Spring 5-5-2023

THE CART BEFORE THE HORSE?: A PHENOMENOLOGICAL STUDY OF THE PERSPECTIVES AND EXPERIENCES OF MAKER EDUCATION SUPERVISORS IN INDEPENDENT SCHOOLS (9-12)

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A Dissertation

Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for

the degree of Doctor of Education

By

Jesse Robinson

May 2023

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ABSTRACT

THE CART BEFORE THE HORSE?: A PHENOMENOLOGICAL STUDY OF THE PERSPECTIVES AND EXPERIENCES OF MAKER EDUCATION SUPERVISORS IN INDEPENDENT SCHOOLS (9-12)

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Over the past decade, makerspaces have increased in popularity all over the globe (Lou & Peek, 2016) and their addition continues to be a popular trend in the K-12 educational space. In the K-12 environment, the decision to implement a makerspace frequently consists of finding, repurposing, or building a suitable space, and outfitting it with the latest technology trends with the anticipation that 'if you build it, they will come.' As a director of a makerspace, my experience is that integrating curriculum across disciplines, or creating pedagogical goals for the makerspace, frequently becomes a priority after the space is designed and the equipment is ordered. This poses a challenge for all stakeholders and accounts for a problem in practice that needs to be addressed. This qualitative study utilized a phenomenological approach inspired by Kurti, Kurti, and Fleming's (2014) philosophy of educational makerspaces to understand the perspectives and experiences of makerspace leaders at independent schools (9-12). In addition, the study explored what challenges and opportunities directors face when designing, implementing, and managing makerspaces centered around design thinking and learning-by-doing. Data was collected via a demographic survey, interviews, artifacts, and a researcher journal. The data was analyzed using first-cycle codes and coding followed by second-cycle coding with pattern codes (Miles, Huberman, & Saldaña, 2014). The findings from this study will inform the development of a framework for Maker Education in independent schools (9-12) and contribute to the growing body of scholarship about Maker Education in K-12 education. Several themes emerged from the participants: 1) why the makerspace was created; 2) the need for a Community Space; 3) novelty and attraction; 4) student engagement; 5) theory to practice; 6) interdisciplinary and multidisciplinary instruction; and 7) challenges. The data suggested the makerspaces were not created based on any specific pedagogical approach, but rather as a result of student interest in a particular piece of equipment. Additionally, there was a strong interest in providing additional opportunities for students within the makerspace, but several factors prevented its growth. Participants commonly mentioned issues such as scheduling, budget, and competing priorities.

DEDICATION

To my wife and partner, Jessika: I want to acknowledge the unwavering support you have provided me throughout this entire process. Your love, encouragement, and belief in me have been an anchor that has kept me grounded and motivated every step of the way.

To my writing group: I wouldn't have completed this work without your constant texts, emails and zoom meetings encouraging me to "get back to it". Thanks for being the crazy bunch of motivators that you are!

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Chapter 1

Introduction

In K-12 schools all around the world, there is a growing presence of Makerspaces, Hackerspaces, FabLabs, and Innovation Labs (Lou & Peek, 2016). Fundamentally, in their simplest form, all are environments dedicated to design, explore, and create (Davee et al., 2015). They provide a place for students to explore questions and collaborate with one another, all in a safe, creative environment that allows them to fail and iterate their design (Smay & Walker, 2015).

Makerspaces also became popular in the commercial world, seeking to provide a space to gather and collaborate and access to tools that were not generally accessible to the public. To meet this need, entrepreneurs established commercial makerspaces that gave users access to a wide variety of tools, along with instruction in their use, in exchange for a monthly fee. TechShop, one example, opened in 2006 and there were several locations in major US cities, including Pittsburgh, before shutting down in 2017. In addition to giving people a place to work on leisure-time interests, workspaces like these have been instrumental in the development of new product ideas and small business ventures.

Statement of the Problem

As makerspaces became more popular in educational settings there remains a dearth of empirical research on these learning environments (Sheridan & Halverson, 2014). While articles on best practices for creating a makerspace can be found readily available on the internet, there is no one-size-fits-all solution. In truth, repurposing or building a new space and filling it with the latest technology might not align with the current needs of the students, faculty and school. In my own experience, the makerspace was designed before conversations regarding pedagogy and learning goals were discussed. I was fortunate to be able to choose and order the bulk of the equipment but there was little time to discuss why the independent school was implementing a makerspace, how it was going to support learning and if it was intended to integrate across disciplines to augment existing curriculum. Are we putting the cart before the horse? In other words, do the pedagogical goals of the makerspace become a priority after the space is already outfitted with the latest technologies? If so, what challenges and opportunities does this pose for leaders who manage makerspaces? To explore this issue further, I am proposing a qualitative study that seeks to better understand the experiences and perspectives of directors in independent schools, grades 9-12 who manage makerspaces.

Purpose of This Study

This proposed qualitative study seeks to better understand the experiences of leaders of makerspaces and the development of maker education in Independent Schools, specifically in grades 9-12, and examine what I perceive to be an area of development in the process of implementing makerspaces. The pedagogical goal of the makerspace becomes a priority after the space is already outfitted with the latest technologies. However, it is important for the success of a makerspace to understand the why before the how. Why are we creating an environment that fosters curiosity, tinkering, and iterative learning (Kurti, Kurti & Fleming, 2014)? It is paramount to dive deeper into the how; past the latest equipment and trends and come up with innovative strategies that support existing curriculum and pedagogy. In what ways will the new space provide scaffolding for existing disciplines and what tools are best suited for that environment? Furthermore, how did the researcher and other leaders in the field develop robust and innovative curriculum in pre-existing spaces while building social capital between students and faculty? When I reference a leader or director of a makerspace, I mean any individual or individuals who are directly responsible for the day to day operation of the makerspace, developing curriculum for the makerspace and/or ordering equipment for the makerspace. My work as the director of a makerspace at an independent school, grades 9-12, offers me the ability to learn from leaders in the field who may be designing, implementing, and managing makerspaces centered around design thinking and learning-by-doing. The findings from this dissertation-in-practice will provide a framework for the implementation of a makerspace in an independent school setting. This research will also contribute to the conversations around best practices in the integration of maker education across disciplines.

The following research question will be examined: *What are the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and makerspaces?* More specifically, what challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 maker space? Also, how does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?

Significance of the Study

Despite the number of Makerspaces around the world increasing significantly (Lou & Peek, 2016), there is very little written about educational makerspaces and the integration of non-STEM subjects despite the apparent ability of constructivism to be equally applied to any subject area (Olusegun, 2015). Existing literature focuses on the need to shift or disrupt common practices in education, to move away from the factory model of classrooms and testing by developing students with complex levels of creativity (Robinson & Aronica, 2015). However, there is an opportunity to research the perspectives and experiences of leaders in makerspaces to evaluate current trends that occur in these environments and best practices moving forward.

Dr. Susan Crichton from the Innovative Learning Centre warns that:

> Unless educators intentionally pursue innovation and creativity as learning outcomes, makerspaces will become “imagination ghettos” where issues of access, purpose, and ownership resemble those common in the cloistered environments of early computer labs and many of today’s shops and students are tasked with cookie cutter activities and trivial projects to complete (Crichton & Carter, 2015, p.3).

Research on how learning happens in makerspaces is still emerging (Lindstrom, Thompson & Schmidt-Crawford, 2017) and while the bulk of the research explores the origins of the maker mindset (González González & Arias, Luis, 2018) and the importance of makerspaces in educational settings (Halverson & Sheridan, 2014) few explore the unique and shared experience from those leaders in the field who create, manage and develop content for these types of spaces. This study will contribute to the growing research on makerspaces in the educational setting, specifically in independent schools for grades 9-12. I hope it will provide some insight for educational leaders as they seek to implement their own makerspaces and contribute to a framework of best practices gleaned from the combined experience of leaders in the field.

Definition of Terms

For clarification, the important terms used in this study have been defined.

The following terms are:

Collaborative learning. Collaborative learning is a pedagogical approach to teaching and learning that highlights the role of a group of students and the process of working together to solve a problem or complete a task. This approach focuses on an individual's effort to support the broader team and the process the group goes through to accomplish its purpose (Laal & Laal, 2012; Loveland & Dunn, 2014).

Critical thinking. Critical thinking is the process students undergo to organize their thinking to distinguish between ideas and decide about how to move forward. It includes the ability to determine relationships between concepts, analysis of available information, and consideration of other perspectives to make the best decision about what to do (Kraft, Schmiesing, & Phillips, 2016; Vieira & Tenreiro-Vieira, 2016)

Design thinking. Design thinking takes place when students are given a problem or introduced to a need and construct a solution to meet it (Berland, Steingut, & Ko, 2014; Brown, 2008).

Engineering design process. The engineering design process is a cyclical process used in engineering challenges. Steps include defining a problem, imagining possible solutions, and planning, creating, and improving the design to meet a need (Museum of Science, Boston, n.d.).

Making. Making is the process of creating, forming, or putting together.

Makers. Makers are the people who use tools and resources to make or create.

Makerspaces. A makerspace is a collaborative workspace for making, learning, exploring, and sharing.

Maker Movement. The maker movement is a cultural trend that places value on an individual's ability to be a creator of things, not just a consumer of things.

Maker Education. Maker Education brings the Maker movement into the school setting to provide students with hands-on learning that promotes creativity, thoughtfulness, and sharing ideas.

Student-centered learning. Student-centered learning is a pedagogical approach to teaching and learning that emphasizes a student's "active responsibility for learning, proactive management of learning experience, independent knowledge construction" and deemphasizes the teacher as a dispenser of knowledge (McCabe & O'Connor, 2014, p. 351).

Limitations and Delimitations

The goal of this study was to compare experiences of directors in makerspaces in independent schools grades 9-12. One possible limitation of this study was that I only inquired into the perspectives of the leaders of makerspaces in independent schools, grades 9-12. The perspectives and experiences of students, teachers and administrators were not considered nor were experiences of makerspace leaders in public schools. Future/further research can include these other populations. Another limitation was the lack of consideration of public schools or independent PK-8 schools/divisions; though makerspaces exist for these populations, there are student developmental and administrative differences that make them poor analogues.

Delimitations were chosen due to my own experience working at a K-12 school, but with a significant emphasis on grades 9-12. Despite having access to Makerspace professionals in a variety of different settings (museums, libraries, and industry tech hubs) I chose to narrow my focus on leaders in the field that aligned closely to mine. As a scholarly practitioner in the field of Technology and Makerspaces, I seek to blend my professional skills and knowledge to name, frame, and solve problems of practice. Additionally, this research will seek to resolve problems of practice by collaborating with key stakeholders and disseminating solutions in multiple ways (Perry, 2015).

Chapter 2

Introduction to Literature Review

A review of the literature related to Makerspaces and their implementation in grades 9-12 is the focus of this chapter. The history of the maker movement, its roots in Piaget's constructivist learning theory, and Papert's constructionist derivative will be explored along with Dewey's theory of education. The history will conclude with modern pioneers in the field of maker education like Gary Stager and Sylvia Martinez. A discussion of why Makerspaces are valuable and the principles that scaffold the maker movement such as Design Thinking, learning-by-doing and Project-based learning will follow. Finally, the physical design of the space and the equipment and who it will serve will be addressed.

Constructivist Framework

Makerspaces borrow heavily from several educational theories regarding the individualized nature and pace of learning supports provided to individuals as they progress through stages and develop cognitive schema (Hira, 2018). In its simplest form, constructivism claims that meaning is something to be made, that learners actively construct their own knowledge and meaning from their experiences (Fosnot, 1996; Steffe & Gale, 1995). Constructivism has roots in psychology and philosophy that extend back through many years and researchers, including Piaget, Dewey, Hegel, Kant, Vygotsky, and Bruner.

Piaget (1956) proposes that learners gain knowledge through engaging in personally meaningful experiences. Knowledge is not something that can be given. Rather, knowledge is constructed by learners through an active, mental process of development; learners are the builders and creators of meaning and knowledge (Gray, 1997). Constructivist Pedagogy is the assemblage of the various principles of different constructivist thought and disciplines to create a foundation that states (Dolittle, 1999):

1. Learning should take place in authentic and real-world environments.
2. Learning should involve social negotiation and mediation.
3. Content and skills should be made relevant to the learner.
4. Content and skills should be understood within the framework of the learner's prior knowledge.
5. Students should be assessed formatively, serving to inform future learning experience.
6. Students should be encouraged to become self-regulatory, self-mediated, and self-aware.
7. Teachers serve primarily as guide and facilitators of learning, not instructors.
8. Teachers should provide for and encourage multiple perspectives and representations of content.

In recent years constructivist beliefs have been applied to teaching and learning in the classroom. Constructivist classrooms are structured so that learners are immersed in experiences within which they may engage in meaning-making inquiry, action, imagination, invention, interaction, hypothesizing, and personal reflection (Gray, 1997).

Constructionism Theory

Constructionism is a constructivist learning theory and a theory of instruction. Constructionism is connected with experiential learning and builds on some of the ideas of Jean Piaget. Developed by Seymour Papert, a protege of Piaget, Papert's seminal work, *Mindstorms; Children Computers, and Powerful Ideas* (1980) states that children should use computers as tools to create their own educational experience. What we now call constructionism, is the term Papert created as a play on the theory of constructivism as well as the words “to construct,” or “making.” It states that building knowledge occurs best through building things that are tangible and sharable (Ackerman et al., 2009). Constructionism asserts that constructivism occurs especially well when the learner is engaged in constructing something for others to see. This serves as an excellent model for maker education. Providing opportunities for our students to make and design with materials such as paper, tape, wood, fabric, etc., we not only embrace the maker movement, we can identify a learner’s personal mental structure to help them understand how things work. When actively creating their own education from first-hand experiences through play, testing, and exploring, students learn by doing, or constructivism. When students make models of ideas, tools for inquiry, or invent to learn, this is constructionism. In recent years there has been a resurgence of educational toys and microcomputers like the Raspberry Pi, Makey Makey, and the Arduino along with software like Scratch and Microsoft’s MakeCode that promote this type of inquiry in students of all ages. These various outlets for exploration are a fine example of the reality of constructionism. This is not a new concept. German educator Friedrich Wilhelm August Froebel, founder of the kindergarten, introduced a set of specially shaped geometric solids called "gifts" and foldable papers which he called "occupations" (Copley, 2010). Froebel's method is based upon open materials and projects and aligns with the makerspace ideology. Froebel is still considered one of the most influential educational reformers of the 19th century (Curtis, 2021).

John Dewey Theory of Learning by Doing or Inquiry-based Learning

John Dewey's reform of the educational system led to the first inquiry-based learning methods in the United States (Concept to the Classroom, 2004). Dewey's beliefs about democracy, community, and problem-solving, guided the development of his social and educational philosophies (Williams, 2017). He posited that schools and classrooms should be representative of real-life situations and that students should construct their own knowledge through personal meaning, rather than teacher-directed activities (Schiro, 2012). This inquiry-based learning approach emphasizes the student's role in the learning process. Students aren't just hearing or writing what they are learning. Instead, students get the chance to explore a topic more deeply and learn from their own first-hand experiences. This learning-by-doing ideology aligns directly with the maker mindset where learner knowledge is built by creating and interacting with physical objects (Kurti, Kurti & Fleming, 2014).

The History of Makerspaces, the Maker Movement and their value

It is not easy to outline a "brief" history of the origins of makerspaces as there are many contributing factors to consider (Davis, 2021). One could argue that making and makerspaces have existed since prehistoric humans made their first fire or crafted their first weapon.

Curiosity and tinkering were a way of controlling the environment and a vehicle for intellectual development (Martinez & Stager, 2013). From Leonardo da Vinci to the earliest philosophers and education reformists like Rousseau and Johann Pestalozzi, these inventors and thinkers were ahead of their time, believing in the power of observation over the prevailing classical writings. While Rousseau wrote about the natural abilities of children and the importance for them to freely develop in nature, Pestalozzi thought that learning resulted from the learner's first-hand experiences and self-activity (Martinez & Stager, 2013). This concept was later expanded upon by Piaget who formalized many of Maria Montessori and John Dewey's theories of education. Montessori education allows young children to engage in playful learning, which is a developmentally appropriate alternative to the traditional pedagogical methods that are often used with young children in classrooms today (Lillard, 2013). Dewey thought that schools and classrooms should be representative of real-life situations, allowing children to participate in learning activities interchangeably and flexibly in a variety of social settings (Dewey, 1938; Gutek, 2014). These examples of learning by doing eventually came to be known as whose fundamental theory implied that knowledge was the result of information being taught due to the learner making sense of the process internally (Martinez & Stager, 2013). The increased availability, and affordability of emergent technology and the ability to share knowledge online has provided "the latest evolutionary spurt in this facet of human development" (Martinez, 2019). Accessibility is the key to the popularity and success of the maker movement. Anyone with access to the internet can find tools, instructions, and ideas and share them to a robust community of DIYers, tinkerers and makers. Stager states that "The Maker Movement is a vehicle that will allow schools to be part of the necessary return to constructivist education. A movement that will allow students to be creative, innovative, independent, and technologically literate; not an "alternative" way to learn, but what modern learning should really look like (TED, 2014).

In 2005 Dale Dougherty, co-founder of O'Reilly Media, launched Make Magazine, a publication inspired by Popular Mechanics (Fernandez, 2015). One year later he is credited with launching the world's first Makerfaire in San Francisco. Makerfaire is primarily focused on showcasing makers who are exploring new forms and new technologies, but it soon began to feature innovation and experimentation across the spectrum of science, engineering art, performance, and craft. By 2017, over 190 independently produced "Mini Maker Faires" plus over 30 larger scale featured Maker Faires have taken place around the world, including Tokyo, Rome, Shenzhen, Taipei, Seoul, Paris, Berlin, Barcelona, Detroit, San Diego, Milwaukee, and Kansas City (Maker Faire, 2017).

Spencer and Juliani (2016) speak of a new digital divide, not between those who have access to technology and those that don't but rather a "Creative Chasm between those who passively consume and those who actively create." Makerspaces seek to bridge this divide. When students are thinking creatively, they are fully engaged in their learning (Juliani & Spencer, 2016). Learning by making, tinkering, and engineering is consistent with Piagetian theories (Martinez & Stager, 2013) but it is also further supported by Lev Vygotsky's sociocultural theory, and more specifically his theory on the zones of proximal development which state that learning occurs between what is already known and the level of potential development as determined (Vygotsky, 1978). Maker-centered learning is valuable because it develops creative confidence and a sense of agency. Students have the ability to creatively solve problems on their own or collaboratively with their peers (Hibbard, 2021).

Makerspaces Come to Schools

In 2003, Mike Eisenberg of the University of Colorado Boulder began to publish articles about the potential of personal fabrication to support constructivist learning in K-12 schools. He believed that these new technologies could vastly extend and reinvigorate the best traditions of student-driven design and construction (Eisenberg & Buechley, 2008). A few years later, Paulo Blikstein of Stanford University began working with K-12 schools to create makerspaces called the FabLab@Schools project. Part of this project involved creating a course for graduate students and teachers to design projects for the K-12 environment using a makerspace. His goal was to provide an environment where students could safely make, build, and share their creations (Blikstein, 2013). The environment was designed specifically to attract students attracted to engineering, but also students who just wanted to tinker and explore with technology they may not have been able to explore in the past.

Pedagogical Methods and the Impact on Student Learning in Makerspaces

Research on makerspaces is primarily anecdotal, focusing on the student experience within the makerspace. However, the success of a makerspace relies in part on the implementation and tools as well as how the teacher or manager effectively facilitates student learning (Duhaney, 2019). Makerspace facilitators utilize practices of student-centered learning, collaborative learning, project- and problem-based learning as well as engineering design and design thinking. Each of these roles require different skillsets and "the differences in the goals and intentions" of makerspaces impact the role of the educator in that setting (Ayar & Yalvac, 2016).

Makerspaces are “largely self-directed” (Curry, 2017, p. 201) allowing users to determine what they would like to create. Teachers and students work collaboratively to co-create a learning plan that best suits the needs of each individual learner. This **student-centered learning** approach is the foundation of most makerspaces. Allowing students to become responsible for their own learning requires teachers to step away from being a “sage on the stage” and becoming a ”guide on the side”. This shift in educational philosophy is key to creating a learning-centered environment as it requires ‘trust in students’ (Bain, 2004). This does not mean the teacher is no longer needed in the makerspace, but rather serves as a resource to the student and is available to facilitate while students decide on their own responses and solutions.

Makerspaces also encourage self-directed learning. Students are provided an environment that supports hands-on learning, inquiring, and discovering. Learners have the opportunity to take control of their own learning, driving all stages of the learning process. During self-directed activities, teachers play the role of facilitators and mentors and can give individualized guidance to students as they work independently (Beyer, 2016). Students also have the opportunity to take their learning as far as they choose, ultimately promoting a student-driven learning environment. Students can set their own goals, suggest their own tools, and develop their ideas for an audience of their own choosing, be it for a class, a blog or an Instructable. Students are more engaged and motivated when they have an audience for their work beyond the teacher. Having an authentic audience gives them purpose and context for their learning (Beyer, 2016).

In **collaborative learning** settings the teacher plays a crucial role in fostering student interaction by presenting a problem or task (Van Leeuwen et al. 2013). Collaborative learning takes place in the makerspace when two or more students work together to find a solution to a problem or task (Kaendler, Wiedmann, Rummel, & Spada, 2015). This type of small-group activity straddles the disciplines of problem-based learning and design thinking and can be encouraged in makerspaces when a teacher presents an activity or problem that requires students to work together and share each other's unique knowledge and perspective. Frequently, the process used to achieve the solution becomes more important than the solution itself. Ultimately, the goal is "not the solution itself, but joint knowledge building and each group member's individual learning gains" (Kaendler et al., 2015, p. 506).

Problem-solving and problem-based learning strategies can be employed by teachers as part of the instructional process in a makerspace. Hmelo-Silver and Barrows found in effective groups, learners (a) build upon each other's ideas, (b) understand the task that they are engaging in at the outset, (c) process the information they gather in their self-directed learning and (d) use the right sources at the right time (Hmelo-Silver & Barrows, 2006). It is the teacher's responsibility as facilitator for "orchestrating the discourse of the classroom" (Seeley, 2017, p. 33)

Makerspaces promote innovation through **Design Thinking**. Fundamentally, educational Makerspaces are used to engage students in hands-on exploration of concepts introduced in the classroom, but they lean heavily towards project-based problem-solving utilizing Design Thinking. Design Thinking is an iterative process in which the student (or designer) seeks to understand the user (or client), challenge assumptions, and redefine problems in an attempt to identify alternative strategies and solutions that might not be instantly apparent with our initial level of understanding (Dam & Siang, 2020). Although there are many variants of Design Thinking and its number of stages depending on the use and environment it is being applied in, they are all very similar. The five primary stages include: *Empathize* with your users, *define* your users needs, their problem and your insights, *ideate* by challenging assumptions and creating ideas for innovative solutions, *prototype* to start creating solutions and finally, *test* the solutions (Patel, 2022). Once the solutions are tested, the process begins anew with any adjustments or changes. Learners in makerspaces use similar, iterative design cycles to make meaning from the objects and tools they are exposed to. By hacking or taking apart existing artifacts, to redesign them into new forms students are participating in a cyclical process of design and learning which has been shown to be effective at increasing content knowledge and transfer of knowledge (Fortus et al, 2005). Makerspaces enable educators to offer complex problems to their students who in turn become more engaged. These problems inspire students to come up with creative and innovative solutions by thinking outside of the box, developing their ideas and crafting real, tangible solutions (KeepnTrack, 2018).

Peer-supported making and tinkering activities have shown positive effects in learning (Bers et al, 2018). In their study examining the design of early childhood makerspaces to explore positive technological development, Bers, Strawhacker and Vizner described two case studies that involved the design of two different early childhood makerspaces. They applied three approaches for thinking about the role of design of the learning environment: the maker movement, Reggio Emilia's Third Teacher approach, and the positive technological development (PTD) framework. The maker movement approach, within an educational makerspace emphasizes the learners as makers of their own projects by experimenting with "powerful ideas, tools, and literacies" (Blikstein, 2013, p.2). Makerspaces in early childhood settings enable children to develop individual agency, foster social interaction and enhance relational knowledge (Marsh et al, 2019). In addition, these peer-supported making and tinkering activities have been shown to have a positive effect on early childhood learners because of the potential for "feedback-in-practice" which contributes to deep and transformative learning (DiGiacomo and Guterrez, 2016). The Reggio Emilia approach aligns with makerspaces as it is also constructivist in nature, student-centered, promotes self-guided curriculum that uses self-directed, experiential learning in relationship-driven environments (Moss, 2018). It is often referred to the Third Teacher approach as the learning environment or classroom plays a key role in providing a space that is suited to the students interests and developmental stages. Finally, the Positive Technological Development (PTD) Framework developed by Bers (2012) suggests how to design learning environments that promotes positive behavior through the appropriate use of technology. Utilizing the three approaches, the authors suggest that the design elements of makerspaces can promote young children's learning through making. A measure of success for any makerspace is the frequency with which the space is used by its target audience (Bers et al, 2018). In the two case studies, observations of the children revealed two key findings. First, artifacts in the space stimulate community building. Children in both spaces were observed participating in collaborative making activities together. Sometimes this work inspired children in other classes after they saw shared or displayed projects. Secondly, children explore new ideas and express themselves using new tools and media. Makerspaces are unique learning spaces as they promote inventing, designing, and tinkering. Children in both spaces created projects that could be found in traditional pre-school classes, but were able to augment these creations with motors, sensors and microcomputers found in most makerspaces.

Additionally, Makerspaces encourage critical thinking skills. In their report on Makerspaces in Primary School Settings, Bower et al. (2018) sought to examine how maker activities using 3D design and printing technology could be pedagogically optimized. The researchers observed 31 makerspace lessons taught by 24 teachers. A wide range of topics were documented and then coded. The study used analysis strategies to identify and label common elements in the data and to structure codes from the data into first and second order themes such as creativity, design thinking and critical thinking. Critical thinking was most often observed when students had to think carefully about creative decisions, or about how to best solve a design challenge. The ability to analyze a problem, interpret the observed information and apply a solution (perhaps after some iteration) can enhance academic performance by allowing students to connect thought processes across multiple disciplines and understand concepts on a deeper level (KeepnTrack, 2018). The study reported that along with critical thinking, when participating in makerspace-based activities, students develop creativity, problem solving skills, inquiry capabilities, collaborative skills, reflective learning capabilities and resilience (Bower et al, 2018).

While research is beginning to emerge regarding makerspaces and maker education in grades K-12, there is little written regarding perceptions and experiences of leaders in the field. Many articles exist on how to build a physical space and their benefits. Shannon Welbourn (2019) shares her own experience being introduced to makerspaces in her book The Making of a Makerspace: A Handbook on Getting Started, and offers a written guide of suggestions on how to create a similar, engaging environment. She reminds us that "the most important thing when getting started is to personalize your makerspace to meet the needs of your students." (Welbourn, 2019). Progressive educators and researchers have been talking for decades about the role of making in learning (Halverson, Erica & Sheridan, Kimberly, 2014). They posit that it is evident that learning is occurring, referencing Martinez & Stager who credit Seymour Papert as "the father of the maker movement" (Martinez and Stager, 2013). Sheridan continues her research in another study and states (Sheridan. Halverson, Brahms, Litts, Jacobs-Priebe & Owens, (2014):

that Learning in each of these spaces is deeply embedded in the experience of making. These spaces value the process involved in making—in tinkering, in figuring things out, in playing with materials and tools.

Further research is emerging on the rise of makerspaces in libraries and other learning environments. Kafai, Fields, and Searle (2014) discuss how informal learning settings are playing an important role in diversifying the maker movement by making tools, materials, and processes more readily available to people who may not initially self-identify as makers. Harron and Hughes (2018) conducted a qualitative study to determine the purpose of educational makerspaces. The authors conducted interviews with participants who led K-12 makerspaces to find out how their makerspace began, how they taught in the makerspace, the resources necessary to sustain the makerspace, and what they thought their makerspace would be like in the future. Six major themes emerged from the data in this study, including "making school more meaningful and relevant, preparing students for the future, creating an inclusive environment, developing student capacity for failure, showcasing the school campus, and helping students become creators instead of consumers" (Harron & Hughes, 2018, p. 259). Kelli Duhaney (2019) conducted a qualitative, phenomenological study that focused on the roles and responsibilities of makerspace educators. Five themes emerged from her data framed by the practices of student-centered learning, collaborative learning, problem-based learning and engineering design: (a) The makerspace teacher is a planner; (b) the makerspace teacher facilitates a student-centered learning environment; (c) the makerspace teacher mentors students as they solve problems; (d) the makerspace teacher provides knowledge; and (e) the makerspace teacher provides resources to students as they learn in makerspaces (Duhaney, 2019).

There is less research and fewer resources related to reconciling the informal learning that takes place in makerspaces with the formal objectives of the school. In other words, there is ample evidence of the potential learning benefits offered by makerspaces, it is less evident how this translates to practical implementation in schools (Salisbury & Nichols, 2020). Incorporating makerspaces into existing curricula can be a complex task, as it requires integrating hands-on, project-based learning into traditional classroom instruction. Educators may need to carefully consider how makerspace activities align with learning objectives and ensure that they are integrated in a way that supports, rather than disrupts, the broader curriculum. The success of makerspaces ultimately depends on the quality of the learning experiences that they facilitate. Even if a makerspace is well-equipped with the latest tools and technologies, if the learning experiences are not engaging, relevant, and meaningful for students, then the space itself may not be effective in promoting learning. Getting this backward is among the most common pitfalls educators face when bringing making into schools (Salisbury & Nichols, 2020). Breanne K. Litts (2015) highlighted three key convergences of learning by making: 1) learning is about building relationships with tools and people; 2) making is a way to learn; 3) producing external artifacts is evidence for learning. Learning by relationship building is not a new concept. Papert (1980) explains that, as learners build relationships with tools, they are also building relationships with knowledge. As students are faced with design challenges or projects and tasks from their instructor, they form relationships with the equipment in the makerspace as they determine the best tool to achieve the appropriate outcome. Making as a way to learn brings us back to the roots of the constructionist learning theory where knowledge-building and meaning-making are iterative, cyclical design processes. The cyclical nature of design has shown to be effective at increasing content knowledge and transfer of knowledge (Fortus, Krajcik, Dershimer, Marx, &

Mamlok-Naaman, 2005). Litts (2015) points to the framework of multiliteracies for an explanation of how learners in makerspaces iteratively make meaning: makerspaces are full of a distinctive blend of "available resources" with which members "redesign" and hack to churn out new forms of media and, thus, fresh ways in which they can make meaning. The framework of multiliteracies was developed by the New London Group in 1996 as a response to the changing nature of communication in the digital age. The framework emphasizes the importance of literacy in a variety of forms, including not only traditional text-based literacy but also visual, digital, and multimodal literacies. The emergence of new, affordable microcomputers like the Arduino and robots like Birdbrains Hummingbird kit can provide an engaging and interactive way for individuals to learn about electronics, coding, and robotics. These kits are designed to be easy to use and accessible to people with a range of skill levels, including those with no prior experience. Litts (2015) posits that these technologies can be tools that support relational knowledge and literacy practices to enhance these design literacies. Ultimately, the process of building and programming a hummingbird robot or an Arduino microprocessor can provide an enjoyable and educational experience that fosters technical skills, critical thinking, and creativity, but also fosters multimodal literacies like coding, robotics, and electronics. Papert (1993) stated that constructing external artifacts allows a learner to explore an idea more deeply. Furthermore, according to constructionism the making of the artifact is the learning process, and the artifact itself embodies the learning that happened. In makerspaces, learners are encouraged to explore and experiment with materials and technologies to create tangible artifacts that provide evidence of their learning. Through the act of making, learners not only develop skills and knowledge related to specific content areas, but they also develop skills related to problem-solving, critical thinking, creativity, and collaboration.

The Physical Design of Makerspaces

Maker classrooms are active classrooms (Stager & Martinez, 2013). It is important to ask the right questions before designing a Makerspace. Too often than not schools will convert an empty classroom and fill it with traditional showpieces: 3D Printers, laser cutter/engraver, a vinyl cutter and an assortment of hand tools without much thought to who the space will serve. What grade levels will your space target? An elementary school makerspace might not benefit from the same type of equipment that would typically go in one designed for high school students. Instead, low-cost, low-tech solutions might be sufficient. What is the experience you are trying to create and who will lead it? A simple and relatively unadorned makerspace with an electric atmosphere of learning will invariably succeed whereas a fully instrumented, equipment-rich space lacking that same spirit is doomed to fail (Kurti, Kurti & Fleming, 2013). Loris Malaguzzi coined the concept of the environment as a "third teacher". Some Makerspaces have dedicated personnel to manage the space and equipment. These professionals can have a variety of backgrounds. Are they educators designing set curriculum for the space or are they working with other teachers to integrate existing material? These "spacemakers" must be resourceful, failure tolerant, collaborative, and always learning themselves, living out the principles and ethics of the makerspace in front of the students (Kurti, Kurti & Fleming, 2013). What are the learning goals and outcomes you want to achieve in Makerspace? Are they aligned with the school's mission or are they dedicated spaces for intrinsic motivation and/or unstructured activity. It is also important to apply the principles of universal design to ensure the spaces, equipment, and community are accessible to as many individuals as possible. Universal design encourages the design of space, products and practices for people with a broad range of abilities, ages, learning styles, and other characteristics (Access Engineering, 2015). Finally, is there enough storage space? Tools, cardboard, wood, and half-finished projects take up space and a makerspace can quickly become cluttered. Organized storage space for materials and supplies is necessary so users can easily find what they need for their projects as well as an area to keep their projects safe as they work on them.

Conclusion

Makerspaces are innovative learning environments that offer students the opportunity to engage in hands-on, project-based learning and experimentation. They typically provide access to a variety of tools and materials, such as 3D printers, laser cutters, and electronics components, as well as guidance and support from mentors or educators. Makerspaces are appearing in independent schools all over the country and the maker movement has gained popularity all over the world. Their core ideology is deeply rooted in Piagetian theory while borrowing heavily from educational theories by Papert, Dewey and Vygotsky. Typically guided by their own intrinsic motivation, students regularly apply the design thinking process to tinker, hack, create, and problem-solve. There are many types of makerspaces, some more high-tech than others, but they all share the common traits of environments where students can engage in both structured and unstructured activities, in a hands-on capacity that promotes learning-by-doing. While makerspaces have the potential to impact learning in powerful ways, they are not always designed with curricular goals in mind. This can sometimes make it challenging for educators to integrate makerspaces into their lesson plans and ensure that students are receiving the maximum benefit from engaging in makerspace activities.

Chapter 3

Methodology

I employed a qualitative, phenomenological approach as framed by Irving Seidman (2006). The purpose of qualitative research is to evaluate and describe areas in which little is known about the topic being explored (Kerr, Nixon, & Wilde, 2010). In its broadest sense, qualitative research consists of a systematic approach that answers questions, collects evidence, and produces findings (Marshall & Rossman, 2010). Researchers have flexibility in both conducting the interviews and interpreting the experiences of the participants (Yanow & Tsoukas, 2009). This study is phenomenological in nature as it explores my experience as well as the participants' individual experiences (Ary, Jacobs, Razavieh & Sorenson, 2006). The primary way a researcher can investigate an educational organization, institution, or process is through the experience of the individual people who make up the organization (Seidman, 2006). This research design used semi-structured recorded interviews for data collection, and phenomenological techniques for analysis. This chapter discusses the methodology used to discover and examine the lived experiences of each individual participant as well as my own experience as a director of an educational makerspace. The study used the three-interview series proposed by Seidman as a framework to examine the focused life history of the participants, the details of their lived experience, and a reflection upon the meaning of the experience.

The following questions guided the study:

Q1. What are the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and makerspaces? More specifically, what challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 maker space?

Q2: How does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?

Research Design

This qualitative research study examined the attitude and experiences of leaders in independent schools, grades 9-12 responsible for creating or managing makerspaces. The design focused on the participants' experience, places it in context, and reflects upon its meaning (Seidman, 2006).

I hoped to identify themes and patterns that would illustrate similarities and differences in the attitudes and lived experiences of the participants. The study seeks to provide a framework for Maker Education in Independent Schools, specifically in grades 9-12, and address what I anticipate will emerge as a weakness in the process of creating makerspaces. Ultimately, it is important for the success of a makerspace to understand the why before the how. Why are we creating an environment that fosters curiosity, tinkering, and iterative learning (Kurti, Kurti & Fleming, 2014)? Is it enough to fill a room with the latest equipment and trends or are innovation leaders sought to come up with innovative strategies that support existing curriculum and pedagogy? In what ways will the new space integrate strategies into existing disciplines; and what tools are best suited for that environment? Finally, how did I (and others) manage and maintain a makerspace, and provide a robust and innovative curriculum while building social capital between students and faculty?

A phenomenological approach focuses on the experience from the perspective of the individual and will highlight the process each leader underwent designing, implementing, and augmenting their environment (Groenewald, 2004). Further, employing this qualitative, phenomenological multiple-participant research design examined commonalities of experience amongst individuals who supervise makerspaces. These commonalities manifested themes and trends from the 9-12, independent makerspace leader experience.

The study follows a phenomenological framing and was conducted through content analysis of narrative interview data using inductive coding, informed by phenomenological design, as appropriate for a dissertation-in-practice. A dissertation-in-practice serves to address a specific problem of practice. Therefore, the sample was selected within the context of the environment I am working in, grades 9-12 in the independent school. An independent or private school for the purpose of this study is defined as a type of educational institution that is not run by the government, but rather by a private organization, individual, or group of individuals. These schools are usually funded by tuition fees, donations, and endowments, rather than public funding. Private schools often have more control over their curriculum, teaching methods, and policies than public schools, and may offer specialized programs, such as Montessori, Waldorf, or International Baccalaureate (IB). They may also have smaller class sizes, more individual attention for students, and more opportunities for extracurricular activities. Independent or private schools may be co-educational or single-sex, and they may serve students from preschool through high school. Admission to these schools is often competitive and may require an application, entrance exam, and/or an interview.

While the same problem of practice may exist in public schools, there are fundamental differences between the two. Because they do not use public funds, private schools can expand their programs and curriculum without public funding regulations. Private schools are not obligated to adhere to legislative mandates in programming, funding, and services. This freedom allows private schools to adopt a curriculum and standards that expand beyond the limitations placed upon public schools. Due to the phenomenological nature of this study, it was important to limit the sample of participants to individuals who worked in similar environments. The dissertation-in-practice is more suited to those in professional careers rather than traditional-based research fields. Ultimately, the results of this research will guide other independent schools as they begin to think about implementing a makerspace. Makerspaces should be as unique as the students they are being designed for and should not be looked at as a one model serves all solution.

This qualitative study also included the use of a demographic information profile sheet to interpret and gather information about the participants.

Sampling, Participants, and Setting

The population sample is leaders of makerspaces in independent schools, grades 9-12. Sampling is an integral part of all research designs (Abrams, 2010). A sample represents the population that is being studied, and the researcher can draw a valid conclusion about the larger group (Kerr et al., 2010). Steinhauser and Barroso (2009) state that compared to quantitative research sample sizes, qualitative research sample sizes are normally smaller. For the purpose of this study, a nonrandom, purposive sample method was implemented, and participants were solicited from two listservs whose members consist of innovators and instructors in makerspaces and technology leaders. The target sample size was between 6-20 individuals. Different textbooks suggest different-sized samples for phenomenological research, however, a sample of between 6 and 20 individuals is sufficient (Ellis, 2016). Once a call for participants was initiated, I filtered results to only makerspace leaders in independent schools, grades 9-12. Seven (7) participants met the criteria, but two ultimately dropped out, resulting in a sample of five (5) participants. All interviews were conducted online via Zoom and take place over a period of three weeks. All interviews were audio-recorded and transcribed in preparation for the data analysis process.

Methods of Data Collection

The instruments for the data collection are a demographic form (Appendix A), interview guide (Appendix B), and the semi-structured interview questions (Appendix B). Phenomenological research consists of lengthy and personal interviews in order to explore the perception of the participants (Cooper, Fleischer, & Cotton, 2012). The study utilized the three-interview series model suggested by Schuman to Seidman and Sullivan in the 1970s. Each interview followed a 90-minute format to provide ample time for participants to reconstruct their experience, put it in the context of their lives, and reflect upon its meaning. An hour has the potential of having participants "watching the clock", an open-ended time period can produce undue anxiety, whereas a 90-minute period is long enough to make the participant feel they are being taken seriously (Seidman, 2006). The interviews were semi-structured, and the questions were open-ended, covering: biographical/demographical data, purpose, and goals of the makerspace, curriculum goals and/or integration, pedagogical rationale for the makerspace and equipment choice, and physical design of the makerspace.

Data Collection Process

The primary area of identifying potential participants for this study was through two listservs. After IRB granted approval, I posted a message calling for participants on the Independent School Educators Listserv (ISED-L) hosted by the Association of Technology Leaders in Independent Schools (ATLIS) and on the Google Group, Resources for K-12 Fab Labs and Makerspaces. While the ISED-L listserv primarily has a global target population of independent school professionals, the Resources for K-12 Fab Labs and Makerspaces has a global target population of educators, school administrators, librarians, vendors, and private entities in the maker field. All potential participants were instructed to click on a link leading to a simple form that explained the study as well as an initial screening to determine if the participant serves as a leader in a makerspace at an independent school serving students in grades 9 - 12. Those that met the inclusion criteria were contacted by email that described the methodology, purpose, expected time commitment, and offered an opportunity to ask any questions. A link to a Calendly schedule was provided along with the demographic and informed consent forms. All scheduled interviews were followed up via email verification. I followed the three-interview series model in collecting data. Seidman (2013) suggests using a three-part interview process to gain a comprehensive understanding of the participant's context and build a trusting relationship. The first interview serves to establish the participant's background and contextualize their experiences. The second interview enables the participant to recall and reconstruct the details of their experience within the established context. Finally, the third interview prompts the participant to reflect on the significance and meaning of their experience. By following this structured approach, researchers can gain a deeper understanding of the participant's experiences and perspectives. All sessions' video and audio were recorded via Zoom. Although each interview was scheduled for 90 minutes, open-ended questions may increase the likelihood of extended responses. The interview questions are comprehensive in nature and semi-structured to capture the attitude and lived experiences of the participants.

Demographic results and additional data were collected from a semi-structured interview guide. I conducted interviews one-on-one with each participant. The entire interview was recorded by Zoom. Seidman warns to respect the structure of the interview since it can be tempting to pursue the participant's lead especially if the information may be interesting, but the narrative may belong in a different interview. Forsaking the structure of the interview may erode the focus of each interview and the interviewer's sense of purpose (Seidman, 2006).

Interview Questions

Questions were asked in individual interviews to maintain consistency and to hold to the semi-structured interview process. The questions that were asked during the interviews are:

Interview 1: History and context

Describe your role at your institution.

Describe the timeline of the creation of the makerspace you lead/supervise/manage.

Who is the target user of the makerspace?

What do you hope happens when a user enters the makerspace?

Interview 2: Details of the experience

To what extent do you believe the makerspace is meeting the goals set at its creation.

How do campus constituencies use the space currently?

What are the current goals of the makerspace? What role did you play in the setting of those goals?

With regard to the physical space, is the capacity enough to meet demand? Do you have the equipment you need?

To what extent do you have the financial means to meet demand and goals?

Interview 3: Reflection

To what extent do you think your current role is aligned with what you were hired to do?

What future goals do you have for the makerspace?

In what ways does maker education and your role with the makerspace inform your teaching? How are you different now that you were before you had this role? How is the institution different than it was before the opening of the makerspace?

Table 1

Timeline of Data Sources

Action	Time Frame
Request for participants	Three days after IRB Approval
Demographic Information	Day 4
Interview 1	Week 1
Interview 2	Week 2
Interview 3	Week 3
Artifacts	Throughout Interviews
Researcher's Journal	Throughout Study

Data Analysis and Interpretation Strategies

The purpose of qualitative analysis is to collect, evaluate, interpret, discover connections, and generate themes (Bradley et al., 2007). In phenomenological research, the researcher listens to and transcribes verbal description interviews. Transcripts of the interviews done over Zoom were automatically transcribed utilizing Rev, an online transcription service. The transcriptions were checked for accuracy and themes were developed in order to organize the data. A combination of content and narrative analysis was applied using the software Thematic, to analyze patterns and themes in the transcripts. Content analysis refers to the categorization, tagging, and thematic analysis of qualitative data (Medelyan, 2021). Narrative Analysis seeks to understand how research participants construct stories and narratives from their own personal experiences. There is a dual layer of interpretation in narrative analysis. First, the research participants interpret their own lives through narrative. Then the researcher interprets the construction of that narrative (Riessman, 1993). In the third interview, the researcher asks participants to reflect on the meaning of the experience that we explored in interview two (Seidman, 2006).

Thematic coding is a form of qualitative analysis which involves recording or identifying passages of text or images that are linked by a common theme or idea allowing the researcher to index the text into categories and therefore establish a "framework of thematic ideas about it" (Gibbs, 2007). A process of manual, inductive coding was applied to the digital transcripts to see what themes developed. This form of open coding starts from scratch and creates codes based on the qualitative data itself (Medelyan, 2021). The purpose of using the inductive approach is to use raw data to derive concepts or themes through the researcher's interpretation of the raw data (Thomas, 2006). Once manual coding was complete, the transcripts were imported into Thematic for inductive coding and the two results were compared and combined into a hierarchical coding frame (Medelyan, 2021). Hierarchical frames organize codes based on how they relate to one another. This allowed for different levels of granularity in my coding, so I could better organize common themes that surfaced from the interviews.

I chose inductive coding because I did not have a predefined set of codes. The codes were created based on the qualitative data itself, arising directly from the transcribed interviews. Inductive coding begins with close readings of text and consideration of the multiple meanings that are inherent in the text (Thomas, 2006). The text will first be prepared in a common, consistent format before being read in detail by the researcher to become familiar with the content. Two levels of categories or themes are then identified. The first, or upper level, were derived from the research aims while the lower level or specific categories were derived from multiple readings of the raw data or transcript (Thomas, 2006). A theme developed when two or more participants had any overlapping coding. Each category was segmented into subtopics which also included contradictory points of view and any new insights that became apparent as transcripts were reread. Independent coding was utilized to assess the trustworthiness of the data analysis for consistency. Finally, the data analysis was compared with the automatic coding functionality of the Thematic software. Thematic coding, also called thematic analysis, is a type of qualitative data analysis that finds themes in text by analyzing the meaning of words and sentence structure (Medelyan, 2021). Findings will be reported from the inductive analysis by utilizing the top-level categories as the main headings in the findings, with specific categories as subheadings (Thomas, 2006).

In addition, I maintained a journal throughout the study. Journal writing has a long and reliable history in the Arts and Humanities, and qualitative researchers may learn a great deal from this activity (Janesick, 1998). As the study is phenomenological in nature, my own experience in managing a makerspace can be accounted for and addressed as similarities and differences are made apparent from the interview transcripts. Janesick provides four points of reasoning for maintaining a journal:

1. Refine the understanding of the role of the researcher through reflection and writing, much like an artist might do.

2. Refine the understanding of the responses of participants in the study, much like a physician or health care worker might do.

3. Use a journal as an interactive tool of communication between the researcher and participants in the study, as a type of interdisciplinary triangulation of data.

4. View journal writing as a type of connoisseurship by which individuals become connoisseurs of their own thinking and reflection patterns and indeed their own understanding of their work as qualitative researchers.

My own reflective data contained data obtained by observation, interviews, and informal conversations. The data was recorded on my iPad Pro utilizing OneNote as my journal software and my Apple Pencil so I could transcribe directly onto the tablet. OneNote provides organizational tools so I could parse out demographic material such as name, age, location along with the date of the interview. Additionally, I wrote down patterns I discovered across interviews, resources brought up during interviews, and ideas shared. Annink (2017) suggests journaling before data collection, while contacting participants, after the first interview, during interviews, and after interviews. Because I obviously needed to focus on the participant and the conversation, I took minimal notes during the interview, instead, focusing on most of my notetaking directly after the interview and/or while watching the recording. Journaling allowed me to reference body language, mood, and tonal inflection/intonation and search for commonalities and indicators of when or why they occurred.

Table 2

Timeline of Data Analysis

Artifact	Process	Tool
Interview 1 (week 1)	Journaling before interview Transcribed and coded over the weekend Journaling after the interview	Researcher's journal Thematic
Interview 2 (week 2)	Journaling before interview Transcribed and coded over the weekend Journaling after the interview	Researcher's journal Thematic
Interview 3 (week 3)	Journaling before interview Transcribed and coded over the weekend Journaling after the interview	Researcher's journal Thematic

Trustworthiness

The interaction between data-gatherers and the participants is inherent in the nature of interviewing (Seidman, 2006). However, as much as the researcher strives to make the meaning derived from the interview a function of the participant's reflection, the researcher must recognize that the meaning is, to some degree, also a function of the participant's interaction with the researcher (Seidman, 2006). Validity and reliability are generally accepted among quantitative researchers; however, qualitative researchers disagree with the epistemological assumptions underlying the notion of validity (Seidman, 2006). Validity determines the true measure of the study and how truthful the results are. However, there are many factors that can alter those results: the rapport between the interviewer and the participant, the current mood of the interviewer and the participant, or even the way the questions are framed (tone, biases, etc).

The three-interview structure provides structures that promote the trustworthiness of the participants' narratives. Trustworthiness establishes credibility, transferability, confirmability, and dependability (Shenton, 2004). Interviewing participants over the course of 1 to 3 weeks can account for idiosyncratic days and allows the researcher to check for consistency. Furthermore, this transferability occurs when the findings are generalized to other settings, populations, and context (Steinhauser & Barroso, 2009; Trochim, 2006). By interviewing a number of participants, the researcher can also check for commonalities and connections between the collected experiences. Determining reliability for research using unstructured interviews is managed internally as data accrue, and the similarity between data from different participants is observed (Morse, 2015). The internal validity of this study was increased through triangulation and member checking. Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena (Patton, 1999). Member checking was used as initial findings from the study were shared with participants.

Ethical Considerations

Researchers are required to pay attention to ethical considerations, such as privacy, anonymity, confidentiality, and informed consent (Vivar et al., 2007). Prior to conducting the one-on-one interviews, informed consent forms were distributed to each participant which were completed and signed. The informed consent form provided the participants with written information about the study, and participants had the opportunity to ask questions and express any issues or concerns prior to signing the informed consent forms (Vivar et al., 2007). In addition, the informed consent form informed participants that they are under no obligations to participate in the study and could withdraw without penalty at any time. The informed consent form addressed the possible benefits of the study as well as the risk involved. Although this study should be deemed to have minimal risk, crisis intervention contact information was included. Participants had the right to review and withhold interview material. The consent information was reviewed with the participants before each interview and participants were reminded that the interview was being recorded. Participants were given access to the video recording and to the transcripts if they requested them. At the start of each subsequent interview, participants were reminded about the consent information and were provided with opportunities to ask questions and reaffirm their willingness to continue in the study (Seidman, 2006). No activities involving the participants commenced without completion of the informed consent form.

Chapter 4: Results

The purpose of this study was to better understand the experiences of directors/supervisors of makerspaces and the development of maker education in independent schools, specifically in grades 9-12, and examine what I perceive to be an area of development in the process of implementing makerspaces. A qualitative, phenomenological research method was most appropriate as studies that aim to understand perspectives and focus on experiences from the participant’s point of view are qualitative inquiries (Rudestam and Newton, 2007) and phenomenological in nature.

The following questions guided the study:

Q1. What are the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and makerspaces? More specifically, what challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 maker space?

Q2: How does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?

Data Collection

I selected participants who responded to the inquiry made on the two listservs outlined in Chapter 3. Seven participants responded and filled out the demographic questionnaire, but two never responded to the invitation to set up interview times. Five upper school educators who lead makerspaces participated in interviews for the study. All interviews were conducted over zoom and averaged approximately an hour long. Interviews were recorded by video and then transcribed utilizing a digital transcription service. The transcription was then rechecked manually for accuracy by the researcher.

Demographic Information

There were five participants who participated in three interviews. Four participants identified as cisgender males and one participant identified as cisgender female. All five of the participants identified as White or Caucasian. Four participants had advanced degrees and one participant had an undergraduate degree. The ages of the participants ranged from 35 to 57 years of age (M = 46.2). Three participants were classified as faculty, one participant was classified as an administrator and one participant was classified as a staff member. The experience level of the participants ranged from three to eight years (M = 5). Three participants worked at independent schools with more than 700 students, one participant worked at an independent school with 301-400 students, and one participant worked at an independent school with 201-300 students.

Participant Descriptions

To maintain confidentiality, each participant in the study was given a pseudonym. Descriptions of each participant are below.

Participant 1 - John is the Director of Technology for his institution. It is a senior-level, 12-month administrative role with supervisory responsibilities for a staff of three. John's primary responsibilities are for any sort of project management, long-range budgeting, and any kind of hardware and software implementation. He is also responsible for any level of software training including the student information system and databases. He is required to teach one class, but periodically teaches additional enrichment classes based on availability and interest. John was responsible for the creation of his Makerspace which initially started from a single CNC router on a table in his office. Eventually, due to noise, the CNC router was moved to a storage room which was cleaned out and began to be utilized for an engineering class taught by a member of the science department. As student interest grew, John petitioned the school's parents association to fully renovate the room, and now his IT budget serves to cover operating costs. The space has been running for five years now.

Participant 2 - Cheryl is the Head Librarian at her institution. Her primary responsibilities are to run the library and do all the library tasks. Cheryl's school does not have a Director of Technology, but they do have an Ed Tech specialist who Cheryl assists. In 2014 she purchased a 3D Printer, and her Makerspace grew from there. Originally, it was placed in the corner of the library but as they reduced the number of books it became more centrally located. Currently, she has a number of 3D Printers, including one a student built, a Glowforge laser cutter/engraver, a silhouette vinyl cutter, Arduino microcomputers and Raspberry Pis, low cost, credit card sized computers, that can be signed out of the library. While she does not teach dedicated classes, Cheryl's main intent for the space was to provide resources for the students.

Participant 3 - Steven is the Makerspace Coordinator at his institution and teaches one elective course per day. Much of his time is spent coordinating with faculty across all content areas to assist them in implementing the makerspace into their curriculum. He is responsible for the maintenance of the equipment, organizing and cleaning the space, and assisting any classes that come to utilize the space including the middle school maker classes, engineering, robotics, and the school's senior STEM capstone class. Steven's school had an initial makerspace that was more of a prototype in the garage of the school's bus depot before a new STEM building was created six years ago. For the STEM building, equipment was bought based on the MIT FabLab model and Steven was hired to run the space after its conception.

Participant 4 - Frank is the Makerspace teacher at his institution and teaches six sections of an elective makerspace course. He is one of two instructors who share the space. The space is new and evolved from a large classroom that served as a lounge for students as well as a multipurpose space that had a few 3D printers and assorted tools. His initial role as a mathematics teacher shifted to include some STEM-based activities due to the access to the equipment and the interest of the students. Eventually, the school decided to create a dedicated space which was completed in September of 2022 and consists of 3D Printer(s), a laser cutter/engraver, a vinyl cutter/printer, Arduinos, welding equipment, and assorted woodshop tools.

Participant 5 - Paul is a co-instructor at his school's Makerspace. He also serves as the upper and middle school's technology specialist. Although he is considered staff, he assists the main instructor in teaching eight sections of the technology class and maintains the equipment. While the class is called a technology class it has transitioned into more of a maker or design class with the creation of a dedicated space. The makerspace was built in 2017 and came from a need to consolidate multiple classroom equipment into one repository. The space is modular and flexible with most tables and storage containers having wheels so that the room can be configured to the current need of the faculty and/or class.

Data Analysis

Data analysis began after the interviews with each participant were concluded and followed the steps outlined in Chapter 3.

Themes

As the participants responded to questions in the semi-structured interviews (Appendix B), themes emerged from the analysis, framed by the research questions:

Q1. What are the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and makerspaces? More specifically, what challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 maker space?

Q2: How does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?

Seven major themes emerged from the analysis of the interviews.

- **The why.** Why was the makerspace created? What need did it fill?
- **A Community space.** Most if not all the participants wanted their makerspace to be a welcoming and inclusive environment.

- **Novelty and attraction.** The lure or attraction of a makerspace and its equipment draws in naturally curious students and faculty.
- **Student engagement.** Makerspaces provide an environment that facilitates student engagement.
- **Theory to practice.** Makerspaces promote multiple theories to practice, including experiential learning, project-based learning, learning-by-doing, and others.
- **Interdisciplinary and multidisciplinary instruction.** The goal of most if not all makerspaces is to provide an environment for interdisciplinary and multidisciplinary instruction.
- **Challenges.** Several challenges were reported by the participants including time, lack of expertise, and intimidation by the technology.

Theme 1: The Why

A makerspace is a dedicated space within a school where students can engage in hands-on, project-based learning activities that encourage creativity, innovation, and problem-solving skills. There are a variety of reasons why a school may want to implement a makerspace. Many of the participants reported having some starter equipment like a 3D printer or a CNC router that captured students' attention. Others mentioned programmatic offerings that expanded as student interest grew which necessitated the creation of a dedicated space.

John's makerspace started as student interest in equipment grew. Initially, he had a small CNC Router in his office, which he eventually moved to a converted storage room in the basement of his school. At the time they were implementing the Duke Talent Identification Program which was an instructional program from Duke University where children from the surrounding area came for a weekend of hands-on activities. The head of the science department was also using the space for bridge-making in his engineering class so the need for a dedicated space came from this shared use.

Cheryl's space was a direct result of Make Magazine, the 3D Printing issue. She saw how affordable 3D printers had become and asked the then-head librarian if they could buy one and put it in the corner of the library. Eventually, they inherited more printers that needed repairs from other classrooms. When the head librarian retired, and Cheryl took up her mantle they were able to get rid of a few stacks of books and move the 3D printing area to a more prominent and visible location in the library.

While Steven's makerspace had its humble beginnings in the garage of the facilities department as a space where the engineering and robotics class could have room to work on projects, the creation of a dedicated building for STEM was the catalyst that created his position. The space was modeled after the MIT Fab Labs initiative that provided a consistent blueprint for centers of innovation and the tools needed for successful student projects. As student interest grew, more equipment was purchased.

Safety was the catalyst that moved the makerspace from an extra classroom to a dedicated building at Frank's school. After an inspector's visit highlighted some electrical and ventilation concerns, the administration recognized the value of the space and raised the money to create a dedicated space devoted to innovation and project-based learning.

A makerspace is a physical location that provides individuals with access to tools, equipment, and technology to support hands-on learning, creativity, and innovation. While the participants reported different catalysts for the creation of their spaces, they all shared similar narratives and goals that aligned with the additional benefits a makerspace could provide, such as promoting collaboration, building community, and providing opportunities for entrepreneurship.

Theme 2: Community space

A common thread reported by all participants was a goal to make their makerspace a community hub for innovation and exploration. While some started in storage rooms or out-of-the-way corners in a library, they quickly outgrew their space as student interest grew. John explained, "We wanted a centralized space. We wanted a community space where people could feel good about going in independently". For Cheryl, the library was a natural place to create a makerspace. The library was the social hub of the school and was constantly filled with students. "So, it was really just to bring this technology…because for me, the library, it's a place about providing resources for students that they can freely use. So, the 3D printers and all our makerspace equipment is just an extension of that."

Steven stated, "I want them (the students) to feel like they belong like it's welcoming to them. So, I want them to feel that there's something for them." While the space was designed with students in mind, it has been visited by constituencies throughout the campus. The admissions department uses it to make giveaways, facilities use it to create signage and they offer a series of professional development opportunities for outside groups. Boarding faculty also utilizes Frank's space as it offers after-hour opportunities. "All the teachers live here. They move here from the US, or Canada, or wherever, and they don't have a lot of tools or whatever." The makerspace has become a community workshop to tinker and utilize however they want. It was also important for him to make the room inviting and welcoming so he created an area with a couch where students could lounge and relax. "A comfortable seat often helps break down a little bit of a barrier. Giving them a space where they can just sit, talk and relax."

It was important to many of the participants to have a space that could accommodate more than just one class. Modular spaces with furniture and storage on wheels provided the most flexibility and allowed rooms to be configured to fit the student and teachers' needs. John explained:

> "We designed the space to where you could have more than one class in it. That was part of the goal. We wanted to make sure you could have a fourth-grade class and a high school class in the space at the same time, with more than one teacher teaching. I think we tried to design it at the beginning with teaching and learning in mind."

Steven indicated that the goal was to be as inclusive as possible, providing resources that would be interesting to multiple subsets of students. This goal to achieve a representative population gender-wise was at the forefront of Steven's mind when he inherited his makerspace. "We've made definite improvements in that over the six years, but we certainly are fighting an uphill battle, getting female students enrolled in our classes at the percentage that they are represented in the general population." Ultimately, it's about the students, and Steven stated his school was very explicit about the opportunities for students from "every background, sexuality, gender, whatever, to feel like it's a space where they can express themselves. Where they can become part of it."

A makerspace is a community space that provides individuals with access to various tools and resources to engage in creative and innovative projects. It is a collaborative environment where people with diverse interests and skill sets can come together to share ideas, learn new skills, and work on projects individually or together. While there were some differences in the amount of access to equipment and supervision required, all the participants recognized the value of a community space that students could work and relax in. Some of the makerspaces provided designated rooms for study and collaboration, others had couches where students could lounge and relax. Others served as the central, social hub of the school. Overall, a makerspace is a space where people can come together to learn, create, and build a sense of community around their shared interests and passions.

Theme 3: Novelty and attraction

The philosophy 'if you build it, they will come' was shared by several of the participants in the interviews. Sometimes it comes down to the shiny and new. Cheryl acknowledged that they focused on the equipment before the teaching and learning, but that if they were able to do it again, they would "start with what our students wanted. Because we were just like, 'This seems cool. Let's try it.' And at the time, there were lots of lists of, 'What do you put in a Makerspace'." Most shared the goal that if students were exposed to the technology it would draw upon their natural curiosity to explore, tinker, and create. "At the bottom level, it's exposure." shared Steven, "Then for those that are exposed, and they really enjoy the experience, they have opportunities to engage to whatever level they want all the way up to a highly focused program."

The goal of Cheryl's library makerspace was to "really give our students the opportunity to play with the technology, not necessarily in a class setting." She continued, "giving these kids access to this technology, that was suddenly becoming more affordable. And I found it exciting, and I thought that the kids would like it too. And it turned out to be true." Cheryl increased the draw to the equipment by providing displays explaining what things were and how they could be used. Students and faculty are not required to use it for school-based projects, which eased the trepidation of her faculty. Initially, they saw the space and equipment as a place where they could be creative, or make gifts for people, but frequently it transitioned into “a teacher saying ‘Oh, I want to use this in my class,’ and then we go from there.”

Makerspaces can serve as a recruitment tool for independent schools. While designed to serve the community, they have the potential to serve a subset of students that want to innovate, create, and solve real-world problems. Having a makerspace might be the differentiation that attracts students who want to become future engineers or entrepreneurs. While Frank stated that safety was the main reason his space moved from a storage room to a dedicated space, he also acknowledged they were trying to attract new students.

> “We were trying to attract students by offering some variety of courses that maybe our competing schools next door, or in other countries can’t offer or don’t. When parents come on tour and see the space they might say ‘This is the place I want to send my kid, because I just came from another school down the street, and they don’t have that, and my kid is into building and making Lego and figurines and armor’ or whatever, but that attracts them and maybe it’s a selling feature for one family or ten. It’s going to pay itself back.”

Emergent technologies are often new and exciting and can capture people's attention simply because they are something they have never seen or experienced before. Exposure to these technologies can pique student interest and foster creativity and the maker mindset. A significant number of the participants admitted to prioritizing the equipment over the pedagogical aspects, reasoning that students' exposure and interaction with the technology would ignite their innate inquisitiveness, leading them to investigate and experiment with its capabilities. Additionally, some recognized the makerspace's potential as a means of attracting students to the institution, potentially distinguishing it from other comparable schools that lack such a facility.

Theme 4: Engagement

Students are engaged in a makerspace through hands-on, project-based learning activities that allow them to experiment, design, build, and create. These activities may include using tools and materials to create prototypes, working with technology like 3D printers and microcontrollers, and collaborating with peers on problem-solving and innovation projects. The focus is on fostering creativity, critical thinking, and collaboration skills, rather than just following a set of instructions. Participants indicated that students were engaged in a variety of ways, ranging from time spent in the makerspace outside of the classroom to the projects they choose to do in the classroom. One of the main goals of Paul’s space is engagement. “I want all students engaged. With all of these hands-on activities, I want all the students to participate at some level. Selling them on the idea of designing something and have a vested interest in it.”.

Play and exploration are important to Cheryl. She noted, “Oh, the kids will play with this, and we’ll see where it goes.” While she admitted the majority of the equipment, she selected for her library was generated from lists across the internet that highlighted “must haves” for equipment. She added that it was important that they use the equipment to create original work rather than, for example, “just printing a 3D model from Thingiverse”, and she had good success teaching that the modeling is more important than the printer. Students are “trying to figure it out and come up with their design for whatever it is they’re working on, and it’s really…I mean, I’ve had kids get very excited.”

The idea of authentic learning is that students learn best when they are engaged in experiences that are tied to their interests and experiences, and when they are given opportunities to use what they have learned in new and challenging situations. Frank noted that he sees the value in the education the students are receiving. "It's more authentic. The kids are having more fun. They're learning like a sponge. They're not passive. They're way more active." Engaging students in the learning process through activities and questioning enhances critical thinking and problem-solving skills and often leads to improved student engagement and motivation.

Theme 5: Theory to Practice

Theory to practice refers to the process of taking abstract concepts, ideas, or principles from a theoretical framework and applying them in a practical or real-world setting. It involves translating theoretical knowledge into practical actions, strategies, or solutions to real-world problems. The goal is to bridge the gap between theory and practice and to demonstrate how theoretical concepts can be used to inform, guide, and improve practical decision-making and problem-solving. Throughout the interviews, a variety of theoretical frameworks for teaching were mentioned by the participants including experiential learning theory or learning by doing, design thinking, and project-based learning.

Makerspaces provide an environment that supports the use of multiple theoretical frameworks, and the resources teachers and students can use to create practical, real-world applications and artifacts.

John stated, "It's undeniable that things you do with your hands, you're going to retain better than things that you only learn, you know, auditorily or verbally, or, you know, whatever the more traditional mechanisms are". Steven indicated, "They are actually learning the content through the process of making the object." He continues, speaking on how the space provides them alternate ways to demonstrate learning and mastery of the content:

> "When they come here and get to get hands-on, I can't even count the number of times that the teacher was like, 'I can't believe how much of a leader so and so was…. or so and so just stepped up and took control of that.'.

Makerspaces are designed to appeal to different learning styles and show students another way that learning can take place. It has the potential to provide opportunities for a subset of students to shine. Steven said in terms of learning a makerspace activates different methods and modes of learning:

> "A project can be designed in a way that the resulting artifact clearly demonstrates that the students understood the content that was being taught, and the skills that the teacher wanted them to learn. I think that's great."

Design thinking is a problem-solving approach that emphasizes empathy for the users, experimentation, and iteration in the development of solutions (Alexander, 2023). It's a human-centered approach that starts with understanding the people for whom a product or service is being created, and then prototypes and iteratively improves the solution. The goal of design thinking is to create innovative and effective solutions to complex problems. John utilizes design thinking frequently in his instruction:

> "The design thinking model is particularly taught well in a makerspace. And then I think its applied well to any pedagogical experience. So, you can take an English paper and you can use design thinking methodology that you learned in the makerspace and make your paper better. You can take a design thinking methodology and use it to make, you know, shooting foul throws in basketball better."

Paul presents his students with the “Big Idea”, typically a problem to be solved, and then has the students utilize design thinking and the design cycle, a process for solving problems and creating new products or solutions. The design cycle is iterative, meaning that steps are repeated as necessary until a satisfactory solution is achieved. He stated. “You come to the space, and you utilize design thinking. What do we want to build? How does it connect? And then that forces you to do some more research.” Frank follows a similar path in his instruction. His makerspace courses are thematic. Students tackle a topic, like upcycling, and are given an outline that they can follow through the design process. While the project has a framework, students have the freedom to choose what they want to upcycle and how they plan to do it. Experiential learning is a form of learning that occurs through experience or doing (College of Charleston Libraries, 2022). It involves actively participating in a real-life situation, reflecting on the experience, and drawing insights and meaning from it. Although Frank’s space is mainly used for dedicated maker classes and community projects, his goal is to invite math and science classes into the space to do projects with more authentic, experiential learning. His experience as a math teacher assists him in directly informing his peer's teaching and helping them integrate across the curriculum.

Project-based learning is a teaching method where students learn by actively engaging in real-world and relevant projects (PowerSchool, 2023). In this approach, students work on a project over a period of time, applying and integrating their learning across different subject areas. Projects often involve problem-solving, critical thinking, and teamwork, and the outcome is a tangible product or presentation. The focus is on the process of learning rather than just the product, with students being encouraged to take ownership of their own learning. Frank’s makerspace evolved as its popularity increased. Three sections quickly became six sections, all heavily STEM-focused culminating in a final group project.

John recognized the potential of the makerspace to support multiple frameworks. He stated:

> "We wanted the classroom teachers to take their kids and integrate things, hands-on things like experiential learning, project-based learning, design-thinking, all those kinds of pedagogy principles into the makerspace. We want this to just be another mechanism of another pedagogic process for learning about content."

The ability of a makerspace to support multiple frameworks provides a safety net when independent schools pivot and change educational pedagogical practices. Cheryl is happy because the institution continues to embrace MakerEd despite several leadership changes which have caused administrators to see different roles for it. "For a while, they were really into design thinking and so they were trying to incorporate that into all of our meetings." Unfortunately, it was implemented badly school-wide (not through the makerspace), and "it didn't really last and they kind of moved on to the next thing".

A summary of the educational theories mentioned by the participants is below:

Table 3

Educational Theories

Theory	**Definition**	**Comment**
Design Thinking	Design thinking is a human-centered, user-centric way of approaching product design, innovation and problem-solving ("*What is design thinking? definition, history and advantages", 2023)*	"Design thinking played a huge role at our school for awhile. It was incorporated everywhere." "..then you come and do some design thinking. What do we want to build? How does it connect? And then it forces you to do

		some more research, which brings you back iteratively." "So we have an outline the kids kind of follow through the design thinking process, upcycling where they turn it into a final product."
Experiential learning	Experiential learning is an engaged learning process whereby students "learn by doing" and by reflecting on the experience ("Experiential learning", 2023).	"…inviting math and science classes into the space to do a project for their teacher. Kind of more authentic, experiential learning."
Project-based learning	Project Based Learning is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge ("What is PBL", 2023).	"The 3D printer changed the way they teach a little bit. They do more project-based learning in the conceptual physics classes" "The goal of the space is to have every student participate in project-based lessons in the makerspace, at least multiple times throughout their time at the school." "So I like to describe to a teacher, we can replace a test. So if it's a three day project that replaces your test. So your review day, your test day and your revision day becomes the project." "I would like for a wider range of that type of project. That develops more over time that maybe could…it's described a little bit more as a project-based learning model where you're actually using the building of the project as the method of delivering instruction."
Learning-by-doing	Learning-by-doing is a theory of education expounded by John Dewey. It is process whereby people make sense of their experiences, especially those experiences in which they actively engage in making things and exploring the world (Bruce & Bloch, 2012).	"We offer outside professional development, inviting groups to come in and do hands-on activities" "..they are actually learning the content through the process of making the object." "That was an original goal of mine. Get kids working with their hands, and building. Learning as they build and make things."

Makerspaces are collaborative workspaces where people can come together to create, learn, and explore using a variety of tools, equipment, and materials. These spaces have become popular in educational settings because they offer a unique environment for students to apply educational theory to practice, as they engage in hands-on, personalized, collaborative, project-based, and creative learning experiences.

Theme 6: Interdisciplinary/Multidisciplinary Instruction

Multidisciplinary refers to the integration of multiple disciplines or areas of study, but each discipline is still studied and approached as a distinct and separate field (Choi & Pak, 2006). Interdisciplinary, on the other hand, refers to the integration of multiple disciplines in a way that they overlap and inform one another, leading to a new, more comprehensive understanding or approach that transcends the individual disciplines. Interdisciplinary often involves collaboration and integration of knowledge, theories, and methods from various disciplines (Choi & Pak, 2006). In simpler terms, multidisciplinary is the combination of different fields, while interdisciplinary involves the integration of those fields to form a new, unified approach.

Cheryl has been relatively successful getting most of the departments to incorporate the makerspace into their lessons although she admits that most of those projects are one-offs, projects that are unique and not expected to be repeated with a specific goal and timeline. She is challenged by integrating the math department's content, ultimately, she says it comes down to the teacher. Some love using the space and others shy away from it. She would love to get the makerspace truly integrated within the curriculum of every department and to one day to have a dedicated maker class that would focus on interdisciplinary instruction.

There is a trend in some independent schools to create multidisciplinary or interdisciplinary signature programs. Signature programs are designed to give students a dedicated learning experience that builds upon their interests. For example, a STEAM signature program would draw from many disciplines, in the hopes of inspiring students to develop breakthrough ideas and solutions to real-world problems through science, technology, engineering, and math. It was this type of signature program that determined the need for Steven's dedicated role. Steven stated, the "goal was to make it possible to have a person in my position that was able to facilitate making and technology activities across the curriculum, so that it wasn't just a sort of robotics and engineering classroom, that it was a space that could be used by any student in any content area." He does this by partnering with faculty to see how the makerspace can connect with the curriculum.

Frank's space is relatively new, but a goal is to work with teachers to create interdisciplinary lessons. "Having the space closer to people and more accessible might lead to those kids of interdisciplinary conversations." Paul's space is more of a traditional classroom that was renovated to handle project-based STEM lessons and activities. His curriculum is designed to be interdisciplinary, but as a self-contained lesson taught by the STEM teachers, not in partnership with other faculty. For example, when they introduce Bluetooth capabilities to a project not only do they explain how the technology works, but they also do a deep dive into the history of the technology, and everything else they might be using, even a Phillips head screwdriver. Interdisciplinary lessons are critical to the role of a makerspace.

A makerspace is a collaborative workspace where individuals with a variety of interests and skills come together to create, learn, and innovate. Interdisciplinary lessons help to promote this collaborative atmosphere by bringing together individuals with different backgrounds and areas of expertise to work together on a common project. Interdisciplinary lessons can also help to encourage creativity and problem-solving skills. By incorporating multiple disciplines, such as art, science, engineering, and technology, makerspace participants are exposed to a range of perspectives and approaches to problem-solving.

Theme 7: Challenges

Teachers are often faced with many demands on their time and resources, and it can be challenging for them to find the time and support to innovate in their teaching practices. While time is often the excuse, a few of the participants mentioned that their faculty are somewhat intimidated by the makerspace and equipment. Oftentimes Cheryl feels challenged to work with teachers due to time and timing. "It kind of depended on what activity I would do, and whether the teachers had the break because our meetings are in the afternoon after a full day of school." She added, "They're usually exhausted, and not really motivated to do anything."

John had similar thoughts to share, "The makerspace gets a lot of use, but it gets a lot of use out of a small number of people. They don't feel like they have the time. They don't feel like they have the expertise." Most faculty understand that content can be taught through other mechanisms beyond traditional methods. John argued, "Some folks buy that. Some folks don't buy that. Actually, I think everybody buys it. They're not willing to invest the time in it."

Steven approached it by comparing it with a task they are familiar with. He challenges the teachers to give him the three days they would normally use to prepare students for a major assessment: a review day, a test day, and a revision day. With three days, he can do a deep dive into a robust project using the content provided by the teacher.

Despite the challenge of time many teachers still find ways to incorporate innovative techniques and technologies into their teaching. Some factors that can help teachers innovate include having a supportive school culture (Cai & Tang, 2021), access to professional development opportunities (Carlson & Gadio, 2002), and collaboration with other teachers and educational experts (DeMatthews, 2024). Additionally, administration can encourage their faculty to work with the makerspace leaders to create robust, interdisciplinary lessons that leverage the makerspaces resources.

Summary

The purpose of this study was to provide a framework for makerspaces and maker education in Independent Schools, specifically in grades 9-12, and address what the researcher perceives to be weaknesses in the process of implementing makerspaces. The data collected in this study included five semi structured interviews with leaders of makerspaces in independent schools around the country (one in Switzerland). Three participants were classified as faculty, one participant was classified as an administrator and one participant was classified as a staff member. Interview questions addressed the makerspace leaders' roles and responsibilities, the history of the space, how the space was being used, and whether the space was meeting the pedagogical needs of the student and the goals of the school. I used a transcription service to transcribe each interview, checked for accuracy, and then coded and analyzed the data.

The first research question for the study was "What are the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and makerspaces? More specifically, what challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 maker space?" The second research question was, "How does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?" The analysis of the data revealed seven themes. Each theme was explored and expanded upon thoroughly with examples given by the participants and are outlined in the table below:

Table 4

Seven Themes from Data Analysis

Theme	Coding (Participant mentions)	Examples
The Why	Curiosity (5), Safety (1), Increased Interest (4)	"It started as a short six week course and an after school activity. The popularity kind of increased, and we saw the value of it." "We put the 3D printer in the lounge area with some instructions on how to use it and the students just started playing with it." "The primary thing and one of the drivers, the reason we got it approved was for safety. The original room was not purpose built." "They are super passionate about something. They come back, or they stay late because they really want to use the space."
Community Space	Community (4), Inclusive (2), Hub (3), Welcoming (4)	"We wanted a community space where people could feel good about going in independently" "I want them (the students) to feel like they belong like it's welcoming to them. So I want them to feel that there's something for them." "Our library is sort of the social hub of our school, so we created the space in the library." "We wanted a centralized space." "We've made definite improvements in that over the six years, but we certainly are fighting an uphill battle, getting female students enrolled in our classes at the percentage that they are represented in the general population."
Novelty and Attraction	Exposure (3), display (2), recruitment (1), excitement (3)	"At the bottom level, it's exposure." shared Steven, "Then for those that are exposed, and they really enjoy the experience, they have opportunities to engage to whatever level they want all the way up to a highly focused program." "I think it was really to give our students the opportunity to play with this technology, not necessarily in a class setting." "Giving these kids access to this technology, that was suddenly becoming more

		affordable. And I found it exciting, and I thought that the kids would like it too. And it turned out to be true." "As an independent boarding school, we're trying to attract by offering some variety of course that maybe our competing schools can't offer." "It's an ongoing process to figure out who we set up and add visuals to the space that encourage kids to think of other opportunities in the space."
Engagement	Engaged (5), excitement (4), fun (2), revisit (2)	"I want all students engaged. With all of these hands-on activities, I want all the students to participate at some level. Selling them on the idea of designing something and have a vested interest in it.". Students are "trying to figure it out and come up with their design for whatever it is they're working on, and it's really…I mean, I've had kids get very excited." "It's more authentic. The kids are having more fun. They're learning like a sponge. They're not passive. They're way more active." "They are super passionate about something. They come back, or they stay late because they really want to use the space."
Theory to Practice	Hands-on (5), learning-by-doing (5), experiential (2), design thinking (4), project-based learning (5), problem-solving (3)	See previous chart for examples
Interdisciplinary/Multidisciplinary Instruction	Interdisciplinary (4), multidisciplinary (2), integrated (2)	"Having the space closer to people and more accessible might lead to those kids of interdisciplinary conversations." "I guess that would be a goal. To connect it more with the curriculum. Basically teachers come to me and say 'I want to do something with this.' And then I'm brought in for a single project. So it's not necessarily really integrated into the curriculum." "I would love for the space to be fully integrated with the curriculum."
Challenges	Time (4), expertise (3), intimidated (2), fear (1)	"They're usually exhausted, and not really motivated to do anything." "They're not willing to invest the time in it."

Chapter 5: Discussion, Conclusions, and Recommendations

This chapter contains a summary of the research study, the problem statement, and the research questions that guided the study. The chapter also discusses the interpretation of findings and recommendations for independent schools to implement makerspaces within their own organization. Lastly, recommendations for future study are suggested.

Overview of the Study

Problem Statement. As makerspaces became more popular in educational settings there remains a dearth of empirical research on these learning environments (Sheridan & Halverson, 2014). While articles on best practices for creating a makerspace can be found readily available on the internet, there is no one-size-fits-all solution. In truth, repurposing or building a new space and filling it with the latest technology might not align with the current needs of the students, faculty, and school. Are we putting the cart before the horse? In other words, do the pedagogical goals of the makerspace become a priority after the space is already outfitted with the latest technologies? If so, what challenges and opportunities does this pose for leaders who manage makerspaces?

Purpose of the Study. This study sought to better understand the experiences of directors/supervisors of makerspaces and the development of maker education in independent schools, specifically in grades 9-12, and examine what I perceive to be an area of development in the process of implementing makerspaces. Frequently the pedagogical goals of the makerspace become a priority after the space is already outfitted with the latest technologies. Of the 5 people interviewed, in 4 instances, the makerspace was designed, and equipment purchased prior to considering the pedagogical goals of the space.

Methodology. I employed a qualitative, phenomenological approach as framed by Irving Seidman (2006). This study is phenomenological in nature as it explored my experience and the participants' individual experiences (Ary, Jacobs, Razavieh & Sorenson, 2006). The primary way a researcher can investigate an educational organization, institution, or process is through the experience of the individual people who make up the organization (Seidman, 2006). The study consisted of semi-structured interviews with five leaders of makerspaces in independent schools, grades 9-12. The data was collected, manually coded, and analyzed for themes with a computer-aided data analysis software called Thematic.

Discussion of Findings

Research questions for this study focused on asking what the perspectives and experiences of leaders in makerspaces in relation to curriculum integration, pedagogy, and their space are. What challenges and opportunities exist when considering the interaction of teaching and learning in the context of a 9-12 makerspace? How does pedagogy inform the creation of a makerspace? Subsequently, how does the creation of a makerspace inform pedagogy?

Seven emerging themes discussed in Chapter 4 provide some insight into the experiences and perceptions of the participants of the study. First, the why. Why was the makerspace created? What need did it fill? While each of the narratives from the participants was different, common threads were apparent. Many of the makerspaces had humble beginnings as nooks, storage rooms, or unused classrooms. A few factors contributed to growth: student interest in the equipment, safety concerns in spaces without proper ventilation, and/or faculty or administrators who recognized the potential value of the space as a pedagogical environment that would allow its users to solve their own problems through making (Gershenfeld, 2012).

The second theme focused on the makerspace as a community hub. Many of the participants chose centralized locations that had student traffic. Others wanted to create a welcoming environment where students could relax, work, and collaborate. A commonality for all the spaces was flexibility and the ability to meet the multiple needs of the students and faculty. It was important for them to have a makerspace that was designed to be a creative community space where people of all backgrounds and abilities could come together to learn, create, and innovate. Makerspaces are rarely just where fabrication could be carried out. Rather, they are hubs of community, where people come together to work together, learn from each other, or simply socialize (Taylor, Hurley & Connolly, 2016).

The third theme was how a makerspace and its equipment attract students and faculty. The education community has recognized the potential for Makerspaces as learning environments that can foster interdisciplinary collaboration and self-directed learning (Hynes & Hynes, 2018) but if you build one, will the students come? Many of the participants acknowledged they focused on the equipment before pedagogy, thinking that if students were exposed to and experienced what the technology could do, their natural curiosity would inspire them to explore and play with the possibilities. Others recognized the value of a makerspace as a recruitment tool, possibly making the school stand out from peer schools that might not have one.

The fourth theme focused on student engagement. Engagement in makerspace activities specifically may lead to higher academic achievement throughout student life (Zyngier, 2008). When students are engaged in a makerspace, and have the opportunity to participate in hands-on, project-based learning experiences that foster creativity, problem-solving skills, and collaboration. They can explore a wide range of subjects and activities, from coding and robotics to woodworking and crafting. Makerspaces can provide students with access to tools, materials, and technologies that they may not have at home, as well as guidance from mentors and peers. Students can learn by doing and pursue their own interests and projects. This type of learning environment can be highly engaging for students and can help to spark a lifelong passion for science, technology, engineering, art, and mathematics (STEAM) subjects. Together with motivation, engagement is viewed as very important for enhanced learning outcomes of all students (Woolfolk & Margetts, 2007).

The fifth theme, theory to practice, refers to the process of taking abstract concepts, ideas, or principles from a theoretical framework and applying them in a practical or real-world setting. Makerspaces are designed to appeal to different learning styles and show students another way that learning can take place. Instead of simply promoting memorization-based learning, a makerspace encourages learning that is fueled by curiosity and active involvement from the learner. This leads to a blending of formal and informal learning styles, accommodating various ways of learning. (Colegrove, 2017). It has the potential to provide opportunities for a subset of students to excel. The participants unanimously recognized that multiple educational frameworks emphasize different skills and learning objectives. Furthermore, by supporting multiple frameworks, a makerspace can provide a broader range of skills and experiences to its users. This can help to foster creativity, innovation, and critical thinking, among other valuable skills.

The sixth theme drawn from the data analysis was the interdisciplinary and multidisciplinary nature of makerspaces. While all participants had curriculum that spanned disciplines, most of it was designed specifically to fit the makerspace environment. This often-involved real-world problems or challenges that required learners to apply their knowledge from multiple disciplines in order to solve them. This can help develop important problem-solving skills and critical thinking abilities. Critical thinking skills are important because they enable students "to deal effectively with social, scientific, and practical problems" (Shakirova, 2007, p. 42). Simply put, students who can think critically are able to solve problems effectively. Most of the participants had varying degrees of success partnering with faculty in different departments, but they all had the shared goal to increase these partnerships. By combining subjects and disciplines, interdisciplinary lessons can help learners make connections between seemingly disparate topics and see how they are related. They can also make better sense of how the lessons connect with the real world. Students with interdisciplinary integration prevailed in the "application to real-world scenarios" (Duerr, 2008, p.176). These connections can deepen their understanding and appreciation of each subject. Holbert (2016) exponds on this by stating that making allows students to integrate multiple disciplines, allowing for different points of entry for students and better access to understanding big ideas.

The seventh theme focused on challenges the participants reported having regarding their makerspace. Several challenges were reported including time, lack of expertise, and intimidation by the technology. Many of the participants reported that their faculty feel that they don't have enough time to incorporate makerspaces into their lessons, as they already have a lot of demands on their time and energy. However, makerspaces can provide a unique and engaging learning experience for students, which can be well worth the effort. According to research, it is estimated that the learning curve on technology doubles every 18 months; thus, it is essential that teachers remain lifelong learners in technology (Reed-Swale, 2009). Maintaining this level of expertise can be daunting to teachers, especially to those whose content don't necessarily center around technology. This also leads to being intimidated by the technology. One of the most prevalent fears of teachers is that they fear they will "look stupid" in front of their tech-savvy students because of their inability to effectively utilize technology in the classroom (O'Hanlon 2009). Other participants reported that the makerspace gets a lot of use, but only by a few of the faculty. Ultimately, it's important for teachers to consider the benefits that makerspaces can bring to their student's learning experiences, and to make the most of the time available to them.

These themes inform the following framework for the implementation of makerspaces in 9-12 independent schools:

Table 5

Framework for the implementation of a Makerspace

	People	**Facility**
Planning Phase	(T1) How do students engage in experiential learning on our campus? (T2) Where do people on campus feel community? (T3) What are the student's needs? How might students leverage the equipment to improve scholarship? (T4) What does student engagement look like? (T5) In what way are faculty already using project-based learning? Learning-by-doing? (T6) How are faculty partnering across disciplines? (T7) In what way does the school provide time for professional development? Are faculty encouraged	(T1) In what way does our curriculum exploit learning-by-doing philosophies? (T2) What facility do we have on campus that promotes community? (T3) Will the budget of the makerspace adequately support students interest? (T4) How does the facility measure or assess student engagement? (T5) In what ways does the facility support authentic context for learning? (T6) In what ways are interdisciplinary instruction important to the institution? (T7) How does the facilitie's schedule support time for project-based learning initiatives?

Implementation **Phase**	(T1) To what extent are faculty and students able to identify the goals of the institution in the curriculum implemented through the makerspace? (T6) What incentives are in place for interdisciplinary curriculum development? (T7) What feedback loops are in place for continuous and just-in-time student training and faculty professional development?	(T3) On what schedule will equipment be refreshed, maintained, or replaced? (T6) How can spaces be configured to allow for multi- and inter-disciplinary work?
Forward-thinking **Phase**	(T1) What can we do to anticipate the future needs of our students and faculty? (T2) How will community continue to thrive within the makerspace? (T3) How will the curriculum maintain the flexibility to keep attracting students from a variety of backgrounds? (T6) How will the director of the makerspace maintain relationships with his/her interdisciplinary cohort?	(T1) In what way will resources to sustain the makerspace's continued growth be made available? (T3) What process is in place for identifying and procuring new tools/equipment?

It is worthwhile to note that the background of the participants contributes to the connection between the makerspace and the pedagogy. Faculty or administrators who have a background in technology integration presumably have experience providing lessons that leverage technology, be it an Arduino, a 3D Printer, or an iPad. Conversely, faculty and administrators who have a background in curriculum and pedagogical design may not find it as difficult to provide a tie to the equipment in a makerspace. Ultimately, we don't need teachers who know the technology. We need exemplary teachers who know how to effectively use all the tools at their disposal for the learning benefit of students (Pierson, 2001)

The Researchers' Role and Expertise

My experience as a director of a makerspace in an independent school, grades 9-12 directly informed this study. The makerspace is an 8000 square feet center dedicated to innovation and making. My first year as Director was spent ordering equipment, meeting with students, and creating partnerships with faculty across all disciplines. I also had the opportunity to design a series of classes that would utilize the space directly. Three classes were developed in the first year, to be launched in year two. First, Projects in Tech & Design was an entry level course that exposed students to all the equipment the makerspace had to offer, provided instruction on its use with minor project-based assessments to show mastery. The course culminated in a large group project and an individual passion project. The second course was Entrepreneurship in Tech & Design. This course's focus was the invention cycle, rapid prototyping and developing a business plan. Eventually, it transitioned into a course focusing mainly on preparing for DECA competitions as the needs of the students and the school changed. DECA is an organization that prepares emerging leaders and entrepreneurs for careers in marketing, finance, hospitality and management in high schools and colleges around the globe. The third course I developed was Community Connections in Tech & Design. This course was a slight departure from the others in that the theme of the course was designed to change every year depending on the interests of the students. The goal was to provide a course that could do a deeper dive into specific content areas as well as leveraging the equipment available in the makerspace. The course would also be used to build partnerships within the larger community of Pittsburgh to serve as mentors, external resources, and content experts. As I am now in my fourth year in my role as the director of the makerspace, the course has had three iterations. The first year the course was in session the students created a children's show where the lessons involved creating puppets, animatronics, animation, and television production. The second year the topic was sustainability, where students focused on hydroponics, learning about growing seasons and best practices as well as creating a Grow Room furnished by open-source plans provided by IKEA. The topic for the third year was assistive technology. Through a partnership with the Open Wheelchair Foundation, Makers Making Change and e-Nable, students created an affordable, electric wheelchair for a child, various hand prosthetics and other 3d-printed, assistive technology which were sent to people in need.

One observation that was unexpected was the number of makerspaces that had only one, dedicated course offering that utilized the space. While all the participants utilized their space as a collaborative hub to assist and support other faculty, only a few had a course that was dedicated to making and utilizing the resources and the equipment that the makerspace had to offer. None of the participants had created courses that could do a deeper dive in content areas that might spark student interest.

My position and skill as a director of a makerspace at an independent school catering to grades 9-12 are limited by a potential disparity between faculty members at independent schools versus those at public schools. I have observed that, at independent schools, educators are typically subject-matter experts but are not typically graduates of teacher preparation programs. As a result, there are difficulties in developing sound educational frameworks for the equipment and student projects in the makerspace. Students are provided with opportunities that can be too open-ended as teachers struggle to work with learning targets in mind and place specific and necessary scaffolds in place.

Recommendations

It is important to recognize these findings and recommendations are specific to independent schools. Public schools are legally obligated to provide education to all students, which can make it challenging for them to cater to every individual's needs. In contrast, independent schools have the flexibility to customize their programs and goals in alignment with their vision and mission. Since they are not subject to the legal obligations that public schools have, they can intentionally set goals and prioritize certain aspects of education. Further, they can limit admission to students who are most likely aligned with that mission. This is one of the reasons why families choose to send their students to independent schools (Davis, 2011).

The pedagogical goals of a makerspace should always be the priority, even before outfitting the space with the latest technologies. The technologies and resources available in a makerspace should support and enhance the educational objectives, rather than dictate them. The technology should serve the pedagogical goals, not the other way around.

Pedagogy informs the creation of a makerspace by determining the educational goals and objectives for the space. The pedagogical approach determines what types of activities and materials will be made available in the makerspace, and how they will be used to support learning. For example, a makerspace designed for hands-on, project-based learning will have different equipment and materials than one designed for more traditional, lecture-based instruction. Results from the data showed the makerspaces were not created based on any specific pedagogical approach, but rather because of student interest in a particular piece of equipment. As this interest grew, a dedicated space was provided for students to explore their ideas using similar equipment. In my personal experience, the administration recognized the need for a space to cater to students who enjoy tinkering and designing, but there was no pedagogical strategy beyond equipping the makerspace with recommended tools commonly found in such spaces.

The creation of a makerspace can inform pedagogy by providing new opportunities for students to engage with materials, tools, and technology in ways that support their learning. Makerspaces can facilitate hands-on, experiential learning and promote creativity, problem-solving, and critical thinking skills. Additionally, the interdisciplinary and collaborative nature of makerspaces can inspire new teaching approaches and pedagogical innovations. By using the makerspace as a learning environment, educators can incorporate new and engaging activities into their lessons, and explore new teaching methods that support student-centered, project-based learning. According to the data reported by the participants, there was a strong interest in providing additional opportunities for students within the makerspace, but several factors prevented its growth. Participants commonly mentioned issues such as scheduling, budget, and competing priorities. However, I also observed a lack of forward-thinking beyond simply providing students with resources and equipment and observing their actions.

Additionally, when setting up a makerspace, it is essential to consider the needs and interests of the students. This includes taking into account their age, skill level, and the projects they want to create. By understanding the student's needs, you can ensure that the equipment and materials selected for the makerspace are appropriate and engaging for them. This will help to create a positive and productive learning environment and promote hands-on exploration and creativity.

Future Study

Future research will be able to more directly pinpoint how maker leaders choose to develop and deploy pedagogical strategies and specific curriculum. This study is not intended to develop recommendations for these areas, though it opens the door for future researchers to make the case for assessing the effectiveness for specific interventions as they have been happened upon by maker leaders doing their best chasing the cart down the road. As makerspaces become increasingly popular and widely adopted, researchers can explore many aspects of this emerging phenomenon, including their impact on education, their role in innovation and entrepreneurship, their effect on communities and local economies, and much more. Additionally, there is a need to continue to study and understand the best practices and principles that make makerspaces successful and to find ways to improve and scale their impact. Other opportunities are highlighted below.

Scope and Sequence of Maker Curriculum

The scope and sequence of makerspaces could be an area of additional research. Modern makerspaces are relatively new despite their constructivist origins and are constantly evolving, so it's not surprising that there has yet to be much research on their structure and organization. However, as the popularity of makerspaces continues to grow, there will be a need to develop a scope and sequence to create a framework of instruction from PreK to 12th grade.

How Makerspaces pivoted during Covid

The COVID-19 pandemic created many challenges in the education and everyday life of children and adults alike (Antle & Frauenberger, 2020). To adapt, many makerspaces shifted to offering virtual resources, classes, and workshops online, and providing take-home kits and supplies for students to work on projects at home. Some makerspaces also offered curbside pickup and limited in-person access with strict health and safety protocols in place. Overall, the pandemic forced makerspaces to think creatively and find new ways to engage with their members and support the maker community.

Problems with Equity

Using a model whereby makerspaces are developed in an ad hoc manner, participants revealed that budget was always a foremost concern. For schools with greater resources, whether those are connections to free or reduced price tools and equipment or just having larger budgets, the eventual arrival of full maker experiences for students may be more likely. Independent schools could leverage those resources to be pedagogically oriented, or not. A school with fewer resources doesn't have the luxury to buy expensive equipment it hopes will be useful. Thoughtful, pedagogy-first maker spaces could be a tool to level some playing fields.

Common language

A common language and understanding of makerspaces and the theoretical frameworks they utilize would be beneficial for administrators to support and facilitate these spaces effectively. In a few of the interviews in this study, there was some confusion over terminology. For example, the distinction between exposure and experience is important because while exposure refers to simply being aware of or introduced to something, experience involves actively engaging and participating in it, leading to deeper understanding and learning. It is not enough to expose students to the equipment in a makerspace. A clear understanding of these concepts would allow leaders to make informed decisions and ensure that makerspaces are providing meaningful experiences for their users through a common language.

Conclusion

Conversations with leaders in makerspaces about curriculum integration, pedagogy, and the connection between teaching and learning in makerspaces revealed seven major themes. Within those themes, leaders interviewed in the study agreed with prevailing literature that the primary focus when setting up a makerspace should be on educational objectives, rather than on acquiring the latest technology. In almost all instances, however, participants reported that student interest in a particular piece of equipment was the catalyst to create an environment that was better suited to foster innovation and creativity. However, it is essential to ensure that the available resources and technologies align with and enhance the pedagogical goals, rather than steering them. Although this research focused on a small sample of leaders in makerspaces in independent schools grades 9-12, it is representative of a global trend of makerspace implementation. This study serves as further evidence that the pedagogical goals of many makerspaces become a priority after the space is already outfitted with the latest technology.

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Appendix A

Demographic Questions

Demogaphic Questions

1. What is your gender identity? (Refer to definitions below)

   Cisgender: A person whose sense of personal identity and gender DOES correspond with their birth-assigned sex.

   Transgender: A person whose sense of personal identity and gender DOES NOT correspond with their birth-assigned sex.

   A. Cisgender Female

   B. Cisgender Male

   C. Transgender Female

   D. Transgender Male

   E. Prefer not to answer

2. My age is __________. (Open-ended response)

3. What is your racial or ethnic identification?

   A. American Indian or Alaska Native

   B. Asian

   C. Black or African American

   D. Hispanic or Latino

   E. Native Hawaiian or Pacific Islander

   F. White

   G. Multiracial/Biracial

H. Other

I. Prefer not to answer

4. Highest level of completed education:

   A. Bachelor's Degree

   B. Master's Degree

   C. Post-Master's Credits

   D. Doctoral Degree

5. Describe your current school status (wording)

   A. Faculty

   B. Staff

   C. Administrator

6. How long have you served in your position as a Makerspace leader? _______(in years)

7. How would you describe the area in which you currently work?

   A. Urban

   B. Suburban

   C. Rural

8. How many students are in your school?

   A. 0 – 100

   B. 101- 200

   C. 201 – 300

   D. 301 – 400

   E. 401 – 500

   F. 501 – 600

G. 601 – 700

H. 700+

9. What level of students do you serve?

A. Elementary

B. Middle School / Junior High

C. High School

D. Multiple levels

E. Other: please describe

10. How many staff / faculty work in your Makerspace? ___ (number) ___ (It's just me)

11. I facilitate making with learners during:

A. Class time in core subject areas

B. The school day as an extracurricular

C. Outside of the school day

12. I have incorporated making into the following courses/subjects:

☐ English/Language Arts ☐ Technology / Digital Literacy ☐ Mathematics

☐ Computer Science ☐ Science ☐ Dedicated Maker/STEAM

courses ☐ History ☐ Social Studies ☐ Library

☐ World Language ☐ Visual Arts ☐ Performing Arts

☐ Outside of coursework

13. What are your three biggest challenges right now related to maker learning?

☐ Capacity (within program/school time, educator bandwidth, fitting in with programs/schools priorities)

☐ Facilitation (of maker experiences)

☐ Advocvating for Maker Resources (supplies – resource access)

☐ Resource overload

☐ Equity

☐ Transition to new learning context (hybrid/in-person)

☐ Finding ideas

☐ Space

☐ New priorities

☐ Engaging families & community

☐ Getting started

☐ Learner Engagement

☐ Assessment

☐ Implementation

☐ Other (Please specify)

14. Please place a checkmark next to the equipment you currently have in your makerspace:

☐ 3D Printer ☐ Laser Cutter/Engraver ☐ Vinyl Cutter/Printer

☐ CNC Router ☐ CNC Mill ☐ SawStop / TableSaw ☐ Drill Press

☐ Miter Saw ☐ Scroll Saw ☐ Band Saw ☐ Welding Tools

☐ Arduinos ☐ Hummingbird Robotics ☐ Raspberry Pis

Appendix B

Interview Guide

Thank you for your willingness to participate in my research on the experiences and perceptions of leaders of MakerSpaces in Independent Schools. I am a doctoral student from Duquesne University in Pittsburgh, PA. The research will be conducted over Zoom, once per week in three, ½ hour sessions.

Your answers to these questions will contribute to a growing volume of research on Makerspaces in the independent, 9-12 educational environment. There are no risks to you and all conversations will remain confidential and anonymous.

This research is voluntary in nature and you have the right to withdraw at any time.

If you have any questions before, during or following the interviews please do not hesitate to contact me via email at robins19@duq.edu or via cell at: 860-995-9111

Interview 1: History and context

Describe your role at your institution.

Describe the timeline of the creation of the makerspace you lead/supervise/manage.

Who is the target user of the makerspace?

What do you hope happens when a user enters the makerspace?

Interview 2: Details of the experience

To what extent do you believe the makerspace is meeting the goals set at its creation.

How do campus constituencies use the space currently?

What are the current goals of the makerspace? What role did you play in the setting of those goals?

With regard to the physical space, is the capacity enough to meet demand? Do you have the equipment you need?

To what extent do you have the financial means to meet demand and goals?

Interview 3: Reflection

To what extent do you think your current role is aligned with what you were hired to do?

What future goals do you have for the makerspace?

In what ways does maker education and your role with the makerspace inform your teaching? How are you different now that you were before you had this role? How is the institution different than it was before the opening of the makerspace?