. However, the goals of Makerspace programming can vary from school to school. As described earlier in this chapter, Makerspaces are hard to define in and of itself, which makes the assessment process even more convoluted. This section sets out to define what the main facets of educational Makerspaces are, and how to best assess each particular area.

Intended Outcomes

There are a few clusters of outcomes generally associated with Makerspaces. As described above, Makerspaces are difficult to define due to their diverse implementations at the different grade levels across schools. However, the following outcomes are generally regarded as the most popular goals of Makerspaces.

1. Promoting STEM
2. Reaching women and minorities
3. Developing Computational Thinking
4. Promoting soft-skills (creativity, innovation, communication, collaboration, problem-solving)

STEM/STEAM Outcomes

A popular goal of Making is to promote STEM careers. The Afterschool Alliance notes that assessing STEM programs has already been tackled by the National Academy of Sciences' Learning Science in Informal Environments report, which showcases a set of interdependent strands for informal science learning (Krishnamurthi et al., 2013). Strands include: "developing an interest in science, understanding science knowledge, engaging in scientific reasoning, reflecting on science, engaging in scientific practice and identifying with the scientific enterprise" (Krishnamurthi et al., 2013 p. 19). The report also acknowledges the goal of science learning is to create life-long endeavor. Another program that has similar informal STEM assessment goals is the Informal Science Education program at the National Science Foundation. Their framework includes assessing STEM impact categories: 'awareness, knowledge or understanding of; engagement/interest; attitude towards; behavior related to; and skills based on' (Bramwell et al., 2009). The overlapping categories of these two reports provide a framework for a systematic way to evaluate the impact of STEM projects.

The research has ignored important prospective data sources such as student design journals. While participant interviews can tell how students felt about the experience, such as YOUMedia's study of the Chicago Library Connected Learning Lab, it leaves out quantitative data on achievement (Larson et al., 2013). When moving into the formal school setting, a pre- and posttest could be a helpful diagnostic assessment piece to identify achievement outcomes. The research seems to focus on student interest in STEM careers without bothering to equip students with computational thinking skills that could help them acquire jobs in this field.

Coil (2014) notes that while assessment may involve testing, it can also focus on evaluating creative products and processes. Additionally, she goes on to note adoption of Common Core State Standards (CCSS) should not limit the mindset of educators to standardized testing, but rather provides an opportunity for developing and assessing creativity (Coil, 2014). Coil proposes to accomplish this through problem-based learning featuring ill-structured problems with no obvious solution mimic real-life scenarios. Additionally, Coil recommends solution for assessment was to integrate the arts. This approach is already being widely disseminated as STEAM (STEM + the arts) continues to gain traction.

Integrating the arts into Makerspaces allows for another assessment angle, meeting objectives in multiple subjects. The digital fabrication process can bring an engineering component to life that is dull in the curriculum, if covered at all (Berry et al., 2010).

Digital products and physical creations may already fall into this domain, including e-textiles, which are rising in popularity within Makerspaces. Checklists, rubrics, and discussions could be ways in which outcomes could be evaluated in the Makerspace domain. Research from Maker Ed notes a new, diverse generation of makers possesses transformative potential regarding STEM careers (Peppler et al., 2015a).

Comparable Fields for Assessment Literature

This study is needed to determine how educators are assessing if computational thinking skills are evoked during Makerspaces activities. The literature around assessment in Makerspaces is lacking. However, there are comparable fields with rich literature in assessing outcomes. One such field is problem-based learning, or PBL. Students are presented an ill-structured problem, which mirrors the complexities of real-world issues. There is not one defined answer, and multiple solutions may help the participants define which result may best fit the issue. In Makerspaces, students are often figuring out a solution to a real-world problem that they have identified. As with PBL, there are multiple solutions and approaches. The problem-based learning literature emphasizes the need for staff development for successful implementation (Stepien, 1993). While problem-based learning has been around for a few decades, professional development is still needed for Makerspace facilitators. Makerspaces are skyrocketing in popularity. A Google query of the terms “Makerspace conference” populates 243,000 results, including three formidable frontrunners: International Society of Technology Educators (ISTE), National Association of Independent Schools (NAIS) and South by Southwest

Edu (SXSWEDU). As with PBL, coaching and facilitating a Makerspace requires a different approach than a traditional classroom model. Teachers need support in order to be successful in their constructivist endeavors. Additionally, it is important to educate and empower stakeholders to advocate the importance of Making in schools.

At the meta level, this begins with policy makers advocating for computational thinking and computer science. There are many lobbyist groups dedicated to promoting the STEM cause. As a result, new STEM initiatives have received funding, like grants at the National Science Foundation. The National Science Foundation's Computing Education for the 21st Century initiative is a threefold approach: augment the research community, empower teachers with 21st century skills, and equip students for the future. This initiative comes with 13 million dollars of support annually. With policy makers giving constructivist STEM learning the spotlight, next is the importance of educating school leaders.

Without the administrative team understanding the role and benefits of a school Makerspace, it can be challenging for the teachers and students to continue. There must be a metric for what constitutes a successful Makerspace, and the assessment piece plays a critical role in communicating this message. Makerspaces are becoming more prominent in education as the mainstream populace are exposed to this unique learning approach. The International Society of Technology Educators received nearly 4,000 proposal submissions for their annual conference, and they aggregate the data to determine popular topics. The trending topics of 2016 all touched on aspects of a Makerspace: coding and robotics, Maker Movement, STEAM, student-driven learning, and flexible learning environments (ISTE Connects, 2016). With Makerspaces being an emerging topic, there is an opportunity to pull from comparable areas with deeper fields of research.

Articles written about assessment in STEM do not explicitly evaluate the computational thinking one would hope to find in Makerspaces. The literature ignores the levels of computational thinking achievement and quality of CT. While there is a dearth of research on assessment in Makerspaces, there are comparable fields in which extensive research has been conducted on assessment. Makerspaces have activities that can be characterized as a type of performance based activity. Makerspaces and performance-based activities have similarities in the collaborative piece; additionally, they are both conducted over time. Problem-based learning utilizes performance-based assessments; and Makerspace activity is easily described as performance-based activities. This next section pulls from assessment literature in equivalent disciplines to identify prospective avenues of evaluating Makerspaces in an educational setting.

The Miami Museum of Science ("Alternative Assessment Definations," 2001) suggests four types of alternative assessment: performance based, authentic/project, portfolio and journal. The performance-based assessment includes a scaled rubric, which is known to the teacher and student in advance. Using a performance-based assessment, students could demonstrate their understanding of operating equipment or lab procedures. As many Makerspaces utilize potentially dangerous tools, a performance-based assessment could be one way to demonstrate proficiency before students used a tool unassisted. Additionally, the performance-based assessment could continue to bolster the credibility of ongoing student projects by meeting specified criteria of a scaled rubric. The authentic or project assessment is an extended form of assessment that may encapsulate elements of performance-based assessment within. This type of assessment can be utilized for nuanced long-term projects, with students crafting solutions for real-world problems. While portfolios are an example of alternative assessment, they are often comprised of representative assignments. This may work in some Makerspaces if not used as the exclusive measurement tool.

The last type of alternative assessment suggested by the science museum is journal assessment. Specific to Makerspaces, design journals may be analyzed to show growth over time. A deeper analysis of a student's design journal could provide evidence of iteration, recognizing errors, and metacognition.

Assessments from the Field

Federal programs, grant funding and schools all rely on outcomes to justify their effectiveness. A Makerspace within the formal educational environment also have stakeholders to answer to. Constructivist implementation of a Makerspace does not lend itself to teaching a strict curriculum; instead, student passion drives projects. However, assessment and reporting on learning outcomes are essential to Makerspace success in education. When selecting the tools for a Makerspace, it is important that they are connected to a need; as projects expand, the potential for new tools will arise (Sheridan et al., 2015).

In their study, Brennan and Resnick (2012) used portfolios, artifact-based interviews, and design-scenarios. They examined three types of assessment for computational thinking, noting that each assessment method they examined had substantial limitations for K-12 implementation. The first limitation of their study on computational thinking was the exclusivity platform: they focused all of their efforts around MIT's Scratch program, which teaches children how to code. In a Makerspace, computational thinking may be found in multiple activities, not limited to such a controlled environment. As the researchers acknowledge, the portfolio-based assessment was limited in scope to final products. Much of the iterative process was lost to this evaluation, and not all student work was published. Artifact-based interviews offer insightful data, but would be too time-consuming as an evaluation tool for educators with hundreds of students. Design-scenarios were the third method of assessment. These pre-made scenarios are limited to Scratch users, in which the students are asked to explain the projects, extend it, fix a bug, and add a new feature. Again, this is very limited in scope and is not scalable to diverse Makerspaces. The researchers admit that none of their assessment pieces adequately evaluate the computational perspective component of the study. Additionally, they called for a combination of assessments to best capture the nuanced approach of computational thinking. This next section explores how the Makerspace experience can be inclusive to all students.

Gender/Racial Issues: Reaching Women and Minorities

Makerspaces are a potential avenue for inclusiveness in a K-12 STEM setting. One example from the field is Dr. Leah Buechley, designer of the Arudino Lilypad, a wearable microcircuit (Baafi et al., 2013). Dr. Buechley's invention is a sewable microcircuit utilizes conductive thread instead of soldering, which eliminates potential barriers of masculine tools and gives an entry point via crafting. Additionally, her research examines how children and teens can engage in making through less intimidating tools (Buechley & Eisenberg, 2008). Recent research has illuminated the positive impact of e-textiles on introducing girls to making (Kafai et al., 2014). Another important study is Digital Divas, an inner-city program in Chicago that focuses on exposing girls to e-textiles and programming (Martin, Erete, & Pinkard, 2015). While the Digital Divas study focuses on the target demographic of this study, it does so outside the school day. Gender identity has been extensively studied in digital spaces and coding communities, there is a still a lack of research in the K-12 Makerspace setting (Kafai, Fields, & Burke, 2001; Kafai, Fields, & Cook, 2010).

In addition to researchers, policymakers play an important role in gender and racial access to STEM programming. In recent years, President Obama has increased awareness about STEM education and made it a focus of his educational policy plan. Additionally, initiatives has been introduced to make STEM fields more attractive to women and minorities. The Department of Commerce's *Women in STEM: A Gender Gap to Innovation* showed that women make on average 33% more when they choose to work in a STEM field (Beede et al., 2011). However, women only make up 24% of the jobs in this industry.

When compared to international math and science test scores, students in the United States rank in the middle. Obama's ambitious plans set out to increase standings in both math and science when compared to other students internationally. A key component to this plan is to target girls and increase minority students who are underrepresented. In 2009, states that competed for a portion of the $4.35 billion dollar Race to the Top initiative increased the focus on STEM implementation. States that could prove they were actively making an effort to eliminate barriers for underrepresented groups received preference for the funding.

One groundbreaking goal included Obama's Cross-Agency Priority that would increase the number of students receiving a STEM undergraduate degree to 1 million students over the next ten years. To achieve this lofty goal, educational opportunities and support is provided for females. In May 2013, Obama released the five-year STEM Education Strategic Plan. This increases awareness of the need for underrepresented groups to hold STEM careers by making it one of five priority areas for interdepartmental collaboration.

The Educate to Innovate campaign includes a main component of representing women. This initiative partners with educators, businesses, and non-profits to help prepare more than 10,000 new math and science teachers. Outside of policy, partnerships are developing that will continue to put a spotlight on STEM education for girls. The partnership between NASA and the Girl Scouts of America is one such example. The government is also allocating grant money to this end. The Department of Education's Invest in Innovation fund gives competitive grants to entities with a record of positive student achievement. This grant assists both educators and students, assuring that they are provided access to rigorous coursework, exemplarily preparation, and chances for professional development.

The Obama administration has set program flexibility as another priority for STEM careers. First Lady Michelle Obama bolstered her husband's policy by hosting an event launch for the National Science Foundation's Career-Life Balance Initiative. This ten-year program attempts to eliminate many of the barriers that hinder females from succeeding in male-dominated STEM careers. Opportunities include yearlong deferrals for childbirth, as well as increased opportunities for virtual panel reviews. The National Institutions of Health has a re-entry program for those who have taken time away from their careers to attend to family duties.

In addition, the Obama administration has made female STEM role models and mentoring programs a priority. Within his own administration, Obama has appointed many female leads in senior STEM positions. The Women in STEM Speakers Bureau is dedicating to inspiring girls in middle school and high school that originated in 2011. The mentoring component is crucial to keeping women interested in both scientific and technical careers. The Presidential Award for Excellence in Science, Math, and Engineering Mentoring is bestowed on individuals for outstanding mentoring service. One of the qualifications for this award is dedication to encouraging young girls in technical careers.

In addition to general STEM policy, there are Makerspace specific initiatives. Career and Technical Education, or CTE, has the opportunity to convert existing spaces into a Makerspace through the U.S. Department of Education's (2016) CTE Makeover Challenge. President Obama instituted the first ever White House Maker Faire, which has become an annual event for student makers. Through his Nation of Makers Initiative, Obama has demonstrated his support for the Maker Education. MakerEd is a nonprofit organization derived from the Nation of Makers initiative which supports museums, community-based organizations, libraries and schools.

Advocacy will continue to increase, and the plight of women and minorities in STEM careers will continue to gain attention. Hopefully, with increased awareness and policy programs, a broader impact can be made on STEM careers, and Makerspaces can be one avenue for this difference.

Creating Sustainability: Measuring Success

With a wide interpretation of the outcomes described above, defining if a Makerspace is successful can be difficult if one does not have clear intentions. Based on intended outcomes, success would be measured differently. From a school perspective, a potential measurement could be increased achievement in STEM subjects. Another closely related STEM measure is interest and attitudes. At the school level, this could be increased enrollment in STEM subject classes after student involvement in a Makerspace. A subset of the measurements described above could be minority and women achievement, participation, and attitudes. Computational thinking is both a set of skills and dispositions that can be tangibly measured. Additionally, computational thinking is found within the Next Generation Science Standards.

While soft-skills are the most difficult to report on, the effects of these skills may be transferred to other areas. For example, a student may apply a problem solving technique that they honed in the Makerspace to the science curriculum. Additionally, the teachers can communicate anecdotes to the parents regarding skills individual students demonstrated during the Makerspace interactions. Design journals may be another source of evidence for these skills.

Best Practices Criterion

As Makerspaces skyrocket in popularity, it is unknown if they are accomplishing the intended goals. For the purposes of this study, the following serve as the criterion for defining best practices of K-12 Makerspaces (mirrors the earlier section of intended outcomes of Makerspaces with the addition of TPACK):

1. TPACK framework is applied when designing activities and projects
2. Diverse student populations are participating, including girls and minorities
3. Positive STEM identity is cultivated
4. Computational thinking skills are evoked
5. Soft-skills are promoted (innovation, creativity, collaboration, problem-solving, communication)

Best practices are needed to evaluate what is working well in established school Makerspaces. Additionally, stories of failure are things that educators as a whole can learn from when venturing into this new frontier. This study looks to evaluate best practices on applied TPACK knowledge, staffing, sustainability/funding, implementation of tools, evoking computational thinking skills, and evaluation.

Current Limitations

The bodies of research on educational Makerspaces are isolated government funded research projects with well-known authorities leading the studies. Often times these studies are more reflective of a sterile lab setting than the true field of education. At the time of publication, there was no literature found on sustained K-12 Makerspaces ran by teachers. There is a vast difference between the funding resources of the National Science Foundation with a fully staffed research project and a classroom teacher implementing a Makerspace with their own resources and understanding. Written through the lens of a current practitioner, this study hopes to bridge the gap from the world of academia to the trenches of fieldwork.

The Need for this Study

This study is needed to determine how Makerspaces are being utilized in K-12 education, and how we can improve thoughtful pedagogically sound practices. Additionally, this study examines outcomes and assessment of Makerspaces, including computational thinking skills and dispositions. Makerspaces are a fad in education, and without a deeper understanding of their purpose situated in constructivist learning theory they are in danger of passing as a fad. Evaluation of Makerspaces can prove if they are effective and garner support for sustainability, growth and expansion. As more Makerspaces erupt on the educational scene, they could use studies like this as guidance for best practices saving valuable time and resources.

Summary

This literature review has examined constructivism, and the Maker Movement as a background for this study of K-12 Makerspaces. Theories, pedagogy and identity surrounding Makerspaces in an educational environment were also explored. Best practices criterion was established, including participation of girls and minorities, evoking computational thinking skills and cultivation of soft-skills (i.e. innovation, collaboration, and problem solving). TPACK was utilized as a framework for a discussion of educators implementing a Makerspace. Evaluation was discussed at length, including program outcomes for gauging success and promoting sustainability. Limitations in the current research were addressed, and the need for this study was established. In chapter 3, the methodology underpinning this study is examined.

Chapter Three: Research Methodology

The overall purpose of this exploratory mixed methods design is to understand the best practices, successes and failures of Makerspace directors in K-12 formal education settings across America. As defined in Chapter One, a Makerspace is a space where students create self-directed passion projects, prototype inventions, and learn new skills based on their interests through collaboration and tinkering.

The popularity of maker spaces and maker culture for learning continues, but relatively few spaces and activities actually take place within the school day as part of the school curricula. Most are after school or enrichment spaces. In order to increase the serious engagement with the maker movement as a realization of constructivist teaching/learning, it is crucial to understand the successes and barriers to school day contexts for Makerspaces.

This study probed the experiences of educators who have established Makerspaces in a formal education environment, not as after school, enrichment, or supplemental activities. Grounded in empirical TPACK literature, the study examines the planning and decision making process regarding Makerspaces. This investigation seeks to inform other educators and researchers interested in a constructionist approach to educational Maker initiatives.

This study examined best practices of Makerspace directors in a K-12 setting over a number of different sites. The successes, failures and lessons gleaned from the educators that run established Makerspaces are the object of this research. From their forged path, other educators may learn from their successes and mistakes to champion new Makerspaces in educational settings, while saving valuable time and expensive resources.

While Makerspaces are somewhat akin to the pioneer frontier, only operations that are over a year old are included in this study. TPACK framework was used to examine the decisions and planning methods of educators running Makerspaces. Constructionist theories of learning heavily influence the pedagogy of a Makerspace, including the culture, roles, and identities explored. The classroom dynamic is transformed from a didactic to a student-centered approach, which provide unique challenges for the educator.

Research Questions

The research questions for this exploratory study are:

- How are educators using Makerspaces in schools?
- What are teachers' experiences of Makerspaces inside the school day?

The questions address what educators are doing with Makerspaces in a K-12 environment and how they are go about doing it. Makerspaces also have the potential to help students develop computational thinking skills and positive STEM identity. Makerspaces gives an opportunity for teachers to demonstrate TPACK principles and a constructivist approach as they plan and execute activities.

Design

A mixed methods design was selected for this study to neutralize biases inherent to each qualitative studies and quantitative studies when performed alone. Creswell (2013) notes by collecting and analyzing both open-ended qualitative and closed-ended quantitative data to address the research question, validity may be established.

Mixed methods are a newer methodology to conducting research, which arose to popularity in the late 1980s and early 1990s from diverse fields of study (Creswell, 2013). Mixed methods can provide a sophisticated approach to analyzing data while mitigating the limitations of qualitative and quantitative approaches. This study is comprised of two distinct phases: a quantitative survey followed up by a qualitative interview. This methodology offers maximum insights into the world of K-12 Makerspaces from the perspective of educators.

As K-12 Makerspaces have not been extensively studied, this exploratory study uncovered insights in the initial survey that were more closely examined in the follow-up interview. In the first phase, a quantitative survey was developed and administered to Makerspace teachers. The survey results informed a second phase of qualitative interviews from a subset of the participant pool.

Survey of Makerspace Teachers: Survey Construction

During phase one, a quantitative survey was administered to K-12 Makerspaces directors. As established in Chapter Two, constructivist teaching can be challenging to implement, yet this approach is key to a successful Makerspace. Using the TPACK framework, this study probes deeper into the logic behind the design of school Makerspaces, ranging from activities to inclusive purchases of equipment.

Survey Instrumentation

Qualtrics is an online survey tool, and the questions were built and administered through this software. A Qualtrics survey was administered electronically to participants. As participants are scattered across the country and working in a role that requires technology proficiency, an electronic survey was the most appropriate choice. After the participants had three weeks to complete the survey, answers were downloaded and coded. The survey consisted of thirty-nine questions in four categories.

The four categories are: Participant Demographics, Makerspace Setup, Intersections of Technology, Content and Pedagogy, and lastly, School Demographics. The categories echo the literature review sections. From a participant perspective, the first part of the survey covers consent, explains the survey purpose, assures their confidentiality, and provides a way to contact the researcher. After providing consent, participants move to the next section. If participants do not provide consent, the survey will end.

Each of the four survey categories relate back to the literature review in chapter two. In the first survey category, Participant Demographics are directly related to the Maker Movement section of chapter two which deals with identity of a Maker. Professional background demographics probe the participant background's experiences to their disposition towards making. Section two explores Makerspace Setup; the learning theories section ties into the Makerspace setup and constructivist approach. Section three asks about Makerspace Activities through a TPACK lens. The Intersections of Technology, Content and Pedagogy are extensively covered in the TPACK section of the literature review. Section four probes the school demographics in regard to their Makerspace. Lastly, school demographics relate to the 'landscape of schools' section of the literature. The next section covers the logistics of the survey.

Sampling for Survey

The target population for this study was Makerspace Directors in a K-12 setting. This includes teachers, technology staff, and librarians, which facilitate the Makerspace and make the planning decisions for it. Participants spanned elementary, middle and high school settings. The Makerspace must be over one year old for the educator to be eligible to participate in the study. Sampling was used to gather a group of participants representative of the larger body of educators. Participants for the study were solicited through Twitter and Google+ groups around key terms involving Makerspaces and educational technology. The survey solicitation timeline serendipitously corresponded with President Obama's National Week of Making, so additional hashtags from this initiative were also included.

Examples of Twitter hashtags used: #MakerEd, #NationOfMakers, #WeekofMaking, #Edtech, #hacklearning, #21stedchat, #ISTE2016, #kidscancode, #STEMchat #Makerspace, #WHChamps, #libchat, and #edthink.

Google groups were also used to promote the survey. Using Google Plus, the survey was posted to the Google for Education Certified Innovators, MakerEd, and Makerspace groups.

Seventy-eight people opened the survey, but only 60 started it. Out of those, 29 participants provided their email and indicated they were willing to be contacted for a follow-up interview.

Survey Sample Demographics

While sixty people began the survey, forty participants completed the entire survey. The results reflect only the sixty that completed the survey in its entirety.

Participant demographics made a large impact on this study because of practitioner concerns about their efficacy with maker materials and concepts. The survey asked several questions about background of the participant, including their educational background, technical skills, and if they possess a maker mindset. The survey contained seven participant demographic questions.

Participants were made up of 15 males (25%) and 45 females (75%). The most popular job title was teacher (13%), followed by librarian (8%), administrator (6%) and other (6%). 60% of respondents' highest degree was a Master's degree; 25% of respondents reported their highest degree was a Bachelor's.

Table 1

Job Title

Title	Number of responses	Total *N*
Teacher	13(33%)	39
Makerspace Director	1 (3%)	39
Instructional Technology Coach	5 (13%)	39
Librarian	8 (21%)	39
Administrator	6 (15%)	39
Other	6 (15%)	39

Makerspace Setup

This section probed into when and how the Makerspace is utilized. Important people in running the Makerspace were identified. Participants also listed the three most essential materials to their Makerspace, and then they identified who choose said materials. They also identified if they have encountered any obstacles in the process of setting up and running the Makerspace; this question triggered a follow-up prompt on the interview section. The next section examines the Intersection of Technology, Content and Pedagogy in an educational Makerspace.

Intersections of Technology, Content and Pedagogy

This section ties directly to the TPACK framework detailed on page 39 of chapter two. While this section asked about student action in the classroom, it provided insights to the underlying pedagogical choices the teacher made when designing the activity and choosing materials. Additionally, this section discussed evaluation in Makerspaces, an important component of formal education discussed at length on page 48 of chapter two. Lastly, this section addressed computational thinking in students a possible shift in their STEM identity. This detailed section is comprised of eleven questions, often in the form of a matrix checklist.

School Demographics

A Makerspace at an elementary setting is different from a high school Makerspace, both in scope of the projects and advanced skills necessary. This study asked how current schools are overcoming the challenges of implementing a Makerspace. Demographics from the survey provided insights to scheduling challenges, staffing, and physical setup that could be helpful to other schools considering a Makerspace setup, reported in Chapter 4.

There was a drop-off in participation as the survey went on. There was a shift from simple demographic questions to the more involved matrix-style questions regarding implementation in the classroom. While 60 participants began the survey, there was a slight decline twelve questions into the survey where responses dropped to an average of 47 respondents. Twenty-three questions into the survey, numbers start to reflect 39-41 people answering questions for the remainder of the survey. Participants were allowed to skip questions. The school demographic section came at the end of the survey, so the total participants are smaller than the original group.

The school sites were diverse. 64% of respondents were from public schools, 33% were Independent, and 3% were charter schools. A surprising number of elementary schools made up the largest percentage or respondents, with high schools making up the lowest group at only 20%.

Table 2

School Site

School site	Number of responses	Total *N*
Elementary (K-2)	22 (56.4%)	39
Upper Primary (3-5)	28 (72%)	39
Middle School (6-8)	18 (46.2%)	39
High School (9-12)	8 (20.5%)	39

Student populations can be seen on the table below. The majority of schools were mid-sized, with student populations of 400-600 making up 38% of respondents. 20% of schools were urban, 56% were suburban, and 23% were rural.

Table 3

School Size

Student population	Number of respondents	Total *N*
Less than 200	6 (15.4%)	39
200-400	7 (18%)	39
400-600	15 (38.5%)	39
600-800	7 (18%)	39
800-1,000	2 (5.1%)	39
1,000-1,500	1 (2.6%)	39
1,500+	1 (2.6%)	39

Only 16 out of 39 educators (41%) stated that all of the students at their school visit the Makerspace. The largest percent of educators (43%) served at schools with low percentages of students qualifying for free and reduced lunch.

Table 4

Socioeconomics

Percentage of students eligible for free/reduced lunch	Number of respondents	Total *N*
I don't know	9 (23.1%)	39
0-25%	18 (46.2%)	39
26-50%	3 (7.7%)	39
50-75%	6 (15.4%)	39
76-100%	3 (7.7%)	39

Data Analysis Plan

Quantifiable responses from the survey were downloaded into SPSS, statistical analysis software that can code data. Categories based on the literature review in chapter two were the basis for the coding process. A descriptive analysis including frequency, mean and standard deviation was run on all applicable questions. Additionally, crosstabs was run on demographic data; these are discussed in the findings in Chapter Four.

Interviews with Teachers: Interview Question Development

The questions for the interview portion were developed based on current literature discussed in Chapter 2. For the readers' reference, the questions will be listed in their entirety and then explained one by one.

Interview Questions:

1. In your own words, please describe the value of a Makerspace to a school.
2. Does design thinking play a role in your Makerspace? If so, please describe how.
3. In the initial survey, you indicated that you had overcome obstacles in your Makerspace. Can you please elaborate on this?
4. Tell me about your experience with professional development for Makerspaces.
5. Describe a typical class in your Makerspace.
6. What is the process for determining which activities or projects to undergo in your Makerspace?
7. What marks the success of a Makerspace program? How do you describe success?

Question 1: Value of a Makerspace

A comprehensive review of current literature revealed a gap in Makerspaces in an educational setting. The literature did note that gender and minority participation in STEM subjects has been at a deficit, and Makerspaces are one way of reaching these groups (Buechley & Eisenberg, 2008). This question was design to probe what educators perceive as the benefit of having a Makerspace.

Question 2: Design thinking

A Makerspace alone in an educational space is not inherently supporting student learning. The teacher may give students explicit instructions and projects, never allowing them to delve into the design thinking approach. This question relates closely to constructivist approach in teaching; students should be given agency in their learning, but with a structured foundation.

Question 3: Overcoming obstacles

The literature described the difficulty of constructivist approach, as it is such a deviation from didactic approach found in many traditional classrooms. The literature posited that a shift in methodology could be difficult for both faculty and students.

Question 4: Professional Development

While rewarding, the constructivist approach to education can be daunting for both the teacher and the student. The teacher needs training to support the unique challenges associated with this methodology. Additionally, the students may face difficulty with the uncertain tasks and ambiguity associated with student-driven Makerspace projects. Training in running an educational Makerspace and best practices from other practitioners can be essential in a successful Makerspace program.

Question 5: Typical class

This open-ended question searched for evidence of the educator incorporating TPACK and computational thinking in the Educational Makerspace.

Question 6: Process for determining activities

There is a danger of tools dominating the Makerspace landscape without the foundational pedagogy to support learning. The TPACK framework described in Chapter 2 provides the rationale for learning in an Educational Makerspace. The teacher must knowledgeably wield tools that are appropriate for the content and pedagogy.

Question 7: Defining success

As noted in Chapter 2, schools are heavily tied to measurable outcomes. For Makerspaces to thrive in an educational environment, they must demonstrate their worth. Researchers have not yet developed assessments to capture nuances of computational thinking (Brennan & Resnick, 2012). This open-ended question allowed the educators in the field to explain in their own words how the Makerspace contributes to the school, and justify why Makerspaces belong in education.

Data Analysis

Just as with the quantitative data, the interview questions were coded based on general categories generated from the literature review in chapter 2. An iterative process was used to develop the coding schema were keywords were identified. The coding rubric involves key terms or phrases that were common in the responses. A definition was created to elaborate on those key terms. Next, a quote that illustrated the message was included in the coding rubric. Finally, there was a count of how many respondents indicated a particular item.

The researcher reviewed the audio file and made notes for each interview. The data from the individual interviews were compiled into a spreadsheet, and then the data was coded question-by-question using the coding rubric, found below. Totals for each main idea from the rubric were identified, and the number of participants who discussed each concept can be found in the last column, listed out of a total of five total participants.

Rubric for Interview Questions

Table 5
Question 1: Typical Day

Terms	Definition	Quote	Totals
Routine/ Structure	Each class follows a predictable workflow, even with students choosing their own projects.	Students complete bell work activity, followed by a mini-lesson for how to use new technology, then students working on their big projects (problems they come up	1/5

(continued)

Terms	Definition	Quote	Totals
		with around home or school), and each day wraps up with a daily reflection log	
No such thing as a typical day	Each day in this Makerspace is truly unique; there is not an established workflow or routine.	Days in our Makerspace can't be defined as typical! There is a variety of ways in which our Makerspace is used for flexible projects.	4/5

Question 2: Design Thinking

Terms	Definition	Quote	Totals
Design thinking is essential to the Makerspace	Design thinking is explicitly taught in the Makerspace.	Design thinking IS the role. It allows for cross-dimensionally across spaces instead of silos.	4/5
No design thinking is apparent	Design thinking is absent from the Makerspace.	No, we didn't use design thinking with our younger students.	1/5

Question 3: Professional Development

Terms	Definition	Quote	Totals
Conferences & Workshops	Edtech conference sessions, workshops by Universities	My experience included FabLearn conference at Stanford and Do Design Discover Workshop. The Do, Design, Discover was a one week making experience as a student, and it provided networking opportunities. At Fablab, we learned more about the background research and access to different approaches. After this experience I saw things at a different level.	4/5
Online resources &	Twitter, blogs, online	I googled Makerspaces myself and joined online communities on Google plus.	4/5
Social Media	professional networks (Google + communities, MakerEd, etc), Webinars	Blogs were a really good resource because they filtered out things, and they were written by teachers. I could pick out little things to try in my own Makerspace.	
Site visit	Time spent in…	Visits to other schools with Makerspaces…	4/5

(continued)

Terms	Definition	Quote	Totals
	a community Makerspace or at other school's Makerspace	allowed conversations with directors to share ideas. I could see how space was setup, and collaborate on safety and classroom management ideas.	

Question 4: Overcame obstacles…

Terms	Definition	Quote	Totals
Change in school culture	Makerspaces aren't easily defined, and they can be difficult for stakeholders to understand.	Not the way we did it before- started with introducing administrators to maker movement to get them on board.	2/5
Change in class culture/expectations of students	A Makerspace presents challenges for students as it is radically different than a traditional classroom. Students must show more initiative and resilience. This also changes the role of the teacher to a facilitator	Having students embrace design thinking was a challenge. At first, when they ran into obstacles, they flatlined… It's a process. As a teacher, being flexible with the learning is very different from other subjects within the school day.	

Question 5: Process for determining activities

Terms	Definition	Quote	Totals
Teacher directed	Teachers give students a project, theme, or challenge	Prompted by themes- what might get kids to try something. Sometimes it is more directed, like wearables.	4/5
Student	Students come up with their own projects	The students decided on their own which tools to work with	1/5

Question 6: Value of a Makerspace

Terms	Definition	Quote	Totals
Creation/Working with hands	Establishes the value of tinkering in the Makerspace	It's a very valuable component. It's not playing, but time to tinker and create. That creation level is what we strive for. Teacher evaluation rubrics are	2/5

(continued)

Terms	Definition	Quote	Totals
		always looking for students to drive their own learning. Makerspaces provide that. Provides environment where students are excited, more willing to push through. They're highly motivated, preserving, and not giving up. It's an opportunity to do more with their hands.	
Develops student identity	Students take ownership of their own learning. Confidence is instilling as they discover their passions.	Give a seat at the table to students who would not ordinarily have one. Students have a way to fit in (born organizer, kid that makes things) Why didn't we do this before? It's a community of learners. Relationships happen there. Mentors come from outside community. This lets children self-identify.	4/5

Question 7: Defining Success

Terms	Definition	Quote	Totals
Sustainability	Focuses on logistical issues of the future of Makerspaces	Success is continued existence, learning how to evaluate the student experience in Makerspace, struggling with testing and problems with testing. We know that the Makerspace is a positive experience for students, but we need to convey this in order satisfy parents who are only concerned with college acceptance.	2/5
Student impact	Focuses on the impact that a Makerspace has on a student	I'd describe success as: 'Kids who are excited to problem solve, try new things, take risks, help one other out. Having teachers who do the same and learn their new role as facilitator rather than head instructor.'	3/5

Question 8: Examples of student work

Terms	Definition	Quote	Totals
Making it fit within goals/parameters of Makerspace	Focuses on logistical issues of the Makerspaces	I had a student that wanted to focus on fashion, specifically, designing handbags. I asked: What kind of problem are you going to solve? He responded: How good the bag looks is a problem. It's the aesthetics, art, and design aspect of maker. The student took the parameters of our Makerspace and created his own project. He was able to explain how it met the goals, why his project was just as good as a hydroflask. It expanded my perception as a teacher of how broad making can be.	2/5
Makerspace uniquely suited to create this type of project	Focuses on the impact that a Makerspace has on a student	I had a Grade 4 student that became obsessed with 3d design. The student sent in their stuff over the summer. He is concerned about leaving our school; he would have been lost in traditional environment. The Makerspace provides an opportunity for me to nurture, recognize and verbalize that student's talent. It changes his ability to believe in himself. We're teaching the students that they can learn. And the teacher learning with the students.	3/5

Question 9: Showcase

Terms	Definition	Quote	Totals
School Community	Student work was showcased to other classes within the school, i.e. Gallery Walk	We host gallery walks for other classes to come and see what we have been making.	3/5
Local Community	Student work was showcased to the community outside the school, like Parents, or Makerfaires	We host a mini-maker faire to share projects with parents. We have the parents complete a design thinking challenge with their families (i.e. create a marshmallow catapult). It's also a great way to involve younger siblings and families, and it's a wonderful opportunity to let them see what their child has been doing in the Makerspace.	3/5
Global Online Community	Student work was showcased on websites, blogs, etc.	Students take photos of successes/things they thought were important and posted it to a blog. We created a website so parents could see. We have a class Instagram Account.	2/5

Question 10: Next Steps

Terms	Definition	Quote	Totals
Get more faculty involved	The goal is to get more faculty using the Makerspace or to create more cross-curricular ties	Get more teachers involved and get particular teachers to be experts on different tech. i.e. Tinkercad expert teacher who has mini-lessons set up, students could obtain badge on a particular tech and then use it during Genius hour.	3/5
Taking it to the next level	The participant's response indicates that they want to advance the use of the Makerspace (i.e. complexity of projects)	Turn question from defining Makerspace to owning Makerspace. Having faculty confident when students know more about machines then they do. Resource management, budget system	4/5

Note. Totals reflect how many interviewees demonstrated this component in their answer out of a total of five participants.

The results of the quantitative data provided context for the questions in the qualitative phase that follows. Due to the lack of research in this pioneer field of educational Makerspaces, a qualitative approach with exploratory underpinnings was explored. The goal was to determine the successes, failures, and wisdom gleaned from the lived experiences of Makerspace directors as they reflect back on establishing the space.

Questions on the survey asked things like "Have you received professional development on Makerspaces?" The interview portion allowed for educators to expound upon the specific training experiences that they found valuable, and it gave them an opportunity to explain why. Another question probed further into obstacles they had encountered while running the Makerspace. While the interview asked participants to check if particular activities took place in their class, the open-ended interview responses illustrated a more detailed picture of the Makerspace flow. The responses from the survey served as a basis for the interviewer to probe deeper to obtain insights about their Makerspace experience.

Sample Selection

Due to time restrictions along with financial limitations, only a subset of five of the initial group of participants was selected to advance to phase two of the research. Phase II: Interview participants were selected from 29 volunteers from the Phase I: Survey. In addition to meeting the criteria for Phase I: Survey selection, participants were selected for maximum diversity, both individually and school settings. For example, a mix of male and female educators was highly desirable in the sample. For the school demographics, a variety of settings were sampled, ranging from elementary to high school in both public and private institutions. These participants were interviewed on Skype with semi-structured questions (see Table 4) constructed based on the literature. Participants were selected based on their willingness to participate as well as demographics of the population they serve. A broad range of public and private schools with a mix of elementary and upper grades Makerspaces is highly desirable. Additionally, diversity in funding and student demographics is also a consideration, as this will make the findings more accessible to all readers.

Participants were selected to be representative of the population, including both public and private schools spanning K-12 in rural, urban, and suburban settings. Two public schools, two Independent schools and one charter school were represented. The table below gives a more detailed look into the demographics among the interviewees. The spaces proved to be extremely diverse, with a surprising amount of Makerspaces found in elementary grades. Dedicated Makerspaces made up 38% from educators interviewed in this study, with libraries coming in at 23%. Interestingly, 26% of educators from this study described their Makespace as ‘other’ denoting that it did not fit within any of the traditional models.

Table 6

Interviewee School Demographics

Setting	Grades	Size	Setting	Students that Qualify for Free/ Reduced Lunch
Independent	Grades 6-12	401-600	Urban	0-25%
Independent	K- Grade 8	200-400	Suburban	0-25%
Charter	K- Grade 8	200-400	Urban	0-25%
Public	Grades 3-5	800-1000	Rural	76-100%
Public	K- Grade 5	401-600	Suburban	26-50%

Research Considerations: Study Assumptions

A critical assumption of this study is that the participants were comfortable representing their role as a Makerspace innovator with the researcher. Considering the researcher’s role as a fellow educator and former technology coach, the participants should have felt at ease to freely share their stories. Another assumption is that the researcher was able to accurately represent the diverse experiences of the educators and communicate these experiences to a large audience. To overcome this assumption, non-technical language was employed to preserve the integrity of the participant's experience.

Scope

While Makerspaces are prevalently found in informal learning environments such as museums or libraries, this study hones in to the formal setting of K-12 school Makerspaces. Both public and private schools were considered. Makerspaces serving students in elementary through high school were sought after. Diversity in school size, demographics of student population, and funding were a consideration when selecting participates. In limiting the setting to this particular population and specific constructs, the narrow research focus created greater internal validity.

Validity and Reliability

Implementing Creswell's (2013) suggestions for establishing validity of an exploratory mixed methods study, validity from quantitative measures must be established before discussing the validity of the qualitative findings. Three colleagues in the educational technology field piloted the survey; after piloting the survey updates were made based on their feedback. In order to establish validity, the quantitative measures must first be proven valid, followed by a discussion of the validity of the qualitative data (Creswell, 2013). The sample size must be adequate on both phases of the study; in Phase I: Survey, 60 respondents started and 41 completed the entire survey. For Phase II: Interviews, 5 participants were selected from the original pool of 29 volunteers.

Human Subjects Consideration

As this study involved adults answering an anonymous survey, minimal risk was involved. All findings were de-identified in an effort to establish anonymity for all participants.

One factor to consider is the inconvenience of time lost by participating in the survey. It is possible the survey could have induced stress as participants were asked to reflect on funding sustainability or stakeholder support. However, participants were advised to stop the study at any time if they needed to. Respondent data are anonymous or aggregated. Data will be stored in a locked safe and destroyed after three years.

Data Management

All participants were de-identified; pseudonyms are used when necessary. All precautions were taken to safeguard the privacy of research participants. Data will be kept for five years in a fireproof safe; afterwards it will be shredded.

Chapter Summary

This chapter began with a description of the design and the rationale for data collection procedures based on methodology. Next, a detailed plan for survey instrumentation along with setting for the survey was discussed. A description of the participants, human subjects consideration, and data management followed. The chapter concluded with means to ensure data validity and reliability.

Chapter Four: Findings

This study used a survey and follow-up interviews to examine the experiences of teachers working with Makerspaces inside the school day, as part of the curriculum. The research questions for this exploratory study are:

- How are educators utilizing Makerspaces in schools?
- What are teachers' experiences of Makerspaces inside the school day?

The chapter begins with the analysis of survey data. Results are organized into four major themes that mirror the survey sections: Comparing Participant Demographics and Making Values; Makerspace Setup; Pedagogy; and lastly, How School Demographics Impacted Responses. Cross tabs which highlight intersections of interesting demographic information is covered last.

The next section of the chapter moves into analysis of Phase II: Interviews. After an overview of interview data, additional results are broken down into descriptive vignettes that capture the essence of each interview. In the final section, findings from the two sources are synthesized to address the research questions.

Survey Results

The sample ($N = 40$) included people with diverse backgrounds, levels of experience, degree majors, and genders. Crosstabs were used to explore the relations between survey demographics educators' perspectives on educational Makerspaces.

The survey questions can be categorized into four overarching categories: participant demographics (11 questions), Makerspace setup (7 questions), pedagogy & curriculum (7 questions), and school site demographics (15 questions). At first glance, it may appear that the questions are imbalanced for the different categories. However, the questions in the Makerspace setup as well as the pedagogy/curriculum section where much more complex matrix questions, offering a wealth of data.

In this sample, the people who chose to respond mainly consisted of elementary teachers, but respondents were also representative of middle and high school educators, librarians, technology leaders and administrators.

There are four important topics that came out of the survey: (a) gender and maker "identity," (b) maker experience and college major, (c) Overcoming a lack of formal training; (d) Perceived lack of support and understanding from other educators. Survey demographics (participant information questions 1-6 and school demographic questions 26-35) are reported in detail in chapter three as a part of the sample description. In this chapter selective demographic data are used in crosstabs to look for differences.

Category 1: Participant Demographics

This first section was designed to collect interesting demographic data on the participants that are running the Makerspace. Questions 1-6 contained the bulk of this section and were reported in Chapter 3. The demographic information from the survey was used in following sections to explore crosstabulations of data, and it will be reported again in Phase II to illustrate the background of the five interview participants.

Professional Development on Makerspaces

Question seven asked participants if they had received training on Makerspaces. While 60% of participants (N =39) indicated that they had received professional development, an astonishing 40% had no training. The next question was an open-ended response which allowed participants to give more information about which professional development they had received.

The coding rubric for this question was determined by clustering similarly themed concepts. The coding categories and illustrative quote can be found in Table 7. Conferences were by far the most reported type of professional development reported, with 26 instances falling under this category; examples include: ISTE, state conferences, and edCamps. Hands-on workshops and reading books were the next most reported forms of professional development, receiving 5 reports each.

Table 7

Coding Rubric and Results: Please briefly describe the professional development you have received on Makerspaces.

Coding Category	Example Quote	Total
Conference (ISTE, GAFE, edCamps)	*Breakout sessions at ISTE, GAFE, and edCamps*	26
Workshops	*Do Design Discover Workshop*	5
Books/reading	*read books, magazines*	5
Online Professional Learning Network/Social Media (Twitter, Google Groups)	*informal twitter PD*	4
Graduate School	*Graduate class on Makerspaces*	4
Local Makerspace	*Thousands of hours in Makerspaces*	3
Youtube/Ted Talks	*TED talks, Youtube videos, etc.*	3
Site visits	*Visits to other schools with makerspaces including conversations with director of space*	3
Regional meetup groups	*forming regional (Northwest Association of Independent Schools) study group, local on-campus study groups*	2
Robotics (Vex, U.S. First)	*I have also had training on Vex IQ Robotics and EasyC programming language.*	1
Webinars	*<Viewed> webinars*	1
Personal/Professional experience (welder, fabriactor, shop experience)	*I was a certified welder fabricator with shop experience including drafting., blueprint reading and most forms of metal forming equipment. I also worked as an instrument designer and fabricator for a research institute. "Big-boy makerspaces" We had several sessions from a local science museum (Telus*	1

(continued)

Coding Category	Example Quote	Total
Science Museum	*Spark, in Calgary)*	1
Technical training (how to operate 3D printer)	*Mostly how to run laser cutter and 3D printers and 3D modeling.*	1
Connected network of schools	*Our school is in a connected network of maker schools. We have readings and have had visits to partner schools. I have not had formal training, but rather connected learning.*	1
Research online	*research online*	1
Maker Faires	*I have gone to … Makerfaires*	1

Next the reporting turns to Makerspace setup to explore the diverse and unique spaces participants reported.

Category 2: Makerspace Setup

The questions in this section were geared to provide information to the reader about the different types of Makerspace setup and activities contained within.

When respondents (*N* = 39) were asked to list their most essential materials, the most popular response was cardboard, with 15 responses. 15 participants listed fasteners, including tape, glue, etc. Legos were the third most popular response with 11 mentions. Eight people stated that 3D printers were in their top three most essential items, in addition to the six that voted for robots/robotics and 4 who voted for computers.

Material category is indicative of the types of activities that can be performed. Table 8 provides a list of the most popular materials mentioned in this open response question, along with tallies of how often the material was mentioned.

Table 8

Most Essential Makerspace Items: Extended List

Material	Total
Cardboard	15
Fasteners (tape, glue, etc.)	15
Legos	11
3D Printer/Laser Printer	8
Robotics	6
Circuitry (microcontroller, LED)	6
Woodwork	5
Recycled materials	5
Computers	4
Scissors	3
Markers	2
Yarn	1

When asked who chooses the materials, a surprising 55% of respondents ($N = 40$) reported that the students selected the materials for their Makerspace. The next question gave respondents categories of materials with examples, and asked them to select call of the categories they used. As Makerspaces have been stereotyped as rooms with expensive equipment such as laser cutters and 3-D printers, it was intriguing to see the number one material category was non-electronics (such as cardboard, woodworking and handicrafts); 92% of respondents reported using this category of materials in their Makerspace. Software and engineering were the next in popularity, with 85% and 82%, respectively. Drones, hydroponics and musical instruments were the least popular categories for Makerspace materials.

Table 9

In our Makerspace we use

Question	*n* (%)	Total *N*
Non-electronics (Cardboard construction, Woodworking/Handicrafts)	36 (92%)	39
Question	*n* (%)	Total *N*
E-textiles, wearables, & sewing	20 (51%)	39
Engineering (arduino, makey makey, 3d design, little bits)	32 (82%)	39
Software (Tinkercad, Sketchup, Scratch, Minecraft, etc)	33 (85%)	39
Video production	27 (69%)	39
Programming	28 (72%)	39
Robotics (US First, VEX, Logo League)	27 (69%)	39
Drones	7 (18%)	39
Hydroponics	2 (5%)	39
Musical instruments (physical & digital)	11 (28%)	39
Prototyping	23 (59%)	39

The next question examined the accessibility of the Makerspace, probing into operating hours and scheduling details. The time when the most educators opened their Makerspace was after school (n = 20; 56%); lunch and recess/breaks were the next most popular choice (n = 20; 51%).

Table 10

Question 15: The Makerspace at my school site

Question	*n** (%)	Total *N*
Is accessible before school to students	10 (26%)	39
Is accessible after school to students	22 (56%)	39
Is accessible to students during recess or break times	20 (51%)	39
Is accessible to students during lunch	20 (51%)	39
Is a scheduled class for ALL students	18 (46%)	39
Is an elective class for students	11 (28%)	39

**Participants could select more than one answer*

Interestingly, 72% of Makerspaces are facilitated by educators (*n* = 28) who run the space in addition to teaching other (non-making) classes. 41% of these Makerspaces also have the help of an assistant (*n* = 16).

Table 11

Question 16: Choose all of the people who assist in the Makerspace:

Question	*n*(%)	Total *N*
Teacher that ONLY teaches in the Makerspace	13 (33%)	39
Teacher who runs the Makerspace in addition to OTHER classes	28 (72%)	39
Assistants (who are school employees)	16 (41%)	39
Parent Volunteers with no expertise	9 (23%)	39
Parent Volunteers who have expertise in areas that are applicable to the makerspace	8 (20%)	39
Outside Experts	8 (20%)	39

33 participants (82.5%) indicated that they had overcome obstacles while setting up and running the Makerspace, while 7 participants (17.5%) said they had not encountered obstacles, with a total of 40 respondents.

Next, respondents were given the option to list what their largest obstacles were. Teachers were given the option to answer a follow-up open-ended question: What were some of the largest obstacles? Answers were clustered by similar categories, a rubric with illustrative quotes can be found in Table 12.

Funding, physical space, and time were the top three most reported answers. Interestingly, a 'lack of understanding by the teachers/students on the value of the Makerspace' was also a top answer (n = 7).

Table 12

Coding Rubric & Responses: What were some of the largest obstacles?

Coding Category	**Example Quote**	**Total**
Funding/Money	*Funding is number 1.*	13
Space	*Space to store projects in progress*	8
Time	*Fitting everything in to short class periods*	7
Lack of understanding by teachers/students on the value of the makerspace	*Developing understanding amongst faculty members as to the approach and ideas of the space*	7
Getting Started/Figuring it out	*Getting started, figuring out how it fit in to my library program*	6
Obtaining materials	*Finding materials*	5
Organization/Storage	*Organization of materials*	5
Safety	*Safety concerns for our young students -- age 3 through grade 3.*	3
Management	*Sustainability of materials, and fairly distributing materials for student need*	3
Learning curve for teacher	*Supervising safety of work with tools and materials when I am not an expert myself*	2

(continued)

Coding Category	Example Quote	Total
Scheduling	*Ongoing challenge: scheduling student time in makerspace. Currently I "donate" my scheduled library classes to makerspace sessions; I am working to convince classroom teachers to bring their students to the Makerspace on their own time.*	2
Support from admininistration	*Consistent support from administration*	2
Faith	*Faith*	1
Noise	*Noise created by hammering when nearby classes were not engaged in makerspace activities*	1

Category 3: Pedagogy & Curriculum

This section of questions makes a transition from the setup of the Makerspace to asking more about the types of activities that take place there. The question type also changes; some questions in this category use a matrix, asking detailed questions about how frequently students engaged in a particular activity.

From question 19, 80% of respondents (*N* = 39) indicated that students decide on their own projects at least once a week. 69% of respondents had their students document their learning process at least once a week. Cross-curricular projects were less popular, with 49% of participants assigning those activities less than once a month, or they indicated it was not applicable. Lastly, only 53% of respondents taught a design process at least once a week.

Table 13

Question 19: In my school's Makerspace…

	Mean (S.D.)	N/A	Less than once a month	Once a week	Multiple times a week	All of the time
A design process is taught to students	2.95 (1.31)	4	15	6	7	8
Cross-curricular projects are assigned	2.87 (1.36)	6	13	7	6	8
Students document their process	3.1 (1.39)	7	6	10	8	9
Students decide on their own projects	3.28 (1.14)	3	6	13	11	7

Total $N = 40$

Thirty participants, who make up the majority at 77%, showcase student projects both within the classroom and within the school. There is a slight decline for showcasing at school events such as parent nights and PTO meetings with 26 respondents (67%) selecting this answer. Impressively, educators showcased their student work to the broader community through community events (36%), Maker Faires (18%), and at conferences (28%).

Educators were given the opportunity to expound upon how they showcased student work. Two respondents indicated a competition: one mentioned a 'world competition' and the other said 'contests'. The most popular open-ended response was online social media with six responses; Twitter, Instagram, blogs, and websites were all given as specific examples. One person wrote in that it was 'still quite new for us- still developing'.

Table 14

Question 20: Do you showcase student products… (Check all that apply)

Question	*N* (%)	Total
Within the classroom	30 (77%)	39
Within the school	30 (77%)	39
At school events (parent nights, PTO meetings)	26 (67%)	39
At community events	14 (36%)	39
At Makerfaires	7 (18%)	39
At Conferences	11 (28%)	39
Other (please specify)	9 (7%)	39
Not Applicable	0	39

To assess student learning in a Makerspace, teachers use a variety of activities. The top four results were: projects (n = 26; 66%), student presentations (n = 24; 62%), rubrics (n = 21; 54%) and student-created videos (n = 21; 54%). In the 'other' category, there were four total responses. Two educators mentioned self-reflections, one additionally mentioned conferencing. Regarding self-reflections, an educator wrote: "the digital portfolios include photos and video of the physical creations in progress, in addition to some written/spoken reflection about it." Another mentioned that they do not use grades, "but students receive feedback from the teacher, from their peers, and from the global community." The last respondent reported that they weren't to this point yet.

Table 15

Question 21: To assess student learning in a Makerspace we use... (check all that apply)

Question	*N* (%)	Total
Rubrics	21 (54%)	39
Peer-assessment	19 (48%)	39
Formal grades	6 (15%)	39
Projects	26 (66%)	39
Student blog posts	5 (13%)	39
Physical Portfolios	5 (13%)	39
Digital Portofolios	15 (38%)	39
Written reports	8 (21%)	39
Student created videos	21 (54%)	39
Websites created by students	7 (18%)	39
Student presentations	24 (62%)	39
Student showcases	19 (48%)	39
Other (please specify)	4 (10%)	39

When asked about types of behavior and activities, 87% reported (*N* = 40) that students teach each other ‘often’ or ‘all the time’. 40% of participants said experts visited their site ‘often’ or ‘sometimes’. 66% of respondents reported students were identified by expertise ‘sometimes’ ‘often’ or ‘all of the time’. Student created tutorials or guides were also popular with 64% of participants reporting they do this activity ‘sometimes’ or ‘often’.

Table 16

Question 22: In the Makerspace…

	Mean (S.D.)	Never	Rarely	Sometimes	Often	All of the time
Students teach each other	4.25 (0.73)	0	1	4	19	16
Experts visit our site to teach students	2.28 (0.93)	9	14	12	4	0
Students create tutorials or guides	2.54 (0.93)	8	6	21	4	0
Students are identified by expertise	2.77 (1.23)	9	4	17	5	4

This next question continued probing activities in the Makerspace, but this question focused more on technical and computational thinking skills. 30% of participants (*N* = 39) reported they there students ‘never’ or ‘rarely’ debug code. The most popular answers were ‘tinker, experiment and play’ along with ‘utilize problem-solving skills’ and ‘troubleshoot problems’ with 79% reporting the activities happening ‘often’ or ‘all the time’.

Table 17

Question 23: In the Makerspace, how often do students…

Question	N/A	Never	Rarely	Some-times	Often	All of the time
Persevere through a problem	0	0	1	10	11	17
Apply logic to predict and analyze	0	0	3	8	15	13
Utilize problem-solving skills	0	0	1	7	10	21
Tinker, experiment and play	0	0	1	7	10	21
Debug code	0	4	8	16	7	4
Troubleshoot problems	0	0	1	7	12	19

Question	Mean	Std Deviation	Variance	Count
Persevere through a problem	4.13	0.88	0.78	39
Apply logic to predict and analyze	3.97	0.92	0.85	39
Utilize problem-solving skills	4.31	0.85	0.73	39
Tinker, experiment and play	4.31	0.85	0.73	39
Debug code	2.97	1.10	1.20	39
Troubleshoot problems	4.26	0.84	0.70	39

This section was very similar to the previous question, focusing skills and dispositions grounded in computational thinking. 92% of respondents reported their students learned from failure and collaborated with peers at least once a week. The least popular activities were developing algorithms (makings steps and rules) and abstracting ideas (removing unnecessary details), each with 38% of participants reporting it was ‘not applicable’ or occurred “less than once a month’.

Table 18

Question 24: *How often do students demonstrate the following skills?*

	Mean (S.D.)	N/A	Less than once a month	Once a week	Multiple times a week	All of the time
Ability to break problem down into smaller, more manageable pieces	3.47 (1.11)	1	8	8	14	8
Perseverance in completing tasks	3.89 (1.11)	0	6	7	10	16
Collaborating with peers	4.32 (.989)	0	3	5	7	24
Developing algorithms (making steps and rules)	2.92 (1.10)	3	12	11	9	4
Utilizing patterns (spotting similarities in problem solving)	3.21 (1.16)	2	11	7	13	6
Abstracting ideas (removing unnecessary detail)	3.05 (1.22)	3	12	7	11	5
Evaluating and making judgments	3.95 (1.01)	0	4	8	12	15
Learn from failure	4.24 (.99)	0	3	6	8	22

Total *N* = 40

**On a five point frequency scale, where 1 = Not applicable and 6 = All of the time*

Question 25 asked respondents to report on if 'Specific projects or materials are incorporated into Makerspaces targeting females." 18 reported 'yes' while 19 said 'no' for a total of 37 responses to this question. Next, participants were asked to provide specific examples if they said yes. One interesting response was an educator who reported "launch girls-only workshop hours next fall." Programmable electronic textiles, or 'wearables' was the most popular response with six educators identifying this material to target females in their

Makerspace; crafts (4), circuitry (4) and robotics (3) were also popular responses.

Table 19

Coding Rubric & Results: Projects or Materials Targeting Females

Coded Cluster Name	Example Quote	Total Count
Wearables (e-textiles, tech costume design, fashion)	*Our younger girls love to knit! We support them with classes about felting, knitting, and using textiles and electrical circuits.*	6
Crafts (paint, recyclables, fabric)	*We have paint, glitter, buttons, recyclables, pipe pipe cleaners, googly eyes available to embellish.*	4
Circuitry (Little bits, makey makeys)	*LittleBits*	4
Robotics	*Robotics materials*	3
Not an issue	*All of them. There is no gender divide. Girls and boys use, and are encouraged to use all modules equally. This has NEVER been an issue at our school.*	3
Coding/Software (Goldiblock)	*Goldiblock*	2
Girls-only activities/workshop	*Girls who Code club, launching girls-only workshop hours next fall*	2
Digital Storytelling	*digital storytelling, projects that express personal relationships*	1
Music & media arts	*Music video / media arts*	1

Category 4: School Site Demographics

The last section of the survey reports on demographics and resources based on school site location. Questions 26-35 involved demographic school data and can be found in chapter 3. Question 36 asked respondents how they perceived their community’s attitudes towards their Makerspaces. Educators reported that Administrators and students are extremely supportive of school Makerspaces. Interestingly, the most support is perceived to come from the student group, with 100% of respondents describing students as ‘somewhat supportive’ (17%) or ‘strongly supportive’ (82%). Administrators were ranked at 97% support, with a breakdown of

28% ‘somewhat supportive’ and 69% strongly supportive.

Interestingly, educators perceived other teachers as the group with the most reservations about Makerspaces entering schools, with 15% neutral and 5% somewhat opposed (with educators being the only group to have any negative perception).

Table 20

Question 36: Overall, how do you perceive your communities' attitudes toward your Makerspace?

Question	Mean (S.D.)	N/A	Strongly Opposed	Some-what opposed	Neutral	Somewhat supportive	Strongly Supportive
Teacher	4.03 (.854)	1	0	2	6	21	9
Administration	4.66 (.534)	0	0	0	1	11	27
Parents	4.71 (.654)	3	0	0	1	12	23
District-level personnel	4.95 (.957)	14	0	0	2	12	11
Students	4.82 (.393)	0	0	0	0	7	32
Community Members	4.87 (.906)	11	0	0	2	12	14

N = 39

The most popular way for educators to connect was online through professional learning groups such as Twitter, Google groups, etc. 95% of respondents reported connecting online (N = 39).

Table 21

Question 38: Do you connect with other Makerspace teachers?

Question	*N* (%)	Total
In person meetups (Makerfaires, Local teachers, regional groups)	26 (66%)	39
Online groups (Twitter, Google Groups, Facebook Groups, Email Listservs- i.e. ISTE)	37 (95%)	39
Forums/Websites	21 (54%)	39
No/Not applicable	0	39

Consistent with the findings from question 38, the majority of 85% of respondents (*N* = 39) reported connecting online with content experts, and 44% connected with experts through forums and websites.

Table 22

Question 39: Do you connect with content experts?

Question 39	*N* (%)	Total
In person meetups (Makerfaires, Community Makerspaces, Local Experts, Hackerspaces, etc)	22 (56%)	39
Online groups (Twitter, Google Groups, Facebook Groups, Email Listservs)	33 (85%)	39
Forums/Websites	17 (44%)	39
No/Not applicable	1 (2%)	39

The final question was open-ended, asking teachers: "Knowing what you know now, if you could change one thing about your Makerspace, what would it be?" A coding rubric was used to cluster responses into themes. Example quotes are included below to illustrate each category. The number one answer was support from other teachers, with six respondents writing in this answer. The ability to redesign and expand the Makerspace was next with 5 responses. Four people wished they had started the Makerspace sooner.

Table 23

Coding Rubric for Question 38: What would you change?

Coding Category	Example Quote	Total
Support from other teachers	*Get more classroom teachers involved -- too many think of dropping off their students instead of actively making/designing with the kids in the Makerspace. In other words, the biggest challenge is transforming the school culture so that making is a systemic means of problem-solving and play.*	6
Redesign/Expand Space	*MORE SPACE.*	5
Start sooner	*Begin earlier*	4
Add additional materials (laser cutter, 3D printer)	*Add more items into our space*	4
Incorporate Making into core curriculum	*<Improve> Lack of co-curricular involvement / connection to other subjects.*	4
Scheduling/time	*More time dedicated to it (the students are on a scheduled time once a week and only get to do it the last two weeks of each month)*	3
Balance of exploration and overstructuring	*I see the Makerspace work being more consistently interwoven into curricular projects, but I don't want to remove the exploration (30 minutes once a week) by over-structuring all of it.*	3
Create a dedicated Makerspace	*My hope is that my administrator would take me out of the classroom and let me take over the Library. If this were to happen, we could have a Makerspace available before school, breaks, and after school for ALL kids. Right now, my students are the only ones who participate because I'm the only teacher interested in Makerspace.*	3
Give students more responsibility (choose projects, hold leadership positions)	*Let students choose projects*	3
More open access	*The space would have more open access to kids throughout the day*	3
Communicate to students and teachers what a	*To try to get communicate with classroom teachers to get them on board as soon as…*	3

(continued)

Coding Category	Example Quote	Total
Makerspace is	*…possible so that ALL the students come into our Makerspace.*	3
Funding	*I would like to see better funding.*	2
Changing the type of lessons (more robotics, coding, etc.)	*I would like to do more with robotics and coding.*	2
More adults to manage the space	*It needs a larger team to support our large classes (20-25 students per class)*	2
Coming up with project ideas	*A larger variety of lessons*	1
Bringing in experts	*Adding in experts regularly to work with kids and help spark their creativity and curiosity*	1
Connect with the community	*Further develop the ambassador program and community connections*	1
Organization/Storage	*More space and more storage*	1

More space and storage was the number one answer with 16% of respondents giving this response. "In our Upper School Makerspace we would have included a "creativity" thinking area. A designated area that is comfortable and quiet to brainstorm, plan, iterate, think!" The next most popular answer was advertising/showcasing the Makerspace within the school and to the local community. "I would create a plan up front to market this to students. They need to see products, exhibitions, demo videos, and commercials about our STEM Center." Extra faculty, more time, and additional cross-curricular connections were other common requests. "I would allow more "play" and tinkering time for students. We were very goal oriented and I think we struggled with creativity. Letting students explore, tinker, and play may be the missing piece." Multiple respondents cited that their school had more than one Makerspace, and they were extremely useful.

Four Main Themes From Survey Data

There were four main themes that emerged from the data: (a) Maker identity: the influences of gender, experience and college major; (b) Maker materials: low-tech barrier to entry (c) Overcoming a lack of formal training; (d) Perceived lack of support and understanding from other educators. These themes will be reported and substantiated in the sections below.

Theme I: 'Maker' Identity

The results from this survey are small and not meant to be generalized. However, there were some interesting findings when gender cross-tabulations were formulated. The first set of gender crosstabs looks at the identity of a Maker, followed by use of materials and finally, showcasing products.

Gender Influences on Identity of a Maker

82% of women (*n* = 29) and 88% of men (*n* = 9) stated that they considered themselves a Maker. Additionally, when asked about their expertise in making, the majority of women (41%, *n* = 29) reported "somewhat high". Furthermore, women (*n* = 29) reported that they use making in their own life: 41% 'sometimes', 28% 'often', and 17% 'always'.

With these results in mind, it is surprising to see female educators use fewer "technical" materials in the school Makerspace (question 12), have less activities that could foster computational thinking (question 23), and they do less showcasing of their students' work outside of their classroom (question 20). These ideas will be elaborated upon in the following sections.

Maker Materials & Activities

Both men and women shared a similar pedagogical approach, with no outstanding differences found during crosstab analysis of questions 21-25.

There were discrepancies when analyzing the materials used in the Makerspace on a gender crosstab of question 14. The overall sample for this question was small (Total *N* = 38), but from those surveyed, 100% of the men (*n* = 9) used prototyping, programming, engineering (arduino, makey makey, 3d design, little bits) and software, while a smaller percent of the women (*n* = 29) responded that they incorporated those materials in the Makerspace. Only 41% of women used prototyping, 58% used programming, 72% used engineering (arduino, makey makey, 3d design, little bits) and 75% used software. Three respondents from each gender category reported using drones, and the only person to report using hydroponics was female.

When it comes to activities, 72% of women (*n* = 29) and 100% of men (*n* = 8) used tinkering ‘often’ or ‘all of the time’. When asked about debugging code, 37% of women and 12% of men reported it was an activity that was ‘never’ or ‘rarely’ done in their Makerspace.

Table 24

Makerspace materials – Whole Sample

	MALE		**FEMALE**		TOTALS		
Programming	NO	YES	NO	YES	Men	Women	*N*
	0	9	12	17	9	29	38
Engineering (arduino, makey makey, 3d design, little bits)	NO	YES	NO	YES	Men	Women	*N*
	0	9	8	21	9	29	38
Prototyping	NO	YES	NO	YES	Men	Women	*N*
	0	9	17	12	9	29	38
Software	NO	YES	NO	YES	Men	Women	*N*
	0	9	7	22	9	29	38
Non-electronics (Cardboard construction, Woodworking/Handicrafts)	NO	YES	NO	YES	Men	Women	*N*
	1	8	2	27	9	29	38
Robotics (US First, VEX, Logo League)	NO	YES	NO	YES	Men	Women	*N*
	3	6	10	19	9	29	38
Drones	NO	YES	NO	YES	Men	Women	*N*
	6	3	26	3	9	29	38
Hydroponics	NO	YES	NO	YES	Men	Women	*N*
	9	0	28	1	9	29	38
Musical instruments (physical & digital)	NO	YES	NO	YES	Men	Women	*N*
	7	2	20	8	9	29	38

(continued)

	MALE		FEMALE		TOTALS		
E-textiles, wearables, & sewing	NO	YES	NO	YES	Men 9	Women 29	*N* 38
	4	5	15	14			

Showcasing

A higher rate of men (50%; *n* = 9) showcased their students' work at Makerfaires within the community versus only 13% of women (*n* = 29); 88% of men showcased their students' work within the classroom and at school events (parent nights, PTO meetings) while 69% of women did the same.

Maker Experience Influenced by College Major

This section will examine intersections of respondent major and key questions to provide a more in-depth examination of the data. Education (26%; *n* = 19) and Science (33%; *n* = 3) were the only two majors where some members of the group did not adopt the identity of a Maker. Interestingly, those who self-identified as 'expert makers' came solely from technology majors (40%; *n* = 5) and the remaining portion of the education majors (5%; *n* = 19); math and science were absent from the analysis. Remarkably, STEM majors would be most likely to let students choose their own materials (67%; *n* = 19); yet education majors were least likely to allow students to select their own materials (47%; *n* = 9). STEM and non-education majors allowed students more freedom in material selection versus being given materials selected by an adult. Next, how experience impacts making identity will be explored.

Table 25 provides a detailed glimpse comparing Makerspace material usage by major. Education majors' most commonly used material was non-electronics (cardboard construction, woodworking/handicrafts. Non-electronics was also listed as one of STEM majors' most popular materials, but with the addition of engineering and software, followed closely by prototyping.

Education majors use the most e-textiles out of any group, while STEM majors used the fewest e-textiles in their Makerspace. Education majors reported eleven participants who do not use prototyping, the highest number from any major. Educators were a group that had the most unique materials: the most responses for drones, and the only responses for hydroponics come from this major.

Table 25

Crosstabs: Question 13/Materials and Question 6/Major

	Education Major (=19)	STEM Major (*n* = 9)	Other major (*n* = 11)	Did not use material
Non-electronics (Cardboard construction, Woodworking/Handicrafts)	18 (46%)	8 (21%)	10 (27%)	3 (7%)
E-textiles, wearables, & sewing	11 (28%)	3 (7%)	6 (15%)	19 (49%)
Engineering (arduino, makey makey, 3d design, little bits)	14 (36%)	8 (21%)	9 (23%)	8 (21%)
Software (Tinkercad, Sketchup, Scratch, Minecraft, etc)	15 (38%)	8 (21%)	9 (23%)	7 (18%)
Video production	16 (41%)	5 (13%)	5 (13%)	13 (33%)
Programming	13 (33%)	6 (15%)	8 (21%)	12 (31%)
Robotics (US First, VEX, Logo League)	12 (31%)	6 (15%)	8 (21%)	13 (33%)
Drones	4 (10%)	2 (5%)	1 (2%)	32 (82%)
Hydroponics	2 (5%)	0	0	37 (95%)
Musical instruments (physical & digital)	6 (15%)	3 (7%)	2 (5%)	28 (71%)
Prototyping	8 (21%)	7 (18%)	7 (18%)	17 (44%)
Total *N* = 39	*N* = 19	*N* = 9	*N* = 11	N/A

Total *N* = 39

Theme II: Lack of Formal Teacher Training

The teachers surveyed were not well supported in professional development regarding Makerspaces in schools; 40% of respondents (*N* = 39) reported they had received no training in Makerspaces. The reason this is important is because it could impact the types of activities and materials in Makerspaces. This survey revealed that while female educators possessed a Maker identity, they were less likely to include programming, prototyping, engineering (arduino, little bits, etc.) and software into the Makerspace. Non-electronic materials (cardboard construction, woodworking, handicrafts) were the most used supplies in educational Makerspaces.

Theme III: Lack of support from fellow educators

Question 39 of the survey was an open-ended response: *Knowing what you know now, if you could change one thing about your Makerspace, what would it be*? This response can be compared with Question 18, which asked: *What were your largest obstacles?*

In both responses, a lack of understanding and support from other teachers was a common theme. Furthermore, this same theme emerged in data from Question 38, which asked: '*Overall, how do you perceive your communities' attitudes toward your Makerspace?*'. In this question, teachers were perceived as the least supportive group, and they were the only group with in the community to be perceived as unsupportive.

From the responses of *Knowing what you know now, if you could change one thing about your Makerspace, what would it be*? the most popular response (*n* = 6) focused around gaining the support of other teachers. The following quotes are from the write-in data on Question 39. Teachers reported a need for *"more pedagogical training for me. Somehow incorporate making into core curriculum."* Another articulated the need for the teachers to become learners themselves: *"Find ways to have teachers really make things.*" While the Makerspace teachers embracing the idea of Making, it is perceived by respondents that not all educators are as receptive to Makerspaces in schools.

Phase II: Interview Results

The survey data provided an overarching picture of what was happening inside of Makerspaces, but a more illustrative picture can be colored through qualitative interviews. The interviews provided respondents an opportunity to expound upon their interview responses.

After an overview of the major themes from interview results, individual vignettes discuss each of the five interviews separately. Reporting data in this manner offers the reader the perspective of how different Makerspaces operate, and how the demographics of each educator influence this experience.

Detailed interview question development can be found in Chapter 3, including a rationale for each question.

Interview Questions:

8. In your own words, please describe the value of a Makerspace to a school.
9. Does design thinking play a role in your Makerspace? If so, please describe how.
10. In the initial survey, you indicated that you had overcome obstacles in your Makerspace. Can you please elaborate on this?
11. Tell me about your experience with professional development for Makerspaces.
12. Describe a typical class in your Makerspace.
13. What is the process for determining which activities or projects to undergo in your Makerspace?
14. What marks the success of a Makerspace program? How do you describe success?
15. What are the next steps for your Makerspace?

Detailed demographics can be found in Chapter 3, but an overview of participant demographics for the interview portion is also listed here for the reader's reference. Thirty-five people offered their consent to be contacted for a follow-up interview. Out of the original group, five educators were selected to give more in-depth interview responses to correspond with the survey data. Selection was based on school demographics. A rich combination of demographics was sought including: public, private, charter schools; urban, suburban, and rural areas;

elementary, middle and high schools, as well as a diversity in socioeconomics. Participants were asked 10 questions in order to paint a richer picture of Makerspaces in education.

A detailed coding rubric can be found in its entirety in chapter 3 on page 76. In the section below, each question will be broken down and the coding rubric for each section is provided. Using the coding rubric, the interviews were analyzed and a total number was determined for each category on the rubric. This first section provides a general overview of the data; as there were five total participants, scores are given out of five. Any time a participants' response aligned with a key term defined in the coding rubric, a tally was added to the overall total. This section does not break down how many times each participant's response included a response. For example, if they gave 3 examples of routine within a response, that data is recorded within the individual vignettes, which offer a more detailed analysis; only one tally for routine is added here, indicating that the subject aligned with this response.

The first question asked participants to describe a typical day in their Makerspace. Four of out of the five responded that there was no such thing as a typical day. One participant stood out, with her organization and structure within a creative environment.

Next, the role of design thinking in the Makerspace was probed. Four participants vehemently argued that design thinking was the point of Makerspaces. The other educator disagreed, citing that her students were too young for design thinking to play a role in their Makerspace.

The following question focused on professional development experiences in Making. As this was an open-ended question, participants could touch on more than one category. Each of the categories were mentioned four times. The categories were: conference/workshops, online resources/social media, and site visits. Participants elaborated on the various strengths of each type of learning; each mode offered something unique.

Four out of the five participants stated that they overcame obstacles in their Makerspace experience. The experience of two participants focused around a change in school culture, while the remaining two participants focused on change at the class level and their experiences with students.

An important factor in the Makerspaces was the process for determining activities. Only one participant out of five allowed their initiated projects. The other four participants focused more on the teachers assigning the students a project, theme or challenge.

The next section focused on what the teacher attributed as the value of a Makerspace. Two answered the question by focusing on the creative process, allowing children to tinker and work with their hands. Four people discussed how students develop an identity through the Makerspace. Note that one participant mentioned both creativity and student identity in their response. The importance of students discovering their passions, working with mentors, and including all student demographics were highlighted when participants discussed student identity in the Makerspace.

Afterwards, participants were asked to define the success of a Makerspace. Two participants spoke about sustainability, focusing on logistical issues involving the future of the Makerspace. The other three participants focused on the impact the Makerspace had on students.

The next question asked educators to give specific examples of student work that had been produced in the Makerspace. In two of the responses, participants focused on how the student work fit within the goals and parameters of the Makerspace. The other three respondents discussed how the Makerspace was uniquely suited to create this type of project.

Question nine prompted participants to elaborate on how they showcased their Makerspace. Two of the responses talked about showcasing work at the school community, where student work was showcased through events such as a Makerspace Gallery Walk where other classes would come and see the projects in the Makerspace. Three answers mention showcasing work to the local community. Parents were invited in to special night events in the Makerspace where they got to experience interactive making challenges. Other people take their students to local Makerfaires, and showcase student work to a broader audience. Lastly, two answers mentioned a global online community where students showcase work on website, blogs, and class Instagram accounts.

The last question asked participants to share their next steps regarding the Makerspace. Three answers mentioned getting more faculty members involved. Interviewees mentioned the potential for a Makerspace to bring more cross-curricular ties to the campus. Two responses focused on taking their Makerspace to the next level. These respondents wished to advance the use of the Makerspace; one specific instance included increasing the complexity of the projects.

Now that an overview of the responses has been shared, the next section will focus on an in-depth look into each of the interviews. Each of the five vignettes follow a template: background, curricular emphasis, value of a Makerspace, and finally, moving forward: connecting with the community and next steps.

Vignette One: Upper Elementary Embraces Design Thinking

Participant One is female teacher with a degree in Business Administration and Elementary Education. Her title is 'Teacher", and she indicated that her primary responsibilities included teaching other classes outside of the Makerspace. She has been in her current position for less than five years.

The public school where Participant One works serves grades 3-5. In this rural setting, approximately 76-100% of students qualify for free/reduced lunch. The student population is around 800-1,000 students.

Curricular Emphasis

When asked about a typical day in her class, Participant One elaborated on seven specific instances (as defined in the coding rubric) in which routine was crucial for the structure of her Makerspace.

Participant one alleges that each class follows a similar workflow, in order to give students a predictable routine.

> I start with an overview of day's activities. We utilize Google Classroom, and students work independently on bell work. Next, I lead students through a mini-lesson (ie. Tinkercad, 3d printing, Thinglink). After learning a new technology, they reflect on their big projects and how the new tools can be incorporated into their ongoing projects. Students guide class; they have to come up with problems around home or classroom. They have to problem solve. –Participant One

Participant One reports that the majority of the time is reserved for student work time. At the end, there is always a sharing portion. The teacher notes that this reflection time is the heard of what happens in the room. As an elementary teacher, this educator teaches all subjects. She noted how running the Makerspace influenced how she approached teaching all other general education subjects. *Because I'm the teacher teaching the Makerspace, I feel more confident bringing that mindset to the general education classroom*. *–P1*

When asked about the role of design thinking in the Makerspace, Participant One discussed the transition from students not grasping to design thinking to the students embracing it and incorporating into all of their projects. "At the start, students couldn't grasp design thinking. They would wait for me to give them ideas. Finally, after that surface level shock of freedom, they got used to the idea of freedom and they started coming up with all kinds of ideas!" –P1 During the interview, Participant one gave eight different instances where she emphasized how design thinking was essential to her Makerspace. "I had to transition them to the next phase of collaborative sharing where others would ask questions, we would talk about constructive criticism in design, and thinking about how useful and helpful it could be instead of taking it in a negative way. Then, look at self-reflection and always have next steps in mind." –P1

She reported that the most difficult part for the students was learning to be resilient, and sticking with her design process. She stated one interesting thing that helped her students was a matrix visual display (very simple) that students could reference when discussing design thinking.

> We would always have one or two students always share out at the end of the day. Through accountable talk, like an engineer would, they explain how they use their thinking time. They would use the organizer and talk through the phases. Each day, they felt like they were suppose to have a tangible object, or artifact to take, and we had to get to a place where they didn't feel like they had wasted their time if they didn't have that. Share your thinking, we want to see your mind map, your decision matrix, see how what you did today. You don't always have to have something to take home. –P1

The culture of the class had to evolve to a point where the students felt valued even without a physical artifact. "The design thinking time was the key."

Next, Participant One was asked about professional development. While Participant one gave one example of a conference she attended, she reported that it was of little value to her. "I went to an EdTech conference on a session on Genius Hour, but it was mostly focused on libraries and librarians. It provided few insights on creating a Makerspace for a teacher." –P1 Participant One stated that due to her lack of professional development, she started exploring Makerspaces online. She gave two examples of how online resources and social media were powerful tools that transformed her Makerspace. The first that she reported was the value of online communities such as Google Plus groups. Second, blogs were an excellent resource for her because other teachers authored them. "Blogs were a really great resource because they filtered out things. I could pick out little things to try in my own Makerspace." –P1

The next question was "What is your process for determining activities for your Makerspace?" When coding her responses, Participant One has a balanced approach to the process for determining activities with four instances of student initiated comments, as well as four teacher-directed, as defined by the coding rubric.

In her response, she describes structuring class time as a "quandary," torn between "teacher directed" and "student choice." "We were so excited to teach them. Should we start with the tech first or the purpose? But if they aren't exposed to the tech, how can they choose it? There was a balance between introducing new technology and letting students choose." –P1 She reported that she decided to give mini-lessons on the tools first so they would know the options available to them.

After students understood the tools, the classroom was segmented into different quads, each area housing special tools. The students made the choice on what to work on. Participant One stated another challenge was ending projects. For makers, it was never good enough. "Projects could go on forever!" –P1 In then end, she stated that she decided to keep moving forward, but at the end of the term, students could choose one project to revisit.

Value of a Makerspace

When coding Participant One's response to overcoming obstacles, she gave an extensive answer with 14 instances how they experienced a classroom culture shift; there were no school-level examples provided. Participant One reported the underlying problem was getting students to make the transition from the traditional didactic classroom to a more student-driven approach. "When students hit obstacles, they flatlined!"--P1 She also reported how this was a struggle for her as an educator.

> I wasn't sure if we should give students answers or let them struggle through it. Finally, I decided to let them examine their resources online or ask a friend/family member. If they asked a question, we would help. It was the responsibility of the students to reach out for help. Getting them to continue working was challenging. —P1

Another problem was figuring out how teaching the technology skills fit within the Makerspace. Students needed to be introduced to the tools so they would know what resources were available to them, but then it may result in 'tangents that deviated from their projects'. She emphasized the importance of being flexible; the "learning is very different from other subjects within the school day. Another challenge was determining what [technology tools] to share with the students because there is so much out there." –P1

When asked about what the value of a Makerspace was to a school, Subject One emphasized the importance of creation and students working with their hands. They had four instances of creation in their response. She emphasized that: "It's not playing, but time to tinker and create. That creation level is what we strive for. Teacher evaluation rubrics are always looking for students to drive their own learning. Makerspaces provide that." –P1

When asked how to define a Makerspaces' success, Participant One gave four instances (as defined by the coding rubric) of student impact and one example illustrating sustainability concerns. “You know your Makerspace is successful when you have kids who are excited to problem solve, try new things, take risks and help one another out. You also have teachers who do the same; they learn their new role as a facilitator rather than head instructor.”—P1

Moving Forward: Connecting with the community and next steps

The next interview question asked participants to give specific examples of student work from the Makerspace. When coding Participant One’s response, she reported five instances of logistics and focused on how a project would fit within the parameters of her Makerspace.

> I had a student that wanted to focus on fashion, specifically, designing handbags. I asked: What kind of problem are you going to solve? He responded: How good the bag looks is a problem. It’s the aesthetics, art, and design aspect of maker. The student took the parameters of our Makerspace and created his own project. He was able to explain how it met the goals, why his project was just as good as a hydroflask. It expanded my perception as a teacher of how broad making can be. —P1

She ended with a different example of a Hydroflask, which provided two instances of how their Makerspace was uniquely suited to create this type of project. When asked about how student work was showcased, Participant One responded with three instances of school community showcases, two instances of local community showcases, and two instances of Global Online Community showcases. She did an excellent job of publishing student work and reflections on blogs and websites, providing an authentic audience for students. Additionally, she held school-wide events such as gallery walks to showcase work to other students and promote interest in the Makerspace. Lastly, she connected with the local community by hosting Mini-Maker Faires at the school. These events included design challenge activities to engage parents and siblings; one example is the marshmallow catapult challenge.

When asked about next steps, Participant One responded with two instances of *getting more faculty involved*, and one instance of *taking it to the next level*. Her goals include: "Get more teachers involved and get particular teachers to be experts on different tech. i.e. Tinkercad expert teacher who has mini-lessons set up, students could obtain badge on a particular tech and then use it during Genius hour."—P1

Vignette Two: Global Entrepreneurs in Middle School

Background

Participant Two identifies herself as an administrator; she has been in this position for less than five years. She is a math major; her highest level of education is a Master's degree. She considers herself a Maker with a 'somewhat high' degree of expertise.

Participant Two works at an Independent school serving grades 6-12. Her location was described as an urban setting serving between 400-600 students. Around 0-25% percent of their students qualify for free/reduced lunch.

Curricular Emphasis

When asked about a typical day in her class, Participant Two was the polar opposite from Participant One's response. "Our Makerspace is anything but typical!" –P2 This educator emphasized the variety of ways in which the Makerspace was utilized. According to Participant Two the Makerspace serves as flexible project space, with no routine or structure. She stated that each class is unique.

Participant two described five instances in which design thinking was apparent in her Makerspace. "We offer entrepreneurial classes as well as a global studies class. We have intensive activities. For example, we took a week-long field trip to design a STEAM yard for a local school." –P2 The teacher mentioned that empathy was embodied in the design thinking process by creating products for a specific audience.

Participant two's response to professional development training was nuanced. She gave six instances of how a site visit was impactful to her practice, often reference the value of discussing how to setup and run the space with other Makerspace Directors. "Visits to other schools with Makerspaces was very valuable. Tours allowed conversations with directors to share ideas. We could see how they space was setup, and discuss safety and classroom management."—P2 She also had the opportunity to visit and international site in Singapore.

Participant two also noted the value of Conferences and Workshops, mentioning those four times in her response. Her conference experience included the Fablab conference at Stanford and the Do, Design, Discover Workshop. The Fablab conference provided insights into the background and academic research, which allowed her to see things at a different level. The Do, Design, Discover Workshop offered the opportunity for educators to embrace the persona of a student in a week-long making experience. "This conference also provided a networking opportunity."—P2

Participant two cites four instances of a teacher-centered approach to designing activities for the Makerspace. Her school utilizes a mobile cart and a shared space which is occupied on a "first signup, first come" basis. The teachers select the activities the students will be working on; there were no examples of student-initiated activities in her response.

Value of a Makerspace

When asked about overcoming obstacles, Participant two discussed two instances of class culture shift and three instances of school culture shift. "By building up small success in the class, we were able to obtain student trust."—P2 In a school-wide imitative, grade level groups go through training and orientation to before entering the maker class. Additionally, students can obtain different levels of safety certifications to become 'experts' on a particular tool, giving them more freedom in their projects.

When discussing the value of her Makerspace to the school, Participant two provided four instances of developing student identity and one example of student creation/working with their hands. “It provides an environment where students are excited, more willing to push through. In the Makerspace, they are highly motivated, and they learn perseverance.”—*P2*

Moving Forward

Next she was asked about defining the success of the Makerspace. Participant two provided three examples of the impact on students. “Kids are excited and motivated to learn. This is exemplified by drop in hours- kids elect to spend their free time there.”—*P2*

When asked to give examples of student work, Participant Two provided three examples of Makerspaces uniquely suited to create this type of project. Interestingly, she described an example where a student was reluctant to use the tool until he found a passion project. “He designed Star Wars models in CAD and created figurines from the Star Wars universe in extraordinary detail. After this exposure, he was hooked! He became an expert on the 3D printer.” –P2 Another example is a Grade 9 physics class that designed and built electric houses- complete with the wiring.

Participant two exemplified one instance of showcasing in each of the three categories: school community, local community and global online community. “The communications department takes photos and writes articles for the website.”—P2 Within the school community, they showcase their work to larger classes. Last, “during lunch or a community break, some parents come as well as administrators” to view the work.

When asked about her next steps for the Makerspace, Participant two provided three instances of taking it to the next level, with one instance of getting more faculty members involved. She reported her future goals were to “help make the space open to the students more, allow students to grow, give support."—P2 Additionally, she wants to hire a 'Resident Tinkerer' to provide more support to students.

Vignette Three: K-8 Charter School Inspired by Local Makerspace

Participant Three has the unique title of 'AmeriCorp VISTA'; this program focuses on alleviating poverty. She is a science major with a Master's degree. She considers herself a maker with a 'Somewhat High' degree of expertise.

She works at an urban charter school, which serves between 200-400 students in grades Kindergarten through eighth grade. Around 0-25% of the student population receives free/reduced lunch.

Curricular Emphasis

When asked to describe a typical day, Participant three reported that the charter school were she worked didn't have typical days, and "there is a heavy emphasis on project-based learning*"*—P3. Participant three did not use design thinking. *"*We do not use design thinking. I work with younger students, and they are too little."—P3 When asked about professional development, Participant Three gave one example of the importance of a site visit. "I worked with a local Makerspace to get ideas". She also had one example of Online Resources and Social Media, citing "MakerEd was a vital resource for me."

Participant three had four instances of teacher-directed approach when asked about who chooses the activities for the Makerspace. Participant three *"*look(s) online and then modify the content. I get materials from a local college."—P3

Value of a Makerspace

Participant three did not list any obstacles that they had overcome in the process of running a Makerspace at school. Participant three discussed the importance of a Makerspace by instilling confidence in students. In one instance, she identifies developing student identity, as students learn to “follow their own path.” —P3

Participant three listed three instances student impact were the most important aspect when determining the success of a Makerspace. “It’s all about the students learning to embrace failure, celebrate it, and finally learn from it.” —P3

Moving Forward

Participant three provided three instances of how a Makerspace can be uniquely suited to create interesting projects. She described a paper rollercoaster created by her class, and the iterative process needed.

Participant three has one instance of a global online community; “we share our work through a class Instagram account.”—P3 Participant three gave one instance of each category: get more faculty involved and take it to the next level. “My goal is to create a cross-curricular science and design unit.”—P3

Vignette Four: K-2 PBL School Embraces Makerspace

Participant Four is an Instructional Technology Specialist, and he has been in his current position for less than 5 years. He is a Communications major with a Bachelor’s degree. He considers himself a Maker with a ‘Somewhat High’ degree of expertise.

He works at a rural public school, which serves between 400-600 students in grades Kindergarten through second grade. Between 26-50% of students qualify for free/reduced lunch.

Curricular Emphasis

Participant four came from a school with a project-based learning emphasis. His results were divided, citing two examples of routine and two instances of how there was no such thing as a typical day. “We think of our Makerspace as a physical resource.” –P4 He reported creating structure "by mitigating student traffic and crowd control."—P4 He exemplified that there was no such thing as a typical day in that "on any given day, experts may be brought in, or you may find students building models or blue sky dreaming." He alleged there was not a prescribed workflow.

Participant four utilized design thinking and gave three specific instances. He described how the Makerspace revolves around purpose, and starts with pedagogy. Design thinking empowers students by 'expanding their toolset'. Participant four described himself as a veteran educator with extensive professional development related to Making. He listed three instances of Conferences and Workshops, as well as three examples of Online Resources and Social Media. "I attends conferences and workshops like programs from Stanford, and I also help organize Ed Camps Make, along with 28 Teacher Summits across the state."—P4 He discussed his background in connecting with other educators online with roots in the Geocities communities, and evolving over the years to more modern networks such as Twitter. "I participate on Twitter in groups like #TOSHA (teachers on special assignment) I coach other teachers and try to be invisible as possible."—P4 Additionally, he reported visiting other local design schools.

Participant four had two instances of teacher-directed approach to choosing activities in the Makerspace. "It's up to the teachers to decide the activities for the Makerspace. Our faculty follows the Buck Institute Training for teachers PBL model."—P4.

Value of a Makerspace

Participant Four had three instances of school culture shift and five accounts of class culture shift when asked about overcoming obstacles. The biggest challenge was overcoming the attitude of administrators: 'That's not the way we did it before." –P4 After the administrators got acclimated to idea of the maker movement, this resourceful educator had to get convince them for funding for the tools and infrastructure. "My position required political skills: how to work a system to obtain funding for tools and infrastructure. Materials are minimal (such as toilet paper rolls, and consumables). We use old math manipulates as consumables that were sitting in a closet!"—P4 While reporting that materials are minimal, this educator states his 3D printer is used least among his tools due to time constraints when working with 600 students. He emphasizes the intellectual process of 3D design, advocating that this is more important. When asked about the value of a Makerspace to a school, Participant four identified both the importance of developing student identity (2 instances) but also the value in creation and working with your hands (2 instances). Makerspaces "give a seat at the table to students who would not ordinarily have one. Students have a way to fit in (born organizer, kid that makes things) Why didn't we do this before?"—P4

When describing the success of a Makerspace, Participant four defined five instances of sustainability and one instance of student impact. Among the sustainability concerns were "how to evaluate the student experience in the Makerspace" and "knowing that the Makerspace is a positive experience for student, but communicating that to the satisfaction of parents who are only concerned about college acceptance."—P4 He also reported the need to give more ownership to the student.

Moving Forward

Participant four describes eight instances of the unique propensity of a Makerspace to "nurture students and recognize their talent." He describes a Grade 4 student who sent in 3D printing projects all summer long, and the student expressed concerns about moving on from that amazing learning environment.

Participant four describes showcasing as a 'future endeavor'. However, they do give local community and school presentations in the auditorium showcasing student work.

When asked about his next steps, Participant four gave one instance of each category: get more faculty involved and take it to the next level. He wants to provide more "guided project options to students during tinker time" and to "engage the relatively young and progressive faculty." —P4

Vignette Five: Experienced Maker Iterates Makerspace Into Next Evolution

Background

Participant Five is a Technology Integrator who is currently finishing his doctoral studies; he is an education major. He considers himself a maker with a 'Somewhat High' degree of expertise. Participant Five works at an K-8 Independent school, serving between 200-400 students. In this suburban setting, around 0-25% of students qualify for free/reduced lunch.

Curricular Emphasis

Participant five emphasized that there was no such thing as a 'typical day' in his Makerspace, giving five examples of how each day may differ from the next:

"Sometimes students would all be working quietly, maybe on the fourth iteration of a 3-D printing project, or learning the machines. The teacher may talk about design, giving students reflective questions instead of focusing on how to use the tools. Each day is different."—P5

Participant five was emphatic that "design thinking IS the role of the Makerspace." –P5 He gave two instances of design thinking in the Makerspace. He emphasized the importance of "cross-dimensionally across the spaces; Makerspaces do not need to be siloed."—P5

Participant five came across very passionately when asked about Professional Development. He gave four examples illustrating the value of Conferences and Workshops including "week-long workshops, leading workshops, presenting at conferences, attending conferences." –P5

Additionally, this educator listed two examples of Site Visits; including many of Portland's Makerspaces as well as Makerspaces in North Carolina. "I've spent thousands of hours in local community Makerspaces. The community aspect is so important; you can leverage their knowledge bank."—P5

He listed three instances of Online Resources and Social Media, discussing webinars that were free to the school where he could enhance his learning. He online interests include "design thinking events" (both educational and non-educational) as well as game design.

When asked about his process for determining activities in the Makerspace, Participant five had two instances of teacher-directed and two instance of student-directed activities.

> "What might get kids to try something? Other times the materials are more teacher directed, like working with wearables, but the outcome of the activity is on the students. Lunchtime in our Open Makerspace is the most exciting time. A challenge is how to document that learning."—P5

Value of a Makerspace

When asked about overcoming obstacles, Participant Five listed four instances of school culture shift. The biggest challenge at this school was "getting people to understand the evolving role of a Makerspace at their school. We are currently iterating our space, yet they are still trying to overcome some systemic culture changes." –P5

A champion of Makerspaces enhancing student identity, Participant Five provides four instances to support his case. "The Makerspace is a community of learners; relationships happen there. Mentors from outside community come in. A Makerspace allows children to self-identify."

When asked how to determine the success of a Makerspace, Participant five struggled with the question, listing no instances when defining the success of a Makerspace.

Moving Forward

When prompted to give specific examples of student work in the Makerspace, ubject five describes four instances in which a Makerspace is uniquely suited for projects. He talks about how “the students designed a camera and 3D printed it. The kids express themselves through their work in the Makerspace, and it impacts their identity”—P5

Participant five described showcasing the Makerspace as “difficult”. Students do create their own videos that are published online (one instance of global online community). Additionally, they host a ‘Makerday’ at school where they showcase student work to the local community. He describes this day as an iterative process; it’s a careful balance not to turn it into a craft fair. At this event, he describes himself as a lifeguard: “Are students engaged? Distressed? It’s important to identify those that may be in trouble.”—P5

Participant five included four instances of taking it to the next level, as well as one instance of more faculty involvement.

> “My next goal is to survive transition to our new Makerspace. I want to turn questions from defining Makerspace to owning Makerspace. Another thing is having faculty confident when students know more about machines then they do. Resource management, budget system are important, too.” –P5

Similarities and Differences in Implementation of Makerspaces

There are four main areas to explore when comparing similarities and differences between the survey and interview data: (a) Maker identity, (b) Challenges and rewards of teaching in a Makerspace, (c) Overcoming a lack of formal training, (d) Perceived lack of support from other educators.

Topic I: Maker Identity

As reported in Phase I: Survey results, it was surprising to see female educators use fewer 'technical' materials in the school Makerspace (question 12), have less activities that could foster computational thinking (question 23), and they do less showcasing of their students' work outside of their classroom (question 20).

Even though many of the women from this survey self-identified as 'makers', as a collective group the men exemplified more maker characteristics through material selection, activities, and showcasing. Perhaps additional hands-on experience and modeling provided by professional develop can get women more comfortable with these materials; 66% of the men (*n* = 9) reported that they had received training, as opposed to only 55% of women *(n* = 29). Women proved they had the disposition for making, but may lack exposure to materials and activities for educational Makerspaces.

The interviews conflicted with the survey data regarding women's aversion to the use of high-tech materials and activities; however, the interviewees were also members of another demographic subset: not classically trained education majors. Comprised of science, math, and Business Administration/Education, these women brought unique perspectives when compared to other majors; not only did they identify as makers, but they also embracing Making activities in their classrooms.

Educators indicated that other teachers were the only group opposed and neutral to Makerspaces. Students were reported to be the most supportive group, followed respectively by school administrators and parents. This is a telling sign; the students embrace the Makerspace, whereas educators have the most difficult time seeing how it fits into the school day.

Topic II: Challenges and Rewards of Teaching in a Makerspace Pedagogy

Education is most famous for the didactic approach to teaching, but in the last few decades, Piaget's work on Constructivism has grown in popularity. This epistemological stance has contributed to rise of the Maker Movement in education. The type of pedagogy found in

Makerspaces can be a constructivist approach. Students are now encouraged to tinker, play, and experiment in a flexible environment, making meaning through their experiences and their ideas.

Throughout the survey data, examples of a constructivist approach can be found. For instance, in question 13, 56% of respondents (*N* = 40) reported that students choose the materials for their own projects. This approach "provides environment where students are excited, more willing to push through. It's highly motivated, with students preserving, not giving up. Opportunity to do more with their hands." –P4 The other interviews echoed this sentiment, but they also illustrated how constructivist teaching can be a challenge for both the educator and the students.

Students at the start couldn't grasp design thinking. They would always wait for me to give them ideas. Finally, after that surface level shock of freedom and they got used to the freedom, they started coming up with all kinds of ideas. I had to transition them to the next phase of collaborative sharing where others would ask questions, we would talk about constructive criticism in design, and thinking about how useful and helpful it could be instead of taking it in a negative way. Then, look at self-reflection and always have next steps in mind. Being able to be resilient, bounce back and keep trying to improve. That part was most difficult. –P1

Participant One reported her initial frustration: "Students would go on tangents that deviated from their project. It's a process. As a teacher, being flexible with the learning is very different from other subjects within the school day." --P1 Eventually, the positive aspects of the Makerspace overcame her initial frustration: "The Makerspace is a very valuable component. It's not playing, but time to tinker and create. Students drive their own learning." –P1

Computational thinking activities

Questions 24-25 focused on computational thinking skills and dispositions as defined by the literature. The most popular answers surrounded educational buzzwords like "problem-solving" and "collaboration". While computational thinking skills and dispositions may be present, educators may not be as familiar with the terminology.

The overall sample for this question was small (Total *N* = 38), but from those surveyed, 100% of the men (*n* = 9) used prototyping, programming, engineering (arduino, makey makey, 3d design, little bits) and software, while a smaller percent (47%) of the women *(n* = 29) responded that they incorporated those materials in the Makerspace.

The survey data also showed that women (*N* = 29) were using activities and materials that could lead to computational thinking, including: debugging (74%), developing algorithms (making steps and rules) (60%), utilizing patterns (spotting similarities in problem solving) (65%), abstracting ideas (removing unnecessary detail) (57%), ability to break problem down into smaller, more manageable pieces (75%), apply logic to predict and analyze (92%).

Topic III: Overcoming a lack of formal training

The teachers surveyed were not well supported in professional development regarding Makerspaces in schools; 44% of respondents reported they had received no training in Makerspaces. Many indicated the difficulties of constructivist approaches, which were reflected in activities. In a breakdown by major, classically trained educators had the hardest time relinquishing control and giving the students the freedom to choose their own projects and materials. Prototyping, teaching a design thinking process, and programming were also represented in lower numbers. These foundational activities can bolster computational thinking. It is important that teachers receive more training moving forward so they can fully utilize all types of activities that can support student learning.

However, the interviews uncovered an interesting finding: even if educators were not supplied with professional development opportunities, they found ways to learn by connecting with other educators online. Participant One went online to research Makerspaces herself after a disappointing professional development experience. “Blogs were a really good resource because they filtered out things, and they were written by teachers. I could pick out little things to try in my own makerspace.”—P1

Participant Four reported that he participated in Twitter chats; Participant Five found webinars online to expand his learning. Question X on the survey asked participants to list examples of Makerspace professional development in which they had participated. Respondents replied with their favorite online professional learning networks, listing Google groups, Twitter, TED talks and Youtube.

Topic IV: Perceived lack of support from other educators

Both the interview, survey responses, and open-ended survey questions provided data that bolstered the claim that there is a perceived lack of support from educators.

Starting with the survey data, question 39 was an open-ended response: Knowing what you know now, if you could change one thing about your Makerspace, what would it be? This response can be compared with Question 18, which asked: What were your largest obstacles? As echoed from earlier in the chapter, each of the both responses demonstrated the common theme of a lack of understanding and support from other teachers. Furthermore, this same theme emerged in data from Question 38, which asked: ‘Overall, how do you perceive your communities’ attitudes toward your Makerspace?’ In this question, teachers were perceived as the least supportive group, and they were the only group with in the community to be perceived as unsupportive.

From the responses of 'Knowing what you know now, if you could change one thing about your Makerspace, what would it be?' the most popular response (*n* = 6) focused around gaining the support of other teachers.

Participant four also encountered attitude at his school, reporting he often heard: "That's not the way we did it before." Participant Five's Makerspace is not new, yet he still reported struggling with "helping people to understand that defining the Makerspace doesn't quantify it" and that he must "constantly define and explain <the Makerspace>".

Answering Research Question 1: How are educators utilizing Makerspaces in schools?

Pedagogy

Research question 1 was: How are educators utilizing Makerspaces in schools? This question relies predominantly on survey data, though several interview responses are also relevant (those will be discussed at the end of the interview results). From the survey, it is clear that low-tech, low-cost materials are providing an easy barrier of entry to educational Makerspaces; question 12 revealed that educators are using readily available materials commonly found in schools to equip their Makerspaces, namely non-electronics (cardboard construction, woodworking, handicrafts).

The survey also reveals that a surprising number of Makerspaces at the elementary level. The young age of students could possibly be another reason why more technical activities were not as prevalent as non-electronics.

There were discrepancies in Makerspace activities and materials found by both gender and major, which will be discussed below.

Impact of Demographics: Gender

Unfortunately, the analysis of demographics reflected gender stereotypes: 59% of women did not prototype, while all of the men responded that they did use prototyping. While 12% of men reported that they did not consider themselves to be a maker, 20% of women responded similarly. All men reported using engineering and software, while only 1/3 of the females did. All of the men used programing; 41% of females did not use programming in their Makerspace. The one area were women possessed an advantage was in the area of robotics: 52% of females use robotics compared to 50% of men.

From the survey, an analysis of majors brought to light interesting responses from educator majors: they were the least likely to prototype, identify as a maker, or allow students to select their own materials. However, they were the most likely group to use e-textiles.

Impact of Demographics: Major

Many indicated the difficulties of constructivist approaches, which were reflected in activities. In a breakdown by major, classically trained educators had the hardest time relinquishing control and giving the students the freedom to choose their own projects and materials. Prototyping, teaching a design thinking process, and programming were also represented in lower numbers. These foundational activities can bolster computational thinking. It is important that teachers receive more training moving forward so they can fully utilize all types of activities that can support student learning.

Teacher Training: Influencer of Material Selection & Activities

The teachers surveyed were not well supported in professional development regarding Makerspaces in schools; 40% of respondents ($N = 39$) reported they had received no training in Makerspaces. The reason this is important is because it could impact the types of activities and materials in Makerspaces. This study revealed that while female educators possessed a Maker identity, they were less likely to include programming, prototyping, engineering (arduino, little bits, etc.) and software into the Makerspace. Non-electronics (cardboard construction, woodworking, handicrafts) was the most used material in educational Makerspaces.

With the lack of professional development asserted on the survey, the interviews provided a more complete picture. Interestingly, the educators interviewed were very resourceful, and filled the void of professional development by connecting with other educators online. Participant Five sought out webinars on his own that were free to the school. When discussing activities and materials, Participant Three noted how she went online to find resources (MakerEd and a local college provided her content). Participant Four participated in Twitter chats. The types of activities found in the Makerspace are influenced by what educators are exposed to; for many of them they are forging their own connections and creating their own learning.

Makerspace Fitting into the Formal Education Environment

The last section of school demographics probed into issues of support and sustainability; this is an important aspect of how educators are using the Makerspace to illustrate how it is integrating into the formal education environment. Interestingly, educators indicated that other teachers were the only group opposed and neutral to Makerspaces. The activities in the Makerspace are more limited if other educators are not viewing the space as a cross-curricular resource and only a select group of students are able to participate in Making. Students were reported to be the most supportive group, followed respectively by school administrators and parents. This is a telling sign; the students embrace the Makerspace, whereas educators have the most difficult time seeing how it fits into the school day. This could be in part due to the lack of training and professional development highlights the benefits of Making, which explain the skill skills that students can acquire through a transformative experience in the Makerspace.

Conclusion

This chapter has explored the findings from two phases of research: Phase I included a 39-question online survey, followed up with in-depth interviews involving five of the initial participants.

Low-tech materials were the most popular material choice for Makerspaces, but they were supported computers. Low-tech materials in the space provide a low barrier of entry to educators looking to implement their own Makerspace.

Computational thinking skills were apparent in the design activities reported by teachers. Unfortunately, the analysis of demographics reflected gender stereotypes: 59% of women did not prototype, while all of the men responded that they did use prototyping. While 12% of men reported that they did not consider themselves to be a maker, 20% of women responded similarly. All men reported using engineering and software, while only 1/3 of the females did. All of the men used programing; 41% of females did not use programming in their Makerspace. The one area where women possessed an advantage was in the area of robotics: 52% of females use robotics compared to 50% of men.

Next, an analysis of majors brought to light interesting responses from educator majors: they were the least likely to prototype, identify as a maker, or allow students to select their own materials. However, they were the most likely group to use e-textiles.

School site demographics revealed a surprising number of Makerspaces at the elementary level. Each vignette explored the background, curricular emphasis, value of a Makerspace and a section on ‘moving forward’. The next chapter will discuss key finding and their relation to the literature, future research implications and offer final conclusions.

Chapter Five: Discussion

> Today, Americans of all ages have the ability to connect and showcase their creativity through a growing maker movement. Just as the personal computer and the Internet transformed our Nation over the last several decades, these new opportunities can inspire the next generation of students, innovators, and entrepreneurs to carry forward our legacy of ingenuity.
>
> —Obama, Presidential Proclamation: National Week of Making

Introduction

The scathing report, (Denning, 1983) served as a catalyst to for ever-changing reforms to permeate the educational landscape. An additional outcome is the dramatic uptick in standardized testing and teacher evaluations. Meanwhile, the American economy has also experienced dramatic changes. Over the past few decades, there has been a shift from an industrial economy to information services, which is fueled by innovation (Apte et al., 2008).

However, innovation has not been reflected in the classrooms. A lack of equity in funding education has a major impact on the resources available for both teachers and students. Minorities and women are disproportionately represented in STEM majors, and STEM careers. While society is advancing at a rapid pace, this change is not reflected in education; a classroom from one hundred years ago would be indistinguishable from many classes today. Education is ripe for a change; the hobbyist community has provided an intriguing solution that is being embraced by educators across the nation.

The hobbyist community created the precedent that small ideas could have a worldwide impact; one example is how the personal computer revolutionized the global economy. Just as the personal computer attributes it origins to the hobbyist community, the Maker Movement has heritage there as well.

Makerspaces offer a solution, providing a dedicated space where students may explore their passions and solve real world problems while developing essential soft skills. Soft skills include creativity, innovation, communication, collaboration and problem-solving (Peppler et al., 2015b). Schools today are often consumed with pressure from a high stakes test environment, leaving little time for these essential soft skills. Ironically, the schools that schools are overlooking are often the most sought after from the employers' perspective. Makerspaces bridge the missing skills gap.

Linda Darling-Hammond posited:

> Bureaucratic solutions to problems of practice will always fail because effective teaching is not routine, students are not passive, and questions of practice are not simple, predictable, or standardized. Consequently, instructional decisions cannot be formulated on high then packaged and handed down to teachers." (2001)

Educational Makerspaces offer the unique opportunity and challenge to educators and students to reimagine the possibilities of what school can offer. As technology has made rapid advancements in recent decades, the role of the teacher has evolved. Students now have access to the wealth of human knowledge at their fingertips; the teacher is no longer the 'sage on the stage' imparting wisdom upon their pupils. Instead, the role of educators is now that of a facilitator, assisting the students to sift through the overwhelming amounts of information, synthesis what they have learned, and apply novel solutions to problems. The Makerspace provides a perfect environment for students to explore their passions at they same time they learn multi-disciplinary skills.

While schools are implementing Makerspaces at a rapid pace, they are not widely studied in the school setting. This exploratory study examines seven dimensions of K-12 Makerspaces: setting, participant structures, teacher training, computational thinking, soft-skills, assessment, as well as issues involving women & minorities.

Research Process

There are two primary research questions for this exploratory study. The first is: 'How are educators utilizing Makerspaces in schools?' which is answered primarily through survey data. The second question, "What are teachers' experiences of Makerspaces inside the school day?" is addressed through five in-depth interviews that followed the survey.

Phase I was a 39-question survey on educational Makerspaces. Phase II examined a cross-section of five educators from the original participant pool; participants were chosen based on school site diversity and their background.

Discussion of Key Findings: Situated in Literature

There were seven key findings, and each of these will be discussed in-depth in the following section. The sections echo the literature review: Makerspace Settings: Variations across spaces, Participant Structures, Teacher Training, Constructivist approach: challenging yet rewarding, Developing Soft-skills, Assessment in Makerspaces, Low barrier to entry, and accessible for women and minorities.

First, the Constructivist approach will be addressed, including challenges and rewards. Next, the low barrier of entry to Makerspaces will be explored, including implications for women and minorities. Finally, assessment in Makerspaces will be addressed.

Makerspace Settings: Variations Across Spaces

At the time of this publication, little research was available on K-12 Makerspaces in a natural element. Some examples of grant-based programs with researchers extensively involved in the implementation process with narrow learning outcomes were available (i.e. focusing solely on Scratch coding platform), but very little was found studying educational Makerspaces that occurred organically with educators as the chief instigator. This study focused on educators operating K-12 Makerspaces independently, without outside resources or funding. A goal of this exploratory study was to provide a glimpse into current programs to provide insights to other educators and researchers regarding what is happening in K-12 Makerspaces.

In the findings, the spaces proved to be extremely diverse, with a surprising amount of Makerspaces found in elementary grades. Dedicated Makerspaces made up 38% from educators interviewed in this study, with libraries coming in at 23%. Interestingly, 26% of educators from this study described their Makespace as ‘other’ denoting that it did not fit within any of the traditional models. There were discrepancies in the experience between elementary and upper grades; in the interview, the only educator who did not utilize a design thinking process came from the elementary level, stating that it was too advanced for the youngest students.

While Making in libraries are one approach, that is not the only solution. Much of the buzz around Making seems to be isolated to librarians, yet that is not the configuration that works for many schools. Professional development needs to be available to all administrators and educators interested in implementing making in their school. Possible configurations include a dedicated lab, mobile cart, library, or classroom that is used for other Participants as well.

Participant Structures

The literature on participant structures focused mainly on community Makerspaces, or specific aspects of making outcomes, i.e. circuitry or Scratch. This research bridges existing research of Sheridan et. al (2014) by adding knowledge about the content and process of learning in educational Makerspace. Use of computational thinking and a constructivist approach abounds in K-12 making. One of the main findings was the popularity of low-tech materials, creating a low barrier of entry to Makerspaces. Educational Makerspaces provide a platform for design thinking and empathy.

Making also transcended the barriers of subjects and grade levels, school-wide open making allowed all students to participate and it was inclusive of the local community as well. An overarching theme was the impact that the Makerspace had on the local community. Many times the students solved community problems. One particular instance is a middle school Maker class designing and building a STEAM playground for a local elementary school. Other instances show students coming up with innovation solutions to school problems, or issues that directly impact them. They are able to design and prototype their ideas, iterating upon their design to improve the final product. One example is the water bottle holders that attach to the student chairs. This solved the loud distraction from the water bottle tipping over, and it also prevented messy slips in the classroom. While this make seems like a small innovation, the students experienced the design thinking process while making an impact at their school.

A prevalent topic in education is preparing students for jobs that don't exist yet as technology rapidly advances. Empowering students to come up with creative solutions to problems, seek multiple answers, collaborate together, and preserve through difficult processes are the foundation for education of the future. Makerspaces have a unique propensity to enhance education in a way unheard of before recent times. With a low barrier to entry and low cost tools and materials, all schools have the opportunity to incorporate making into their curriculum.

Implications for Teacher Education and Community Collaborations

There is an opportunity for additional professional development on Makerspaces. An astounding 40% of respondents ($N = 39$) stated that they had never received any professional development on Makerspaces. In vignette one, the teacher further elaborated that the professional development that she did receive was focused on librarians, and not as applicable to classroom teachers. We need to empower all teachers who are interested in making.

Importance of Connecting with other Educators in Maker Education

The interviews revealed that professional development served multiple purposes. The first benefit is to provide a professional learning network of other individuals that are undergoing similar challenges in Makerspaces. Participants found it very beneficial to discuss ideas, projects, management structure, workflow and resources with other educators running a Makerspace. After establishing these connections at conferences and workshops, they had colleagues in which to collaborate. Site visits were also a very beneficially form of professional development where educators could gain inspiration from the layout, tools, and management of resources that other educators shared. Two interviews mentioned working in their local community Makerspace, and how that enhanced their classroom experience. Positive remarks were made about Stanford University's professional development on Makerspaces, and the Do, Design, Discover workshop.

Community Connections

Another area of improvement is to tap into the local community. Communities can provide local experts to mentor students and the Makerspace can be a way for the public to connect with the school. The schools that appeared to be the most successful were the ones that brought their Makerspace out of the school walls and connected well with their community. One example from the interviews is a student-designed STEAM playground that was implemented at another local school. This collaboration between the two schools enhanced the student experience at both schools. Another interview uncovered that their school was bringing in the parent community to have a night devoted to making. Families were given their own challenges to experience the making process, and student work was showcased. Three of the interviews mentioned that they weren't to that stage yet, but that was a future goal.

Recognizing Online Learning

Educators cited the benefits of online resources and social media for professional development. Blogs served as a virtual window into classrooms inaccessible because of distance. One interviewee mentioned the value of blogs because other educators in similar positions authored them. Educators collaborated virtually, noting the importance of Google plus groups on Makerspaces as well as Twitter. As educators are gaining knowledge through online resources, schools and districts should take note. Many districts require prescriptive professional development, which doesn't meet the needs of the individual educator. It is standard practice to personalize learning for the students, but often that same courtesy is not extended to educators. Participating in online professional learning needs to be validated; educators are spending hours collaborating and sharing their knowledge with peers.

Next Steps: The Potential Role of Teacher Preparation Programs

This study found that 40% of participants (N = 39) received no training on Makerspaces. One implication of this study is how we can address this gap. There are many ways to improve training, including professional development at the district level and teacher education programs at the university level. While women adopted the identity of a Maker, they used less technical materials and activities; training might compensate for this gender gap.

There are many professional development opportunities for schools to consider. Conferences provide another opportunity for educators to collaborate and share ideas, and Makerspaces are a trending topic in educational spaces. While national conferences might be costly, there are also opportunities for learning at the state and local levels. "Edcamps" are a movement for free professional development for teachers, by teachers. Districts could harness the power of learning at the local level for a cost-efficient way to train their faculty. Additionally, exemplarily educators from within the district could put on professional learning for their peers. By connecting with others, these educators can share their learning and expand their teaching repertoire. Another opportunity could be to recognize online learning. Micro-credentials or badging could be offered as an incentive to recognize online learning. Some districts do not have the resources to offer personalized learning, and they often ignore the learning that their faculty are doing on their own. When educators participate in a twitter chat or spend hours interacting with their peers on websites like MakerEd forums, they could receive professional development credit for their time.

Another area that could infuse making are the teacher education programs at the university level. Teacher education programs can infuse design thinking with the teacher candidates' curriculum. The survey data showed that education majors were the least likely group to allow students to choose their own materials. Teacher education programs have an opportunity to teach constructionist principles. These programs responsible for training teacher candidates could inject making into schools via new teachers. The constructionist methodology of Makerspaces is complex, and deviates from traditional teaching methodology found in many schools today. If teacher-training programs introduced this methodology, newly minted educators could enter schools armed with valuable knowledge for integrating Making into the curriculum. As stated before, low-cost tools and resources were the most widely used by current Makerspace teachers in this study. This low barrier to entry could assist educators to implement making and inspire cross-curricular projects. It would save districts money for training if more educators graduated with a deep understanding of constructionism and how it can be applied to educational Makerspaces.

Other savvy teachers were able to connect with experts online, and many responded that they learned through their social media networks. If educators coming into the field do not know how to leverage these essential structures, they will be left at a disadvantage. Additionally, education majors were a group that did not identify themselves as makers. Teacher education programs can help shape the identity of teachers coming into the workforce as confident makers.

Constructivist Approach: Challenging yet Rewarding

The literature posited that the constructivist approach was rewarding, but could be a challenge for both teachers and students. The results of both the interview and survey portions of this survey confirm the dualistic nature of constructivism. Constructivist learning is unique in that it does not follow the typical status quo for schools; learning is experiential and student driven. This model proves a challenge for students who are experts at the game of school: they know how to get the right answer and make all A's. For these individuals, a constructivist environment can be extremely disarming. There is no set agenda, right answer, or one way to solve a problem. The students themselves maybe determining what the problem is that they wish to solve. For those who need the scaffolding of rigid classroom structure, this may be a challenging learning opportunity. The respondents mentioned their own learning curve when transitioning to a Makerspace environment.

> Students at the start couldn't grasp design thinking. They would always wait for me to give them ideas. Finally, after that surface level shock of freedom and they got used to the freedom, they started coming up with all kinds of ideas. I had to transition them to the next phase of collaborative sharing where others would ask questions, we would talk about constructive criticism in design, and thinking about how useful and helpful it could be instead of taking it in a negative way. Then, look at self-reflection and always have next steps in mind. Being able to be resilient, bounce back and keep trying to improve. That part was most difficult. –P1

The results of the survey showcased the differences in each Makerspace implementation. One teacher had a predictable routine within the Makerspace, even when the students were driving the learning. Others demonstrated a unique space in which the workflow for each class was completely different.

Assessment in Makerspaces

Assessment can be a challenge in many Makerspaces. One educator reported students' concern if they didn't have a product at the end of every class; it was a process to get them comfortable with sharing out their thinking process instead. She used a thinking matrix to help the students express what they had accomplished during the session, even if it focused on planning and they had not tangible outcome.

> We would always at the end of a day have one or two students share out. Through accountable talk, like an engineer would, they explain how they use their thinking time. They would use the organizer and talk through the phases. Each day, they felt like they were supposed to have a tangible object, or artifact to take, and we had to get to a place where they didn't feel like their time wasn't wasted if they didn't have that. Share your thinking, we want to see your mind map, your decision matrix, see how what you did today. You don't always have to have something to take home. The design thinking time was key. –P1

Makerspaces are a unique area that sometimes falls outside of the traditional curriculum, focusing on student-driven passion projects. In other setups, they are incorporated into a traditional classroom and curriculum. When asked about assessing learning in Makerspaces, projects, student presentations, rubrics, student-created videos and peer assessments were the most popular responses. From this study, only 15% of educators used formal grading in the Makerspace. Some special area classes involve subject material that is harder to quantify (particularly in the elementary grades), like physical education class, music or library. If grades are required to meet the requirements of the school, satisfactory rating scale could be used, including participation. The popular assessment options listed above (rubrics, peer-assessment, etc.) could also be used to assign a grade if necessary. Video presentations, blogs, and class Instagram accounts are ways in which some respondents showcased their students' work and connected them to the global community.

Other Makers took the opportunity to showcase their work to the broader community. Some schools hosted gallery walks inviting the classes within the school to visit the space to view the current projects, while others invited the community to participate in hands-on Maker nights. Others showcased student work to the broader community by presenting at local Maker Faires with thousands of participants.

Low Barrier to Entry, Accessible for Women and Minorities

The most popular materials reported in Makerspaces were simple items easily accessible to any classroom. This low-tech option provides a low barrier to entry for both educators and students. It affords an opportunity to expose more women and minorities to Making and STEM education. Students may adopt the identity of an engineer, mathematician and computer scientist while engaging in making activities.

Computational thinking may be demonstrated through Making activities. Students have the opportunity to create a virtual representation of their product, even without a 3D printer. Decomposition, abstraction, modular thinking, recognizing patterns, and developing algorithms are all essential to the computational thinking experience. While they are rooted in computer science, these skills can be transferable to any discipline to enhance students' analytical thinking.

Implications of Findings

Initiatives for early STEM education appear to be working, as Makerspaces pervade in the elementary setting. More programming and professional develop is needed to support Making with the youngest students. Another limitation of professional development in Making is focusing solely on libraries; in many schools the Makerspace is run by educators who are not the librarian. Professional development isolated to this demographic can isolate other educators who face different obstacles than libraries. Dedicated Makerspaces and mobile labs are growing in popularity, and were the two most reported spaces in use. A goal of many schools is to create an interdisciplinary space to serve as a resource to all teachers.

Makerspace Directors need to adopt the identity of a Maker themselves. 20% of respondents did not consider themselves to be a Maker; how can they expect their students to take on this identity? There was a gender disparity in this area; more women did not view themselves as Makers.

There is still a need for more women exposed to STEM, and more education majors exposed to this way of thinking as well. As a group, women were the least comfortable with programming and prototyping. One of the foundational pillars behind Makerspaces is Computational Thinking, yet when asked the frequency in which computational thinking is found in the classroom, it was consistently low. This may be a lack of education on the part of Makerspace directors. Computational thinking may still be present yet unidentified by the educators. If programming and coding are going to remain, there is a need to educate teachers on the fundamental thinking approaches behind these tools. The goal of coding in education is not to make every child a computer programmer; instead, the analytical computational thinking approach can transfer across disciplines to enhance the student's thinking repertoire.

Aside from computational thinking, there were other struggles when transitioning a Makerspace to a school. Education majors had the most difficult time with relinquishing control to students. The constructivist approach can be difficult for teachers and students alike as it is so different from the traditional classroom routine. Teachers discussed the transition to the freedom was a shock for the students, and it could be challenging for them as well. Conversely, they also champion the cause of Makerspaces, celebrating the meaningful impact it has on student lives. Multiple interviews discussed the change in children and how the Makerspace gave them an opportunity to recognize student talents not normally in schools.

A challenge moving forward is showcasing the work done inside the school Makerspace. Many innovative educators shared their ideas, including gallery walks, Mini-Maker Faires for families. Others suggested more advertising in the form of commercials and student STEM ambassadors.

Conclusions

This survey identified a need for support for Makerspaces in education. Respondents identified other educators as the least supportive group. Educators outside of the Makerspace have the most trouble understanding the underlying purpose and pedagogy that supports the Makerspace. The biggest wish of educators running a Makerspace was for more storage and space. There other key insight was they wished they had started their Maker program sooner. The most valuable materials to them were the low-cost and readily available ones: cardboard, tape, scissors, glue and Legos. This low barrier to entry allows for all students to be able to participate in Making, and for any school to add a Makerspace. Additional materials that were popular included computers, robotics, wood, and 3D printers. Design thinking was an important aspect to making. The constructivist approach with the teacher serving as a facilitator was an essential part of the Makerspace. Many teachers found that this was a difficult transition for them as well as their students, but in the end, they found that it was well worthwhile.

Recommendations for Further Research

A longitudinal study of educational Makerspace would add to the body of literature the evolution of Making in schools. Studies exploring the impact of Makerspaces on women and minorities would be interesting. Attitudes about STEM careers, empowerment and entrepreneurial through the Making experience would be interesting. A more in-depth study of computational thinking skills is needed with diverse materials in K-12 Makerspaces. Additional case studies and vignettes are needed to probe deeper into the topic of educational Makerspaces.

Summary

This study hopes to fill a gap in the literature as an exploratory examination of Makerspaces in the K-12 school setting. Makerspaces can be leveraged as a powerful space for students to tinker, create, design and explore. With the low barrier to entry resulting from the popularity of low-tech materials, more Makerspaces may appear in educational spaces in the future. More professional development is needed to support Makerspaces in different school environments, starting with the youngest grades. According to the data from this study, more women need to embrace the identity of a Maker. Community partnerships can be leveraged, and student work can be showcased outside of school walls.

The constructivist principles that bolster a Makerspace can be difficult for students and teachers to embrace. However, when a Makerspace is successful, the benefits are life changing for both the educators and the students (Adrianson, Cameron, & Horvath, 2015).

REFERENCES

Adrianson, D., Cameron, R., & Horvath, J. (2015). New shop class, 243. doi:10.1007/978-1-4842-0904-2

Alternative Assessment Definations. (2001). Retrieved from http://www.miamisci.org/ph/lpdefine.html

Anderson, C. (2016). The maker movement: Tangible goods emerge from ones and zeros. *Wired*. Retrieved from http://www.wired.com/2013/04/makermovement/

Baafi, E., Buechley, L., Dubow, W., & Qiu, K. (2013). *A Curriculum for Teaching Computer Science Through Computational Textiles*. Retrieved from http://pepperdine.worldcat.org/title/a-curriculum-for-teaching-computer-science-throughcomputational-textiles/oclc/5136080897&referer=brief_results

Baldwin, D. (2013). A blueprint maker programs for youth. *New York Hall of Science*. Retrieved from: http://dmp.nysci.org/system/files/filedepot/1/NYSCI_MAKER_BLUEPRINT.pdf

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads, 2*(1), 48-54. doi:10.1145/1929887.1929905

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., & Doms, M. (2011). *Women in STEM: A Gender Gap to Innovation*. Retrieved from http://www.esa.doc.gov/sites/default/files/womeninstemagaptoinnovation8311.pdf

Berry, R. Q., III, Bull, G., Browning, C., Thomas, C., K., S., & Aylor, J. H. (2010). Preliminary considerations regarding use of digital fabrication to incorporate engineering design principles in elementary mathematics education. *Contemporary Issues in Technology and Teacher Education, 10*(2), 167-172. Retrieved from http://www.citejournal.org/volume-10/issue-2-10/editorial/use-of-digital-fabrication-toincorporate-engineering-design-principles-in-elementary-mathematics-education/

Bertot, J. C., Jaeger, P. T., Lee, J., K., D., A. J., M., & Real, B. (2014). *2013 Digital Inclusion Survey: Survey Findings and Results*. Retrieved from: http://digitalinclusion.umd.edu/sites/default/files/uploads/2014DigitalInclusionSurveyFinalRelease.pdf

Blikstein, P. (2013). Digital fabrication and 'making' in education: the democratization of invention. In J. W.-H. C. Büching (Ed.), *FabLabs: Of Machines, Makers and Inventors*. Bielefeld: Transcript Publishers.

Bramwell, F., Campbell, P., Clewell, B. C., Davis, D., Fortenberry, N., Garcia, A., . . . Stoll, A. (2009). *Framework for Evaluating Impacts of Broadening Participation Projects*. Retrieved from https://www.nsf.gov/od/broadeningparticipation/framework-evaluating-impacts-broadening-participation-projects_1101.pdf

Brennan, K. (2015). Beyond Technocentrism: Supporting Constructionism in the Classroom. *Constructivist Foundations, 10*(3), 289-296. Retrieved from http://scholar.harvard.edu/kbrennan/publications/beyond-technocentrism-supportingconstructionism-classroom

Brennan, K., & Resnick, M. (2012). *New frameworks for studying and assessing the development of computational thinking*. Paper presented at the American Educational Research Association meeting, Vancouver, BC, Canada.

http://scratched.gse.harvard.edu/ct/files/AERA2012.pdf

Buechley, L., & Eisenberg, M. (2008). The LilyPad Arduino: Toward Wearable Engineering for Everyone. *IEEE Pervasive Computing, 7*(2), 12-15. doi:10.1109/MPRV.2008.38

Casebeer, W. (2013). Low-cost brain monitoring for hobbyist using EEG. Retrieved from http://makerfaire.com/makers/low-cost-brain-monitoring-for-hobbyists-using-eeg/

Cohen, A. (2011). *Innovation and Economic Growth*. Retrieved from: http://www.goldmansachs.com/our-thinking/archive/archive-pdfs/gsr.pdf

Cohen, B. (2004). Beam Center at Brooklyn International High School. Retrieved from https://www.youtube.com/watch?v=WzecDktaJbM&feature=youtu.be

Coil, C. (2014). Creativity in an Assessment Drivent Environment. *American Library Association, 42*(5), 48-53. Retrieved from http://www.carolyncoil.com/Creativity-AssessmentDriven.pdf

Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,* (4th ed.). Thousand Oaks, CA. SAGE Publications, Inc.

Darling-Hammond, L. (2001). *The Right to Learn: A Blueprint for Creating Schools that Work*. San Franscisco, CA: Jossey-Bass.

Denning, P. (1983). A Nation At Risk. *Communications of the ACM, 26*(7), 467-478. doi:10.1145/358150.358154

Dougherty, D. (2012). The Maker Movement. *Innovations, 7*(3), 11-14. doi:10.1162/INOV_a_00135

Ferrari, M., & Mahalingam, R. (1998). Peersonal cognitive development and its implications for teaching and learning. *Educational Psychologist, 33*(1), 35-44. Retrieved from doi:10.1207/s15326985ep3301_3

Graham, C. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*(3), 1953–1960. doi:10.1016/j.compedu.2011.04.010

Grover, S., & Pea, R. (2013). Computational Thinking in K-12: A Review of the State of the Field. *Educational Researcher, 42*(1), 38-43. doi:10.3102/0013189x12463051

Holman, W. (2015). Makerspace: Towards a New Civic Infrastructure. *Places Journal*. doi:10.22269/151130

ISTE Connects. (2016). The 10 hottest topics in ed tech. Retrieved from https://www.iste.org/explore/articleDetail?articleid=674

Jenkins, H. (2009). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. Cambridge, MA: The MIT Press.

Juliani, A. J. (2015). *Inquiry and Innovation in the Classroom*. New York, NY: Routledge.

Kafai, Y. B., Fields, D. A., & Burke, W. Q. (2001). Entering the Clubhouse: Case Studies of Young Programmers Joining the Online Scratch Communities. *Journal of Organizational and End User Computing*. doi:10.4018/joeuc.2010101906

Kafai, Y. B., Fields, D. A., & Cook, M. S. (2010). Your Second Selves. doi:10.1177/1555412009351260

Kafai, Y. B., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014). A Crafts-Oriented Approach to Computing in High School: Introducing Computational Concepts, Practices, and Perspectives with Electronic Textiles. *ACM Transactions on Computing Education (TOCE), 14*(1). doi:10.1145/2576874

Kapur, M. (2008). Productive Failure. *Cognition and Instruction, 26*(3), 379-424. doi:10.1080/07370000802212669

Kelly, B. (2016). Schools, city announce entrepreneurial 'Innovation Center'. Retrieved from http://currentnoblesville.com/schools-city-announce-entrepreneurial-innovation-center

King, H. (2016). College student 3D prints his own braces [Press release]. Retrieved from http://money.cnn.com/2016/03/16/technology/homemade-invisalign/index.html

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70. doi:10.2190/0ew7-01wb-bkhl-qdyv

Krueger, N. (2014). Create a school makerspace in 3 simple steps. Retrieved from https://www.iste.org/explore/ArticleDetail?articleid=103

Lang, V. (2007). *Beyond the Three Rs: Voter Attitudes toward 21st Century Skills*. Retrieved from http://www.p21.org/storage/documents/P21_pollreport_singlepg.pdf

Litts, B. K. (2015). *Exploratory Study of the Physical Environment in Makerspaces: Implications for the design and user evaluation of a new workstation-system.* (Doctoral dissertation), University of Wisconsin-Madison, Retrieved from ProQuest Dissertations & Theses. (AAT 3672348)

Mackey, J., & Evans, T. (2011). Interconnecting Networks of Practice for Professional Learning. *International Review of Research in Open and Distance Learning, 12*(3), 1-18. doi:10.19173/irrodl.v12i3.873

Maker Education Initiative. (2014). Retrieved from http://makered.org/about-us/mission/

Martin, C. K., Erete, S., & Pinkard, N. (2015). Developing focused recruitment strategies to engage youth in informal opportunities. doi: 10.1109/respect.2015.7296522

Martin, L. (2015). The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER), 5*(1), 4. doi:10.7771/2157-9288.1099

Millsaps, B. (2016). Will 3D Printed Coral Reefs Help Save the Marine Ecosystem? Retrieved from http://3dprint.com/124869/3d-printed-coral-reefs/

Montessori, M. (1912). *The Montessori Method*. Radford, VA. Wilder Publications.

National Research Council. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Retrieved from: http://www.cslnet.org/wp-content/uploads/2013/07/Next-Generation-Science-Framework-Final-Report.pdf

Nguyen, T. (2016). Yes, that 3D-printed mansion is safe to live in. Retrieved from https://www.washingtonpost.com/news/innovations/wp/2015/02/05/yes-that-3d-printed-mansion-is-safe-to-live-in/

Packer, M., & Goicoechea, J. (2010). Sociocultural and Constructivist Theories of Learning: Ontology, Not Just Epistemology. *Educational Psychologist,* (35), 227-241. doi:10.1207/S15326985EP3504_02

Papert, S. (1993). *Mindstorms: Children, Computers, And Powerful Ideas*: New York, NY: Basic Books.

Papert, S. (1994). *The Children's Machine: Rethinking School In The Age Of The Computer*. New York, NY. Basic Books.

Papert, S. (1996). An exploration in the space of mathematics educations. *International Journal of Computers for Mathematical Learning*. doi:10.1007/bf00191473

Peppler, K. (2013). STEAM-Powered Computing Education: Using E-Textiles to Integrate the Arts and STEM *Computer, 46*(9), 38. doi:10.1109/mc.2013.257

Peppler, K., Maltese, A., Keune, A., Chang, S., & Regalla, L. (2015a). *Survey of Makerspaces, Part II*. Retrieved from http://makered.org/wp-content/uploads/2016/01/MakerEdOPP_RB7_Survey-of-Makerspaces-2_final.pdf

Peppler, K., Maltese, A., Keune, A., Change, S., & Regalla, L. (2015b). *The Maker Ed Open Portfolio Project: Survey of Makerspaces, Part 1*. Retrieved from http://makered.org/wp content/uploads/2015/02/OPP_ResearchBrief6_SurveyofMakerspacesPart1_final.pdf

Perry, K. E., & Weinstein, R. S. (1998). The social context of early schooling and children's school adjustment. *Educational Psychologist, 33*, 177–194. doi:10.1207/s15326985ep3304_3

Piaget, J. (1973). *To Understand Is To Invent*. New York, NY: Grossman Publishers.

Plemmons, A. (2014). Building a Culture of Creation. *Teacher Librarian, 41*(5), 12-16.

Polin, L., & Moe, R. (2015). TPACK as Mediated Practice. In S. B.-B. K. J. Graziano (Ed.), *Online Teaching in K–12*. Medford, New Jersey: Information Today, Inc.

Resnick, M. (1998). Technologies for lifelong kindergarten. *Educational Technology Research and Development, 46*, 43-55. doi:10.1007/BF02299672

Roth, W.M., Anita. (1992). The Social Construction of Scientific Concepts or the Concept Map as Device and Tool Thinking in High Conscription for Social School Science. 5(76), 531–557. *Journal of Science Education*. doi: 10.1002/sce.3730760507

Rousseau, J.-J. (1763). *The social contract*. London, UK. Penguin Books.

Schmidt, D., Baran, E., Thompson, A., Mishra, P., Koehler, M., & Shin, T. (2009). Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers. *Journal of Research on Technology in Education, 42*(2), 123-149. doi:10.1080/15391523.2009.10782544

Sheridan, K. M., Halverson, E. R., Litts, B. K., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2015). Learning in the making: A comparative case study of three Makerspaces. *Harvard Educational Review, 84*(4), 505-531. http://dx.doi.org/10.17763/haer.84.4.brr34733723j648u

Shulman, L. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*(2), 4-14. doi:10.2307/1175860

Stewart, L. (2014). Maker Movement Reinvents Education. *Newsweek*. Retrieved from http://www.newsweek.com/2014/09/19/maker-movement-reinvents-education-268739.html

Tate, W. E. (2012). *Research on schools, neighborhoods, and communities: Toward civic responsibility.* New York, NY: Rowman & Littlefield Publishers.

Thompson, A., & Mishra, P. (2007). Breaking news: TPCK becomes TPACK. *Journal of Computing in Teacher Education, 24*(2), 38–64 doi:10.1007/S11528-013-0692-7

U.S. Department of Education. (2016). CTE makerover challenge. Retrieved from www.ctemakeoverchallenge.com

Vockley, M. (2008). *21st Century Skills, Education & Competitiveness*. Retrieved from http://www.p21.org/storage/documents/21st_century_skills_education_and_competitiveness_guide.pdf

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Willis, R. (2009). Playful Learning. *History Today, 59*(2), 20-21. Retrieved from http://www.historytoday.com/richard-willis/playful-learning-history-progressiveeducation

APPENDIX A

SURVEY QUESTIONS

Teacher Demographics

The first section will ask questions about your background as an educator and as a maker.

1 What is your title?

- ○ Teacher (1)
- ○ Makerspace director (2)
- ○ Instructional Technology Coach (3)
- ○ Librarian (4)
- ○ Administrator (5)
- ○ Other (6) ____________________

2 How many years have you been in your current position?

- ☐ 0-5 years (1)
- ☐ 6-10 years (2)
- ☐ 10-15 years (3)
- ☐ 15-20 years (4)
- ☐ 20+ years (5)

3 What is your highest level of education?

- ○ High School (1)
- ○ Associate's degree (2)
- ○ Bachelor's degree (3)
- ○ Master's degree (4)
- ○ Specialist degree (5)
- ○ Doctorate (6)

4 Please select the field that most closely represents your major.

- ○ Education (1)
- ○ Science (2)
- ○ Technology (3)
- ○ Engineering (4)
- ○ Math (5)
- ○ Other (7) ____________________

6 What is your gender?

- ○ Male (1)
- ○ Female (2)

7 My primary responsibilities include:

- ○ Teaching the Makerspace class (1)
- ○ Teaching other subjects (not in the Makerspace) (2)
- ○ Running another department (library, technology) (3)
- ○ Other (4) ____________________

8 Have you received any professional development on Makerspaces?

- ○ Yes (1)
- □ No (2)

If No Is Selected, Then Skip To Do you consider yourself a "Maker"?

9 Please briefly describe the professional development you have received on Makerspaces.

10 Do you consider yourself a "Maker"?

- ○ Yes (1)
- □ No (2)

11 How would you rank your expertise in Making?

- ○ Novice/Beginner (1)
- ○ Somewhat low (2)
- ○ Average (3)
- ○ Somewhat High (4)
- ○ Expert (5)

12 Do you use making in your personal life?

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometimes (3)
- ○ Often (4)
- ○ All of the time (5)

Technology: Makerspace Setup

This section will ask questions about when and how the Makerspace is used.

13 What are the three most essential materials in your Makerspace?

Material 1 (1)
Material 2 (2)
Material 3 (3)

14 Who most frequently chooses these materials?

- ○ Teacher/Adults in the organization (1)
- ○ Students (2)

15 In our Makerspace we use... (check any that apply)

- ❑ Non-electronics (Cardboard construction, Woodworking/Handicrafts) (1)
- ❑ E-textiles, wearables, & sewing (2)
- ❑ Engineering (arduino, makey makey, 3d design, little bits) (3)
- ❑ Software (Tinkercad, Sketchup, Scratch, Minecraft, etc) (4)
- ❑ Video production (5)
- ❑ Programming (6)
- ❑ Robotics (US First, VEX, Logo League) (7)
- ❑ Drones (8)
- ❑ Hydroponics (9)
- ❑ Musical instruments (physical & digital) (10)
- ❑ Prototyping (11)
- ❑ Other (please list) (12) ____________________

16 The Makerspace at my school site.... (check all that apply)

- ❑ Is accessible before school to students (1)
- ❑ Is accessible after school to students (2)
- ❑ Is accessible to students during recess or break times (3)
- ❑ Is accessible to students during lunch (4)
- ❑ Is a scheduled class for ALL students (5)
- ❑ Is an elective class for students (6)

17 Please choose all of the people who assist in the Makerspace

- ❑ Teacher that ONLY teaches in the Makerspace (1)
- ❑ Teacher who runs the Makerspace in addition to OTHER classes (2)
- ❑ Assistants (who are school employees) (3)
- ❑ Parent Volunteers with no expertise (4)
- ❑ Parent Volunteers who have expertise in areas that are applicable to the makerspace (5)
- ❑ Outside Experts (6)

18 Have you overcome obstacles in regards to setting up and running the Makerspace?

- ○ Yes (1)
- □ No (2)

If No Is Selected, Then Skip To End of Block

19 What were some of the largest obstacles?

Technology, Content and Pedagogy

The questions in this section will focus on the intersections of technology, content and pedagogy in a Makerspace.

20 In my school's Makerspace...

	Not applicable (1)	Less than once a month (2)	Once a week (3)	Multiple times a week (4)	Everyday (5)
A design process is explicitly taught to students (4)	☐	☐	☐	☐	☐
Cross-curricular projects are assigned (1)	☐	☐	☐	☐	☐
Students document their process (5)	☐	☐	☐	☐	☐
Students decide on their own projects (3)	☐	☐	☐	☐	☐

21 Do you showcase student products... (Check all that apply)

- ❑ Within the classroom (1)
- ❑ Within the school (2)
- ❑ At school events (parent nights, PTO meetings) (3)
- ❑ At community events (4)
- ❑ At Makerfaires (5)
- ❑ At Conferences (6)
- ❑ Other (please specify) (7) ____________________
- ❑ Not Applicable (8)

22 To assess student learning in a Makerspace we use... (check all that apply)

- ❑ Rubrics (1)
- ❑ Peer-assessment (2)
- ❑ Formal grades (3)
- ❑ Projects (4)
- ❑ Student blog posts (5)
- ❑ Physical Portfolios (6)
- ❑ Digital Portofolios (7)
- ❑ Written reports (8)
- ❑ Student created videos (9)
- ❑ Websites created by students (10)
- ❑ Student presentations (11)
- ❑ Student showcases (12)
- ❑ Other (please specify) (13) ____________________

23 In the Makerspace...

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	All of the time (5)
Students teach each other (1)	☐	☐	☐	☐	☐
Experts visit our site to teach students (2)	☐	☐	☐	☐	☐
Students create tutorials or guides (12)	☐	☐	☐	☐	☐
Students are identified by expertise (13)	☐	☐	☐	☐	☐

24 In your Makerspace, how often do students...

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	All of the time (5)
Persevere through a problem (1)	☐	☐	☐	☐	☐
Apply logic to predict and analyze (2)	☐	☐	☐	☐	☐
Utilize problem-solving skills (12)	☐	☐	☐	☐	☐
Tinker, experiment and play (13)	☐	☐	☐	☐	☐
Debug code (14)	☐	☐	☐	☐	☐
Troubleshoot problems (15)	☐	☐	☐	☐	☐

25 How often do students demonstrate the following skills?

	Not Applicable (1)	Less than once a month (2)	Once a week (3)	Multiple times a week (4)	All of the time (5)
Ability to break problem down into smaller, more manageable pieces (1)	☐	☐	☐	☐	☐
Perseverance in completing tasks (16)	☐	☐	☐	☐	☐
Collaborating with peers (17)	☐	☐	☐	☐	☐
Developing algorithms (making steps and rules) (18)	☐	☐	☐	☐	☐
Utilizing patterns (spotting similarities in problem solving) (19)	☐	☐	☐	☐	☐
Abstracting ideas (removing unneccessary detail) (15)	☐	☐	☐	☐	☐
Evaluating and making judgements (14)	☐	☐	☐	☐	☐
Learn from	☐	☐	☐	☐	☐

failure (13)					

26 Specific projects or materials are incorporated into Makerspaces targeting females

- ○ Yes (if yes, please list example) (1) ____________________
- □ No (2)

School Demographics

In the final section of the survey, questions will focus around the demographics of your school setting.

27 How many years has your Makerspace been in existence?

- □ 0-1 years (1)
- □ 2-3 years (2)
- □ 3-4 years (3)
- □ 5-6 years (4)
- ○ 6+ years (5)

28 Select the choice that best represents your Makerspace

- ○ Dedicated Makerspace (1)
- ○ Mobile Lab (2)
- ○ Library Makerspace (3)
- ○ Cross-Curricular Lab (4)
- ○ Other (5) ____________________

29 Is your site a public, charter, magnet or independent school?

- ○ Public (1)
- ○ Charter (2)
- ○ Magnet (3)
- ○ Independent (4)

30 Which best describes the school site where your Makerspace is located? (please select any grade bands that use the Makerspace at your site)

- ❑ Elementary School (K-2) (1)
- ❑ Upper Primary (3-5) (2)
- ❑ Middle School (6-8) (3)
- ❑ High School (9-12) (4)

31 How many students are at your school (at the campus where you teach)?

- ❍ Less than 200 (1)
- ☐ 200-400 (2)
- ☐ 401-600 (3)
- ☐ 600-800 (4)
- ☐ 800-1,000 (5)
- ☐ 1,000-1,500 (6)
- ☐ 1,500+ (7)

32 The gender makeup of my school is:

- ❍ Co-ed, a mix of boys and girls (1)
- ❍ All girls school (2)
- ❍ All boys school (3)

33 What is the overall gender distribution of students who are enrolled in Makerspace classes?

- ❍ About equally girls and boys (1)
- ❍ Somewhat more girls than boys (2)
- ❍ Somewhat more boys than girls (3)
- ❍ Large imbalance: more girls that boys (4)
- ❍ Large imbalance: more boys than girls (5)

34 Do all of the students at my school go to the Makerspace?

- ❍ Yes (1)
- ☐ No (2)
- ❍ Other (3) ____________________

35 My school's setting is best described as...

- ○ Urban (1)
- ○ Suburban (2)
- ○ Rural (3)

36 What percentage of students are eligible for free & reduced lunch?

- ○ I don't know (1)
- ☐ 0-25% (2)
- ☐ 26-50% (3)
- ☐ 50-75% (4)
- ☐ 76-100% (5)

37 Overall, how do you perceive your communities' attitudes toward your Makerspace?

	Strongly opposed (1)	Somewhat opposed (2)	Neutral (3)	N/A (6)	Somewhat Supportive (4)	Strongly Supportive (5)
Teachers at your school (1)	☐	☐	☐	☐	☐	☐
Administration at your school (2)	☐	☐	☐	☐	☐	☐
Parents of your students (3)	☐	☐	☐	☐	☐	☐
District-level personnel (4)	☐	☐	☐	☐	☐	☐
Students at your school (5)	☐	☐	☐	☐	☐	☐
Community members (6)	☐	☐	☐	☐	☐	☐

38 Do you connect with other Makerspace teachers? If so, please check all that apply

- ☐ In person meetups (Makerfaires, Local teachers, regional groups) (1)
- ☐ Online groups (Twitter, Google Groups, Facebook Groups, Email Listservs- i.e. ISTE) (2)
- ☐ Forums/Websites (3)
- ☐ No/Not applicable (4)
- ☐ Other (5) ____________________

39 Do you connect with content experts? If so, please check all the ways in which you connect

- ☐ In person meetups (Makerfaires, Community Makerspaces, Local Experts, Hackerspaces, etc) (1)
- ☐ Online groups (Twitter, Google Groups, Facebook Groups, Email Listservs) (2)
- ☐ Forums/Websites (3)
- ☐ No/Not applicable (4)
- ☐ Other (5) ____________________

40 Knowing what you know now, if you could change one thing about your Makerspace, what would it be?

41 If you are willing to give a follow-up interview, please add your best contact email here.

APPENDIX B

IRB APPROVAL FORM

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: June 16, 2016
Protocol Investigator Name: Elizabeth Cross
Protocol #: 16-05-273
Project Title: TINKERING IN K-12: AN EXPLORATORY MIXED METHODS STUDY OF MAKERSPACES IN SCHOOLS AS AN APPLICATION OF CONSTRUCTIVIST LEARNING
School: Graduate School of Education and Psychology

Dear Elizabeth Cross:

Thank you for submitting your application for exempt review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46.101 that govern the protections of human subjects.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Since your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,
Judy Ho, Ph.D., IRB Chairperson
Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

Page: 1
cc: Dr. Lee Kats, Vice Provost for Research and Strategic Initiatives
Mr. Brett Leach, Regulatory Affairs Specialist
Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000
Page: 2

Question Number & Description	Definition	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Question 1: Typical Day Routine/Structure	Each class follows a predictable workflow, even with students choosing their own projects.	7	0	0	2	0
No such thing as a typical day	Each day in this Makerspace is truly unique; there is not an established workflow or routine.	0	3	1	2	5
Question 2: Design Thinking Design thinking is essential to the Makerspace	Design thinking is explicitly taught in the Makerspace.	8	5	0	3	2
No design thinking is apparent	Design thinking is absent from the Makerspace.	0	0	1	0	0
Question 3: Professional Development Conferen	Edtech conference sessions,	1	4	0	3	4

ces & Workshops	workshops by Universities					
Online resources & social media	Twitter, blogs, online professional networks (Google + communities, MakerEd, etc), Webinars	2	0	1	3	3
Site Visit	Time spent in a community Makerspace or at other school's Makerspace	0	6	1	1	2
Question 4: Overcame Obstacles Change in school culture	Makerspaces aren't easily defined, and they can be difficult for stakeholders to understand.	4	3	4	2	2
Change in class culture/expectations of students	A Makerspace presents challenges for students as it is radically different than a traditional classroom. Students must show more	4	2	0	0	2

	initiative and resilience. This also changes the role of the teacher to a facilitator					
Question 5: Process for determining activities Teacher directed	Teachers give students a project, theme, or challenge	0	4	4	3	4
Student initiated	Students come up with their own projects	14	0	0	5	0
Question 6: Value of a Makerspace Creation/Working with hands	Establishes the value of tinkering in the Makerspace	4	1	0	2	0
Develops student identity	Students take ownership of their own learning. Confidence is instilling as they discover their passions.	1	4	1	2	4

Question 7: Defining Success Sustainability	Focuses on logistical issues of the future of Makerspaces	1	0	0	5	0
Student impact	Focuses on the impact that a Makerspace has on a student	4	3	3	1	0
Question 8: Examples of student work Making it fit within goals/parameters of Makerspace	Focuses on logistical issues of the future of Makerspaces	5	0	0	5	0
Makerspace uniquely suited to create this type of project	Focuses on the impact that a Makerspace has on a student	2	3	3	1	4
Question 9: Showcase School Community	Student work was showcased to other classes within the school, i.e. Gallery Walk	3	1	0	1	0
Local Community	Student work was showcased to the community outside the school, like	2	1	1	1	1

	Parents, or Makerfaires					
Global Online Community	Student work was showcased on websites, blogs, etc.	1	1	1	0	1
Question 10: Next Steps Get more faculty involved	The goal is to get more faculty using the Makerspace or to create more cross-curricular ties	2	1	2	1	1
Taking it to the next level	The participant's response indicates that they want to advance the use of the Makerspace (i.e. complexity of projects)	1	3	2	1	4