8-2017

Makerspaces: A Qualitative Look into Makerspaces as Innovative Learning Environment

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MAKERSPACES: A QUALITATIVE LOOK INTO MAKERSPACES AS INNOVATIVE LEARNING ENVIRONMENT

A Dissertation Submitted in Partial Fulfillment
of the Requirements of the Degree of
Doctor of Philosophy

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College of Education and Behavioral Sciences
School of Teacher Education
Educational Technology

August 2017

This Dissertation by: Catherine Otieno

Entitled: *Makerspaces: A Qualitative Look into Makerspaces as Innovative Learning Environment*

has been approved as meeting the requirement for the Degree of Doctor of Philosophy in College of Education and Behavioral Sciences in School of Teacher Education, Program of Educational Technology

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ABSTRACT

Otieno, Catherine. *Makerspaces: A Qualitative Look into Makerspaces as Innovative Learning Environment*. Published Doctor of Philosophy dissertation, University of Northern Colorado, 2017.

This study examined makerspace instructor's pedagogical practices and how these influenced learning within the space. Three different Makerspaces located in a library and K-12 were selected and studied. The instructors teaching within these spaces were observed, interviewed and artifacts collected. Preliminary results showed that the pedagogical practices of Makerspace instructors were in line with constructivist, framework for 21st century learning and constructionism theoretical framework. These results further showed that making and tinkering in the makerspace does contribute to learning if we define learning from the lenses of constructivist, framework for 21st century learning and constructionism framework. This study has several implications on education, learning through making and tinkering, on understanding Makerspace instructors and how their pedagogical practices are influencing students learning. In addition, administrators must provide support for teachers teaching in Makerspaces if they are to succeed in instilling the maker mindset.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my committee and more so to my advisor Dr. Mia Williams and Dr. Christine Kyser for the endless support, wisdom and feedback throughout my studies and dissertation. I want to also thank my family for the endless support, my Dad and my Mom who taught me at a young age to go after what I put my heart to and never forget where I come from and who remain my number one fans. Thank you for your advice prayers and unconditionally love. To all my friends and colleagues who have given me support throughout thank you, to my husband and my best friend thank you for being my champ. To my teachers who opened their doors for me to visit and observe their Makerspace, thank you this study would not be complete without your help. Above all I want to thank God for the far he has brought me. I am who I am today because of His unfailing love.

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CHAPTER I

INTRODUCTION TO THE STUDY

Overview of the Problem

Education has evolved over the years beyond the three Rs, reading, writing, and arithmetic (Papert, 1993a). In the 20th and 19th century these skills were sufficient for the learners to succeed in the work force (Papert, 1993a). However, with rapid technological advancement and a constantly evolving global world in the 21st century, a need has evolved for graduates to not only succeed but also lead in this growing, changing hyper connected world of today (Wagner, 2008). The call for graduates who showcase a diverse range of skills beyond the three Rs to succeed in the workforce cannot be emphasized enough. Teachers are as such constantly faced with the challenge to meet a much broader range of learning needs and dimensions than they were decades ago (OlPhen, 2008). Students today must, therefore, master and show a range of functional skills and literacies if they are to be effective citizens and workers of the future (Soulé, & Warrick, 2015).

To cater for this new set of skills brought about by the diverse global world, the National Education Association (NEA) embarked on a journey in 2003 to establish the Partnership for 21st Century Learning (P21; 2003a) framework to outline expertise and skills relevant to the 21st century (21st c) that learners must master to be successful. The mission of P21, therefore, is to ensure that all learners are equipped with the necessary skills and knowledge they need to succeed in the global platform where learning never stops and change is inevitable (P21, 2003a). This framework was used as a definition basis for this study. The framework divides the 21st c skills into four categories: (a) Core subjects and 21st century themes; (b) Learning and Innovation skills (creativity, communication, collaboration and critical thinking, 4Cs); (c) Information media and Technology; and (d) Life and career skills (P21, 2003a). The first set of skills caters for the core content areas that the learner must still master, the third set of skills caters for the need of students to critically produce and consume information in diverse formats and the fourth skills are geared towards ensuring students are equipped with skills to navigate the complex nature of work and life environments (P21, 2003b).

Formal and informal learning environments must as such use pedagogical practices and create learning spaces that equip learners with these set of skills needed as stipulated by the P21. Formal schooling has for years attempted to design and execute pedagogical practices that focus on equipping students with these 21st century skills. This study focused on the 4Cs. Previous studies have shown how schools work to enhance the 4Cs (Huffaker, 2005; McGrail, & Davis, 2011). However, there exists little research on how innovative learning environments pedagogical practices are equipping learners with this same set of skills, specifically the 4Cs. How are instructors in these unique innovative learning environments selecting teaching strategies that help learners succeed in the 21st century? Innovative learning environments have been defined as “an organizational space that embraces the learning arrangements catering for a group of learners in context and over time” and is located either in a school institution or non-school institution (Istance & Kools, 2013, p. 47). These spaces range from but are not limited to museums, libraries, after school programs, and makerspaces. This study specifically focused on teaching and learning that happens in makerspaces, defined by Dougherty (2005) as accessible spaces to create, tinker and make, to determine the pedagogical strategies instructors use within these spaces to help equip learners with 21st c skills.

Makerspaces as a term first appeared in 2005 coined by Dale Dougherty. It emerged from the technology-driven "maker movement and culture," associated with Make magazine and the Maker Faires started by the founder Dale Dougherty (2005). The maker movement, which saw the birth of makerspaces, was mostly motivated by the majority interest in DIY (do it yourself) culture which saw individuals make and tinker materials on their own outside formal learning spaces; these spaces have been referred to as makeshops, hackerspaces, makerspaces, techshops, and fablabs (Honey & Kanter 2013). Dougherty (2005) referred to makerspaces as publicly-accessible places to design and create. They are mainly characterized by informal spaces where people of all ages can go to learn "tinker" and "make;" terms synonymously used to refer to act of "designing and producing things for sheer pleasure of figuring out how things work and repurposing them at will" (Honey & Kanter, 2013, p. 5). Since they were first realized, makerspaces have become quite common in museums, libraries and recently started getting established in K-12 and higher education environments. In the informal settings, individuals can attend classes and guided practice organized by the instructors on how to make and tinker using the technology within the space. These technologies often vary depending on the facility and funding available but quite common ones in any space are microcontrollers, 3D printers, other fabrication tools, Video and media tools, robotics tools which individuals use for fast prototyping, and explore questions, fail, and retry, bounce ideas off one another and build something together. As the idea for providing informal space for project design and construction has caught on in education, makerspaces continue to be used by people from all occupations including teachers, faculty, students, and staff for self-directed learning, providing workspace to tinker, try out solutions, and hear input from colleagues with similar interests (Educause, 2013; Honey & Kanter, 2013).

In 2009, Obama called for the need for education to embrace hands-on, project based learning to encourage students to be makers and not just consumers. When launching his Educate to Innovate campaign he said:

> Students will launch rockets, construct miniature windmills, and get their hands dirty. They will have the chance to build and create and maybe destroy a little to see the promise of being the makers of things and not the consumers of things (Obama, 2009).

This call for action from the former president saw the rise of many maker initiatives to provide students with makerspaces that enhance their innovation. One such organization is the Maker Education Initiative (MEI; 2016), a non-profit organization whose goal is “Every child a maker” and works to establish makerspaces in K-12 schools and afterschool settings to develop hands on projects for young people as well as recruiting mentors who are willing to share their passion and expertise with young mentees. Quinn and Bell (2013) observed that makerspaces as informal learning environments have the potential to provide stimulating learning experiences, promote voluntary and differentiated learning as well as providing avenues to use classic and new advanced learning technologies.

There is potential and benefit in learning through making, and even though this mindset does make sense to educators and learning communities there is lack of research and empirical evidence to this effect and how we can attribute making as something that influences students learning (Anderson, 2012; Honey & Kanter, 2013; Litts 2015; Martinez & Stager, 2013; Sousa & Pilecki, 2013). Makerspaces have the potential to immensely contribute to teaching and learning and this study intended to find out exactly how this is happening and what contribution is there. Kalil (2013) raises several questions that educators need to think about as they adopt or plan to provide makerspaces in the K-12 as well as in informal environment. For instance; “What projects should the maker communities be co-designing and co-creating? What foundational knowledge and practical skills would ‘maker’ students acquire along the way and what real world problems could they solve? What are the biggest barriers of bringing makers and their tools into the classroom and informal settings, and how can we solve or work around these barriers?” (Kalil, 2013, p. 16).

Given that makerspace as innovative learning environment is a fairly a new concept, several questions, in addition to Kalil’s, still need to be addressed if we are to establish a relationship between tinkering and learning, as well as the pedagogical practices of instructors and how these assists learners acquire 21st c skills. These include: Is it really learning or is it just play? What really are they learning? How can we assess and determine learning in a makerspace environment? How are the instructors and teachers designing activities and lessons for students in makerspace environments? This study aimed to answer some of these concerns to add to the research and literature of makerspaces and learning.

Learning in the Makerspaces

Constructivist learning framework holds that learning takes place through actively engaging the learners in meaningful activities, and that learning is an active process of meaning making gained in and through experience and interactions with the world (Driscoll, 2005; Papert, 1993b; Reiser & Dempsey, 2012). To constructivist, learning opportunities arise as people encounter cognitive challenges through naturally occurring as well as planned problem-solving activities (Driscoll, 2005; Papert, 1993a; Reiser & Dempsey, 2012). Learning is a communal activity involving collaboration, negotiation, and participation in authentic practice of communities and it involves learners taking responsibility of their learning by setting their own goals and regulating their own learning with assessment embedded naturally within the learning activities (Driscoll, 2012; Papert, 1993a; Reiser & Dempsey, 2012). In addition, Constructionism learning theory holds that making an artifact is a crucial part of learning (Papert, 1993b). This is the heart of what making and tinkering in the makerspace learning environment aims to achieve. The question, what contributions are makerspaces providing towards students learning and acquisition of 21st century skills? can be answered using the lenses of constructivism and constructionism learning theories. Learning, as defined by these frameworks goes beyond product and grades and looks at learning in the aspect of process. If we look at makerspaces under these lenses, we can to some degree, answer the question what learning occurs in makerspaces? To determine how learners within the makerspaces are learning and acquiring the 4 Cs skills, and how pedagogical practices occur in the makerspaces I referenced the learning framework and definitions as proposed by constructivist and constructionism. In addition, I used Petrich, Wilkinson, and Bevan,

(2013) learning dimensions (see Table 1.1) to identify how learning takes place through tinkering. Using the framework for K-12 science education established by National Research Council in 2011, Petrich et al. (2013) designed this guideline to help educators identify learning within a makerspace environment (Petrich et al., 2013).

Table 1.1

Original List of Learning Dimensions as Visible in Makerspace Learning Environment

Learning Dimension	Indicator
Engagement	• Duration of participation • Frequency of participation • Work inspired by prior examples • Expression of joy, wonder, frustration, curiosity
Intentionality	• Variation of efforts, paths, work • Personalization of projects or products • Evidence of self-direction
Innovation	• Increasing efficiency/fluency gained with scientific concepts, tools, processes • Evidence of repurposing ideas/tools • Evidence of redirecting efforts • Complexification of processes and products
Solidarity	• Borrowing and adapting ideas, tools, approaches • Sharing tools and strategies; helping one another to achieve one's goals • Contributing to the work of others

Note. Learning categories as identified by Petrich et al. (2013, p. 66)

Purpose of This Study

Considering the above overview, this study explored and critically examined how makerspaces are aiding learning and equipping learners with communication, creativity, critical thinking, and collaboration skills as proposed by the P21 (2003a) to help these learners not only succeed academically but globally. This study examined at the micro-level the makerspace in an informal and formal setting to determine the pedagogical practices instructors in these spaces are using to help learners make, tinker and learn. I shadowed makerspace instructors to observe how they facilitate learning in the makerspace including, their choices, beliefs, pedagogy, and design elements in the makerspace environment. Data was qualitatively collected and involved observations, interviews, and artifacts all of which were analyzed.

The purpose of this study, therefore, was in twofold. First, by working with makerspace instructors I analyzed at the micro- level how these mentors/instructors are teaching and integrating technology within makerspaces to help learners be fluent in the 21st century skills and help set the “make mindset” (Dougherty, 2013, p. 9). I looked keenly at their understandings of pedagogy and how this play together to ensure technology integration that facilitates learning. Instructors/teachers in the makerspaces were target participants because, not only is there a lack of vast research in makerspaces movement, but also because there is lack of research that specifically looks at the instructors in the makerspace and how they facilitate learning. The limited existing research focuses solely on the space, and learner. Understanding the perceptions, beliefs, and pedagogical practices of makerspace instructors, as well as their thoughts on the influence maker movement has on students learning, can provide immense insight into the visible impact technology has in preparing learners for the global environment. I believe it immensely informs the literature and will help education sectors adopt more of the makerspace mindset.

The second purpose of this study was to determine what kind of learning happens in the makerspace. Through extensive observations and interviews, I intended to identify learning as it manifests itself in the makerspace. When students are making and tinkering, are they learning and if so what kind of learning does this constitute? Can we identify the 4Cs acquisition in the Makerspaces? These were some of the questions I addressed in the space. The following research questions were examined;

Q1 How does learning happen in a technology rich makerspace?

Q2 How does pedagogy manifest itself in a technology rich makerspace environment?

Need for Study

The maker movement and our understanding of making as a fundamental educational benefit is still at its infancy (Honey & Kanter, 2013). Even though making, or learning by doing, has been a concept that learning philosophers and psychologists have raised for years, the advancement of technology has changed how we make, create and innovate. Makerspaces are a recent phenomenon and there exist little research and empirical data that shows their effectiveness and contribution to educational sector even though learning potential might be evident to the human eye. Makerspaces as learning communities allow for learners to get hands on activities, make artifacts, collaborate, and iterate realizing that failure is just a process to get better (Petrich, et al. 2013). These spaces provide learners with an informal non-scheduled place to tinker, and get their creative gear on (Kalil, 2013). But the questions that these raises are vital in informing the education sector. What are the pedagogical practices used in these spaces, and how are makerspaces contributing to learner acquisition of 21st c skills? These questions have not been answered by previous research and in this study, I intended to inform this gap in the research by providing an account of makerspaces to learning, pedagogy and 21st c skills in an informal and formal setting in a prolonged qualitative study.

Significance and Implications

The goal of this study was to understand makerspace instructors' pedagogical practices and how they are facilitating tinkering and making to help their learners learn. This study further intended to determine how makerspaces are using new technology, community space to enhance learning and equip learners with 21st c skills, specifically the 4Cs. The knowledge gained from this study have implications for maker movement in general, makerspace instructors, learners, policy makers, and educational administrators who undoubtedly have the interests of students and teachers in mind when passing policies in education and more so policies affecting learning through doing and see the potential of makerspace contribution to learning and teaching process.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

Because of the nature of this study, a thorough review of the literature was conducted to better understand the breadth and depth of making tinkering and makerspaces in general.

Constructivist Framework

To explain and account for “constructs linking observed changes in performance with what is thought to bring these changes” psychologists and philosophers proposed many learning theories to help us understand learning as a construct and what teaching strategies to employ help enhance this learning construct (Driscoll, 2005, p. 9). Among these theories are Constructivist and constructionism learning theories. Constructivism has multiple roots in psychology and philosophy from Piaget’s cognitive development to Vygotsky's and Bruner’s cultural and interaction practices to the contextual nature of learning as seen in situated cognition (Driscoll, 2005). They hold that knowledge is constructed by the learner and that the learner makes meaning or sense of this knowledge based on context of the situation (Driscoll, 2005; Vygotsky, 1978). To this framework learning goals must focus on equipping learners with knowledge they can use in the context of meaningful activity (Driscoll, 2012; Vygotsky, 1978). Learning, therefore, is a lifelong process and can arise when acting in situation (Driscoll, 2012). It is important that learners in a constructivist lens identify and pursue their own goals. Reiser and

Dempsey (2012) suggested that instructors guide and direct instruction in these instances to maximize learning without preempting student's own initiatives and closely monitor students to provide assistance as needed. Other goals of constructivist learning entail problem solving, reasoning, critical thinking, active and reflective use of knowledge and rather than emphasizing the product of learning, this learning theory emphasizes the process of learning. Constructivists have greatly influenced learning environments and how teachers design instructions to support learning goals. Constructivist researchers recommend that complex learning environments be created and used to engage learner's knowledge construction, facilitate test of this knowledge as well as reflection on the process (Reiser & Dempsey, 2012). Teachers in these learning environments must as such,

> Engage learners in activities authentic to their disciplines in which they are learning, provide collaboration opportunities for multiple perspectives on what is being learned, support learners in setting their own goals and regulating their own learning and finally encouraging learners to reflect on what they learned. (Reiser & Dempsey, 2012, p. 41)

Constructionism

Papert's (1993a) constructionism theory redefined learning through making. This theory builds on constructivist framework and goes beyond building knowledge to incorporate learners consciously building and constructing a "public entity or artifacts" (p. 142). Papert's learning framework as such established learning through making. The approach helps educators understand how different media can be used to express and transform multiple ideas in different context (Ackermann, 2001). To Papert, learning happens when the learner's thinking is worked out through the making of external artifacts that "can be shown, discussed, examined, probed, and admired", a distinction from constructivist where leaner build knowledge (Papert, 1993a, p. 142). Constructionism further expands on constructivist mental knowledge to include questions when making such as “How can one become expert in constructing knowledge? What skills are required? And are these skills same for different kinds of knowledge?” (Papert, 1993a, p. 143). Learning is as such the central focus of constructionism as it intends to determine how we learn by constructing, making, and doing (Papert, 1993b). To engage his math students, Papert (1993b) used computer assisted learning using LOGO programming software to teach students how to make math the way they would make art. This experiment made abstract math concepts concrete, relevant and accessible to the learners as they build. Papert’s (1993) belief that children make ideas as opposed to getting them, a concept that holds knowledge as active process that is created. To Papert (1993a), therefore, we learn when we make knowledge and artifacts that portray this knowledge.

Gagné’s Theory of Instruction

Gagné proposed conditions of learning that teachers and educators must allocate if learning is to be successful. He identified multiple learning outcomes desired, verbal, intellectual, cognitive, attitudes, and motor skills (Gagné, & Merill 1990; Gagné, 1977). Once a teacher has identified these then they must provide learning conditions that helps learner be fluent in those learning outcomes. He designed nine events of instructions that teachers have referenced to and used for years. These include, gaining attention, informing the learner of the objective, presenting stimulus, providing learning guidance eliciting performance, providing feedback, and assessing performance (Gagné, 1977; Driscoll, 2005; Gagné & Medsker 1995). For years Gagné’s theory of instruction has been used by teachers and instructional designers to effectively design instruction that are learner centered.

CHAPTER III

MAKER MOVEMENT

The maker movement originally became known in early 2000. It is characterized with the idea that people are makers and creators rather than consumers and has recently become a social, technology and economic movement (Brahms & Werner, 2013). Maker movement has seen rise of makerspaces, tinkering studios, techshops and fablabs which are generally spaces where making takes place. The way educators, students and teachers view and see learning is being reinvented and transformed by the maker movement (Brahms & Werner, 2013). The evolution of new technology such as 3D printing, microcontrollers laser engravings, robotics, physical computing, and fabrications has recently seen the movement rise in the digital setting allowing users and learners to innovate, make and tinker (Petrich et al., 2013). According to Martinez and Stager (2013), the maker movement emphasizes making, “an active process of building, designing, and innovating with tools and materials to produce shareable artifacts--as a naturally rich and authentic learning trajectory” (p. 32). Makers generally put things together, take things apart, put things together in a new way and find it intrinsically rewarding to do so (Kalil, 2013, p. 15). It is, therefore, a very hands-on, learn by doing movement. Honey and Kanter (2013) observed that the maker movement has potential to transform education and foster a “make mindset” among students (p. 5). The movement as such has the potential to promote creativity, problem solving collaboration and self-expression, skills that are vital to succeed in the 21st century environment (Kalil, 2013, p. 16).

Makerspaces

Makerspaces were inspired by the do it yourself (DIY) phenomena that arose in the 1990s. They have been generally defined as physical the "physical location where people gather to share resources and knowledge, work on projects, network, and build with technology" (Hackerspaces, 2015, para. 1). Makerspaces provide tools and space in a community environment--a library, community center, private organization, or campus (Honey & Kanter, 2013). Other terms that have been used to refer to makerspaces include but are not limited to hackerspace, techshops, Fablab and makeshops (Honey & Kanter, 2013). The first wave of hackerspace originated in Europe where a group of programmers shared a physical space to tinker and make in 1995 and did not take effect in the United States until 2007 when a group of North American hackers visiting Germany took interest in the concept and brought it back to New York and started their own hackerspaces (Cavalcanti 2013). According to Nick Farr, founder of the Hackerspace Foundation and blogger on hackerspaces.org the hacker movement who has been credited to the birth of makerspace, happened in three successive waves:

> **First wave** spaces date back to the early 1990s and "showed us that hackers could build spaces"; Farr refers to these spaces as "the stuff of legend" and, thus, continue to shape the movement.
>
> **Second wave** spaces were sparked by hackers in Europe who paved the way for a more sustainable and official approach to building hackerspaces by gaining recognition from the government and credibility from the public.
>
> **Third wave** spaces are those popping up all over the world today, and Farr claims these spaces are tasked with providing us with a "critical mass" or will fade out altogether. (Farr, 2009, para. 1 -11).

Most makerspaces are cross disciplinary and provide materials and room for physical learning. Students from a variety of fields can, therefore, use them and find technical assistance from mentors and experts in different fields they are interested in if available as well as collaborate with peers to build authentic artifacts (Petrich et al., 2013). Due to its inquiry and problem-based pedagogy, makerspaces provide opportunities for students to not only get hands-on use of emerging technologies, they also take control of their own projects that they have not just designed but defined as well (Simon & Brown, 2013).

Teaching and Learning in the Makerspaces

Each person is born curious, eager to understand the world around them and take charge for how they live it. The desire and need to make and create comes from this inherent nature of humans (Papert, 1993a). The question what is learning, what is knowledge, what is mind and how does the mind acquire knowledge, has been a complex matter that psychologists and philosophers have considered for centuries (Driscoll 2005). Learning has been generally defined as the acquisition of knowledge, with most psychological theories defining it as “persisting change in human performance or performance potential” (Driscoll, 2005 p. 9; Papert, 1993a). Driscoll (2012) further states that “to be considered learning a change in performance or performance potential must come about because of the learner's experience and interaction with the world” (p. 9). According to Reiser and Dempsey (2012) learning can be many things but must, however, be distinguished from human “maturation and human development,” “changes in ability that are temporary” and “learning as an instruction process and learning as a cultural process” (p. 35).

The ideas behind making and maker movement are at least a decade old as people have always made, but with the new advanced technology such as digital fabrication tools, making in the formal and informal learning settings has become more popular and common. Making unites, inspires, informs, and entertains a growing community of resourceful people of all ages who undertake amazing projects (Honey & Kanter, 2013). Maker movement celebrates the right of individuals to tweak, tinker, hack, and bend any technology to their will (Honey & Kanter, 2013; Petrich et al., 2013). Making "develops an alternative and powerful way of knowing and of thinking things through that contrasts with mere abstract analysis" (Washor & Mojkowski, 2013, p. 208). With the younger people, making provides opportunities to use their hands and minds stimulating them to develop their imaginative, creative, entrepreneurial, and scientific abilities (Honey & Kanter, 2013; Washor & Mojkowski, 2013). Characterized by the iterative process of developing a personally meaningful idea, becoming stuck in some aspects of physically realizing the idea, persisting through the process, and experiencing breakthroughs individual involved in tinkering/making process must enhance their creativity, problem solving skills to find solutions to problems (Petrich et al., 2013). Petrich et al. (2013) further stated that the iteration process in tinkering and becoming "unstuck" is a fundamental process in learners learning as they develop "authentic authorship, purpose and deep understanding of the materials and phenomenon" (p. 55). Making, or tinkering, as such "centers on the open-ended design and construction of objects or installations, generally using both high- and low-tech tools" (Blikstein, 2013; Dougherty, 2013, p. 9; Petrich et al., 2013). In the late 2000s, most researchers and educators seriously started considering the influence makerspaces have in education. Stanford University in 2008 launched the FabLab@School project, and started building FabLabs in K-12 schools around the world. In 2009, the MC2STEM High School in Ohio (USA) opened its first digital fabrication lab. In 2011, the Maker Media launched the Makerspace project. In recent years, countless museums, schools, universities, community centers, and libraries have established and started many digital fabrication and “making” facilities.

Making as a learning trajectory has been a discussion for centuries by previous learning psychologists and philosophers and as such supported by learning theories like constructivist, sociocultural and situated cognition (Driscoll 2005; Honey & Kanter, 2013; Papert, 1993a). The benefit of learning and working with our hands cannot be overemphasized. According to Wilson (1998) to engage the hand is to engage the mind and education must provide students with a hands-mind approach to not only engage the learners but also to deepen their learning and understanding of what quality looks like as well as appreciation for artifacts, a model that will produce thinkers and creators who can apply what they learned (Washor & Mojkowski, 2013). The development of and access to newer technologies that make different learning possible has risen over the years and calls for the need to reevaluate the benefits of learning by making (Dougherty, 2013; Honey & Kanter, 2013; Petrich et al., 2013). In a learning environment where making is the sole practice, learners engage with the materials, peers, teachers, practice, and ideas present in the makerspace, and since the challenges or problems are not assigned they discover and engage in an exploratory manner (Petrich et al., 2013, p. 59). This is in line with Papert’s (1993b) constructionism learning view that builds upon Piaget's constructivism and states that learners construct knowledge when they build, make, and share their artifacts with not only their peers but the public as well. In the makerspaces, learners can make variety of items depending on the technology or tools available in the space. These range from but are not limited to phone cases, home amenities, toys, mugs, wheels, parts of equipment needed all using 3D printer, Use Laser tag engraving tools to engrave their metals or plastic personalizing them in the process, robotics where the learner put together robots based off problem to find solution or perform a task using the put together robot, programming where the learners program avatars to perform tasks and create games, and many more.

Within the makerspaces, instructors are mostly mentors whose role is to guide the learner during their making sessions (Blikstein, 2013; Honey & Kanter, 2013). They facilitate learning rather than dispense it something that constructivist proposes in a learning environment. New Technology in the makerspaces provide opportunities that put advanced and novice tools in the hands of the learners who in turn use these to explore, create, build, design, and program (Blikstein, 2013). Previous studies have shown that learners interaction with advance technology within makerspaces have led to powerful and generative creation of "ideas and artifacts" (Berland, 2008; Blikstein, 2013, p. 6; Petrich et al., 2013). These studies further expand the difficulties experienced by the learners on tasks within the makerspace "were due to deficient design rather than learner's cognitive deficiencies" (Berland, 2008; Berland & Wilensky, 2006; Blikstein, 2013, p. 6; Brahms, 2014; Petrich et al., 2013).

Blikstein (2013), in his study to identify how digital fabrication benefits learning amongst K-12 schools, reported three areas where making contributed to learning. The first benefit was that digital fabrication in makerspaces "enhanced existing practice and behavior" and it does so by "augmenting rather than replacing familiar and powerful practices that students already possess" helping students "recognize their own previous expertise in what they accomplish in the spaces, rather than acquiring a new identity altogether" (Blikstein, 2013, p. 7). Secondly digital fabrication in the makerspace increased the process of "ideation and invention" as students could fully commit their attention to improving their designs through iterative process of make, remake and remake again if they did not like their design "as opposed to reading a manual on how to transform an idea into a product" (Blikstein, 2013, p. 7). Not only did this enhance student's creativity but also greatly increased their self-esteem as they were able to bring back artifacts they made to share. Finally, Blikstein (2013) reported that makerspaces provided students with long term projects and deep collaboration as students could "engage in intellectual activities and practices that would not be possible anywhere else, and experience new ways of work and novel levels of team collaboration" (p. 7). Blikstein (2013) also reported that students were engaged and worked enthusiastically in creation and production of their products using available complex technology. Petrich et al. (2013) supported these findings as they found that learners took ownership of their learning by creating their own goals and developed these goals to maturity as they became familiar and confidence with the phenomena and materials. They further reported the iteration process of tinkering as learners pursued ideas, become frustrated, gain breakthrough through their own ingenuity and collaborations which enhanced problems solving, collaboration and creativity skills (Petrich et al., 2013).

With makerspaces, disciplinary boundaries are reconfigured as making process taps into all areas, and more so STEAM, leading to a more diverse learning opportunity for the students (Blikstein, 2013). Making and maker movement has widely been discussed in relation to Science, Technology, Engineering, and mathematics and later added Arts (STEAM) learning. Making and use of such advanced technology plays a big role in helping learners learn the STEAM content, as well as build interest and enthusiasm in young minds to learn these subjects (Petrich et al., 2013). For instance, programming with kids in a makerspace "reinvented differential geometry by adding computer algorithms to children's everyday bodily movements--forward, turn right, turn left, and 'robotics kits' added computational behaviors to familiar materials--crafts, Legos, wheels--and behaviors--'light up if dark, bounce off the walls,' follow the dark line" (Blikstein, 2013, p. 8). Science Technology Engineering Arts and Mathematics as such is part of tinkering and making but because there exists such rich study on STEAM and tinkering, this study will not focus solely on it. Making using carefully designed advanced tools added a technological layer to students' every day, familiar materials and practices providing them with a new form of expressiveness (Blikstein, 2013)

Makerspaces as Learning Communities

Makerspaces are embedded within the community making learning a social practice. Makerspaces provide opportunities for learning to occur within a community setting through collaboration, mentorship, and peer work. This is supported by the situated cognition and sociocultural learning theories that holds that learning is a social phenomenon as we learn from interacting with and within our society (Driscoll, 2005; Vygotsky, 1993). These theoretical frameworks further hold that learners can acquire new strategies and knowledge of the world and culture as they collaborate and work together in joint activities (Driscoll 2005; Vygotsky 1993). Learning, therefore, occurs when learners take part in the practice of the community and as such integrate knowing by doing (Driscoll, 2012). In learning communities, there is culture of learning which calls to advance the students collective knowledge which in turn advances the individual knowledge (Vygotsky, 1993). Students in a learning community come with different interests and experiences and the community provides them with the tools to learn new different things, therefore, equally distributing the expertise (Driscoll, 2005). In a learning community, social structure transforms into one in which the teacher and learner work collaboratively to achieve important goals that might as well have been established jointly (Driscoll, 2005, p. 177). When students are involved in a learning community, they build their knowledge within their community. Learners in the makerspace community are engaged in the process of developing a purpose, pursuing concepts and tools that will help them realize that purpose in a social context (Petrich et al., 2013). They work together with peers, instructors, and community as they make and form identity to what they make.

The Framework for 21st Century Learning

Learning in the makerspace can also be explained from the framework for 21st century learning. Partnership for 21st Century Learning (P21, 2003b) acknowledged that no longer are the three Rs enough to prepare learners for 21st century environment. This framework was geared towards updating the skills students were expected to be fluent in at the end of their educational experience from the three Rs alone to more interweaving skills relevant to succeed in the 21st century. To achieve this, they established, through collaboration with educators, business groups, community and government entities, well defined elements that capture skills today's' students need to be skilled, and proficient in as well as the support system that can help them achieve this (P21, 2003b). These skills, as seen in Figure 2.1, are broken into categories; "life and career skills, information media and technology, learning and innovation skills, content knowledge and 21st century themes" (P21, 2003b). These skills are not mutually exclusive as they work together to ensure students preparedness.

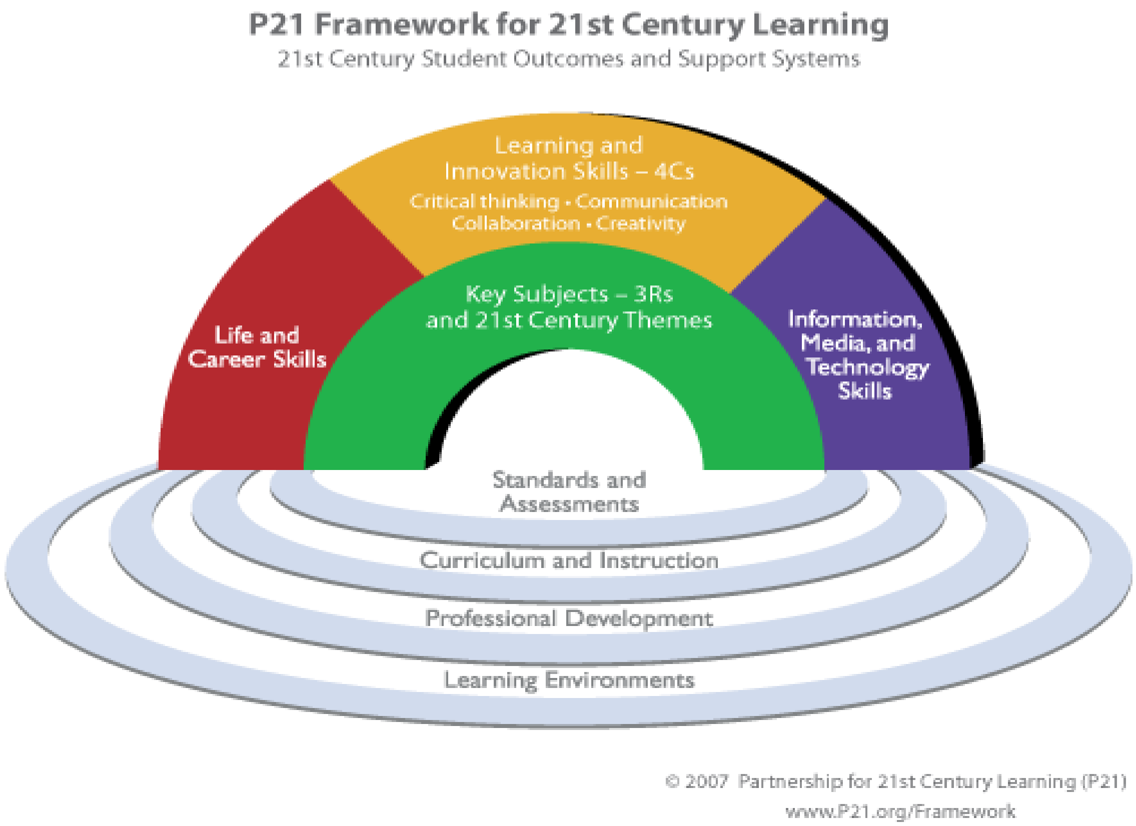

Figure 2.1. Partnership for 21st Century Learning framework for 21st century learning. Reprinted with permission from P21©2009 http://www.p21.org//

Partnership for 21st Century Learning stipulates that students must have knowledge and be experts in the core subject areas as stipulated in their curriculum as well as in civic, health, financial and global literacy to meet the content knowledge and 21st century themes skills (P21, 2003b). Teachers must provide and create learning environments that helps student gain life and career skills if they are to successfully navigate the challenging global, career environment. These skills call for students to be cognizant of the diverse rich cultures of today, be “flexible, adaptive responsible as well as take initiatives” (P21, 2015, p. 6). These skills are all not mutually exclusive and work together to ensure students preparedness. Learning and innovation skills, according to P21 (2003a), are geared towards equipping students with the four Cs (4 Cs); Communication, collaboration, creativity, and critical thinking skills. Today's students need to master theses fours Cs, in addition to the other set of skills earlier mentioned, if they are to be successful in the 21st century global community.

Critical Thinking and Problem-solving Skills

Partnership for 21st Century Learning (P21, 2015), defined this as the ability of a learner to “reason effectively both inductively and deductively as appropriate to the situation, ability to use system thinking, make judgments and decisions as well as problem solve” (pp. 9-10). Teachers today must strive to teach their students problem solving skills if they are to compare evidence, evaluate competing claims, inquire, and make sensible decisions in everyday life (Wagner, 2008). Problem solving and critical thinking skills provides the avenue for learners to develop improved thought processes, in depth analytical skills, higher level of concentration, systemic perspectives, and curiosity (P21, 2003a; Wagner, 2008). If these students are to be competitive in the global market, they must possess critical thinking as today workforce require their employees to problem solve and think critically of ways to better serve customers, develop better products and most importantly continually better themselves within the ever-changing global economy (P21, 2003a). With the dramatic change in corporations over the last twenty years, a learner’s specialty is no longer enough to define work, but rather the task or challenge worker is to solve and the end goal intended become part of the learner's specialty. As such the workers must use critical thinking and problem-solving skills to find these solutions making this skill one of the most important competencies needed to succeed in the workforce (Wagner, 2008).

Teachers and educators have constantly employed different methods in teaching and learning to help equip learners with critical thinking and problem-solving skills. Pray (2001) reported that online discussion forums have the potential to tailor learning to meet the diverse learning style and needs of students. Those asynchronous discussion forums provide the opportunity for learners to think through their contributions, discuss approaches to complex issues, apply theory to learning, and develop skills in appropriate critiquing of peer's work (Pray, 2001). In their study, Chiang, and Fung (2004) reported that online chat forums provide a learning environment for discussion and problem solving among students as they can post their topics, thoughts and viewpoints and collaborate in being problem solvers with teacher assuming the coach role to guide, provide suggestions in steering a problem, and interactively joining the discussion. The learners together can think of different ways to solve the issue and problems that come by building on to each other's knowledge (Chiang & Fung 2004).

Communication

This skill is defined by P21 (2003b), as the ability of students to communicate clearly by "articulating their thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of contexts and forms, listen and effectively decipher meaning, communicate effectively in a diverse environment and use communication to inform instruct, motivate and persuade" (P21 ,2003b, p. 15). The ability of individuals to clearly express their views in a democracy as well as communicate effectively across culture is a prerequisite in global economy (Wagner, 2008). According to North Central Regional Educational Laboratory (NCREL) and Metiri Group, (2003), to succeed in today's global world, students must possess effective communication skills and technology can facilitate this need. North Central Regional Educational Laboratory (NCREL) and Metiri Group (2003) further acknowledge that the presence of various information and technology tools require learners to be competent in communication skills to succeed in the 21st c century global economy. Wagner (2008) added that students must also be able to access and analyze information from multiple sources, discern meaning from them, and effectively communicate and relay this meaning.

Many web 2.0 tools can be integrated in the classroom setting to help students master communication skills. Previous studies reported that blogs are a good avenue for communication and interaction and their interface allows for self-expression and recounting of personal events to the blogger community, allowing teachers to facilitate learning communication skills through dialog and storytelling as students are free to express and support their own ideas and opinions fluently (Huffaker, 2005; McGrail, & Davis, 2011; Otieno, Schulz, Tankovich, Wang, & Gall, 2013). Social media tools, for instance twitter, Facebook, Pinterest, when effectively integrated can help students master oral, written, and reading skills in the classroom as students need to think strategically how they convey and receive information with and from peers (Foote, 2013). Other studies reported that students use social networking sites to communicate and discuss academic issues, and meet their academic goals both formally and informally (Greenhow & Robelia, 2009; Mazer, Murphy, & Simonds, 2007; Otieno et al., 2013).

Collaboration

This set of 21st century skill has been defined by P21 (2003a) as the ability of the student to be able to "work effectively and respectfully with diverse team, exercise flexibility and willingness to be helpful in making necessary compromises to accomplish common goal, as well as ability to assume shared responsibility for collaborative work, and value the individual contributions made by each team member" (P21, 2003b, p. 21). Students must learn to work together with peers to produce "extremely inclusive and valuable resources" (P21, 2003b, p. 20). Because of globalization and rise of technology, this skill has not only become necessary but vital as it generates a more holistic result and intelligent decision necessary to succeed in today's global society (P21, 2003a). According to Wagner (2008), various multinational corporations today require workers to be proficient in working with networks of people from different cultures as well as across boundaries. This skill works hand in hand with global awareness to ensure students are conscious of the diverse nature of today's global environment (P21, 2003a).

Teachers have used the many web 2.0 resources like, wikis, blogs, discussion forums, videos, and podcast to help learners collaborate and build this skill (Boling, 2008; Huffaker, 2005; Miller & Shepherd, 2004; Otieno et al., 2013). In a study conducted by Churchill (2011) the use of blogs in the classroom was found to enhance student collaboration. The researcher reported that students could share their reflections, give, and receive constructive feedback freely and willingness to make corrections based off these feedbacks (Churchill, 2011). Wikis, another web 2.0 tool, have also impacted teaching positively in terms of teaching student's collaboration skills (Boling, Castek, Zawilinski, Barton, & Nierlich, 2008; Doult, & Walker, 2014; Huang & You-Lin, 2011; Otieno et al., 2013; Warschauer & Grimes, 2007). Other studies also reported the use of social networking tools to equip learners with collaborative skills (Lampe, Wohn, Vitak, Ellison, & Wash, 2011). By connecting students in informal learning environment, social networking sites allow students to learn through the process of collaborative sense making (Lampe et al., 2011). In addition, previous studies have reported the use of mobile devices and mobile apps in helping improve learners' collaboration (Ciampa & Gallagher, 2013)

Creativity

Defined as the ability of the learner to "think creatively, work creatively with others and implement innovation" this skill requires teachers to equip their students with the ability to regularly innovate and create to succeed in a professional and personal capacity. (P21, 2003b, p. 26). Soulé and Warrick (2015) referred to these skills as one that plays an important role in the framework as learners are required to use wide range of idea creation techniques in today's world to succeed in the workforce. Not only do they need to put their creative caps on, but students should also be able to effectively and efficiently communicate these new ideas to others, work creatively together to reiterate, develop, and implement such ideas as well as demonstrate responsibility, self-direction, and productivity in the workplace (Soulé & Warrick, 2015). Students need to be ready for the global world that currently requires individuals who are self-starters, ones that take initiatives and are entrepreneurial (Wagner, 2008). In a study to determine the relationship between technology and creativity among students, Jackson et al. (2012)

found that educational videogames had a role in helping students perform better in creativity assignments. Integration of mobile games applications have been seen to create a learning environment that allows for healthy competition among teams which in turn are motivational and engaging to the students allowing them to creatively work with their peers (Ciampa & Gallagher, 2013).

Literature and past studies provide evidence that different technologies have been used to help learners enhance their 4 Cs, however, little research exists that shows how makerspaces achieve similar results if any.

CHAPTER IV

METHODOLOGY

Chapter Introduction

The aim of this case study was to understand the pedagogical practices of instructors in makerspaces, how these pedagogical practices in the makerspaces are contributing to students learning, and acquisition of 21st century skills. The following research questions were examined:

Q1 How does pedagogy manifest itself in a technology rich makerspace environment?

Q2 How does learning happen in a technology rich makerspace?

This chapter specifically covers case study methodology, discusses sampling, participants, data collection procedures, and ethical issues with this type of methodology.

Research Design and Rationale

This study used qualitative research design, that is, it "begins with assumptions and the use of interpretive/theoretical lens that inform the study of research problems addressing the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2007 p. 37). Qualitative researchers collect data in natural settings that are unique and sensitive to the participants of the study and they use both inductive and deductive analysis methods to explore patterns and themes from the data (Creswell, 2007). Exploring a problem or issue drives qualitative research as I developed a complex detailed understanding of makerspace pedagogy and learning. This can best be addressed through multiple data sources such as observation, narrative, and listening to the real stories of the makerspace instructors and students who have and are experiencing a makerspace community to better understand the makerspace environment (Creswell, 2007; Merriam, 1998). It is for these reasons that I chose to use qualitative research methods to understand instructors in makerspaces pedagogical practices as well as how makerspaces are contributing to students learning and proficiency in the 21st century skills.

Defining Case study

There exists a major varying in definition of case study and what it means to different researchers. Yin (1994) for instance defined case study in reference to the process of the research. To Yin (1994) a case study is an "empirical inquiry that investigates a contemporary phenomenon and context that are not clear" (p. 13). Creswell (2011) on the other hand categorizes a case study as a type of ethnographic study and defines it as an 'in-depth exploration of a bounded system based on extensive data collection" (p. 465). The bounded system in this instance could be 'activity, events, individuals and means that the case is separated out of research in terms of time, place or some physical boundaries' (Creswell, 2011, p. 465). Merriam (1998) specifically defined case study as "a holistic description and analysis of a single instance, phenomenon or social unit" (p. 27). Despite the different definitions, the common denominator in all these is that a "case is a thing, single entity, and a unit around which there are boundaries" (Merriam, 1998, p. 27). A case can, therefore, be a student, teacher, principal, program, school, and a class, individuals in a group or separately, community and activities (Creswell, 2011; Merriam, 1998).

For this study, I used instrumental multiple case study strategy as I believe studying and observing informal and formal makerspace settings allowed me to represent "diverse cases that will fully describe multiple perspectives on the issue of makerspace, learning and its influence in education" (Creswell, 2011, p. 129). Case study in this research allowed me to investigate makerspace instructor's pedagogical practices, beliefs, and process that they use within these learning communities to facilitate learning. It also allowed me look in-depth into complexity that informal spaces play in the learning using new available technology.

Case Study Rationale

Understanding makerspace instructor's pedagogical practices, beliefs, and process they use within this informal learning community to facilitate students learning, as well as understanding the complexity that informal learning spaces plays in the learning using new available technology, and how these spaces equip learners with 21st century skill requires understanding of the culture of these informal spaces, and learning communities. Given that there is little research that exists on makerspaces conducting prolonged observations in the natural setting to see how makerspaces influence learning provided me with authentic data to inform the field of technology integration in education. In addition to prolonged observation of teachers and students in their natural settings, observations allowed me as the researcher to put more emphasis on discovering the meaning these technologies use and interactions must both teachers and students (Lee, 2006).

Setting

This study took place in a library and middle school makerspaces in the rocky mountain area. I observed the technology integration process in the natural setting, makerspaces, as well as conducted interviews with the instructors.

Library Makerspace

The first setting was library makerspace. This makerspace is in a public library within the rocky mountain region. The library is among seven others in the county serving a patron population of 368, 652 users and 144 librarians and other staff (Library Research Services, 2016). It is in this space that STEAM activities are mostly carried out. Tools available in the space include Makerbot 3D printer, sewing machines, digital photography lab with multiple digital SLR cameras, three mac desktop computers, about twenty laptop computers, software programs like sploder for videogames and 3D model designs, toys for younger age groups such as kibo, and other supplies for DIY crafts and textile projects. Except for the laptop computers, the rest of the tools were strategically located around the room. Up against the wall were most resources, in the middle of the room were three tables and chairs. Laptop computers were always set on the tables and users would work from these computers. They would freely move around the space to access the resources if they needed to. The studio itself is walk in and open to any age groups. The library offers programs/lessons on the use and creation with these tools to users of all age groups. These programs are offered throughout the year to the public and are facilitated by the library staff. For this study, I specifically focused on the younger age group, 10 to fourteen years of age, patrons attending the makerspace programs to learn and tinker. Technology provides opportunity to equip students with hands on activities that foster acquisition of 21st century skills as stipulated by P21 (2013a), and given that makerspaces provides access to some of these resources and space to tinker, it is crucial to determine how this space is helping prepare these young people for the global world and how the instructors within the space are enhancing this acquisition.

There were three librarian guides that specifically cater for instruction in these makerspaces. Each instructor was responsible for guiding specific instruction activities in the space in an area of their specialty. I observed three 3D modeling and printing sessions with one instructor and one game design and 3d printing session with the second instructor. Each session lasting for an hour and half.

Middle School Makerspaces

Middle school #1. In this makerspace, the teacher/instructor provide different activities for the students that focuses on STEAM within the school scheduled timeslot of forty-five minutes each session. The makerspace is used in the school's "Advanced Robotics," "Science/Technology," "Computer Science," "Introduction to Engineering," "Digital Media," and "Electronic Publications" scheduled courses. This makerspace was the biggest among the three observed. It had four sections. First section was the classroom study area with round tables and chairs facing the smartboard and teacher desk. The other section was an office, a student display and work in progress station, a small library with reference resources, a secluded area with 3 desktop computers and workout space and finally a computer lab with about thirty-three individual desktop computers facing the teachers station. Apart from the desktop computers, the space also had Makerbot 3D printers, laser cutter and engraving tool, cart system iPads, software for design, gaming, and coding. Students had access to all these resources. For safety reasons, the teachers monitored access and gave an okay for high end tools. I observed two sessions each in this makerspace with sixth and seventh graders. The first two observations were engineering making class with sixth graders. The second two observations were with seventh graders 3D design class. A thirty-minute interview was also conducted with the instructor on their pedagogical practices at the makerspace.

Middle school#2. This was a regular art classroom that the teacher turned into an art makerspace. In this makerspace, the teacher provided art related making and tinkering within school 45 minutes' time slot. The activities varied depending on the lesson day. The room had tables and chairs in the middle space where students would seat and work, these faced the teacher's projector, tools and resources all strategically located close to the walls around the room. There was one iPad cart system, painting resources, class station with all pottery materials, pottery throwing tools, sewing stations with fabrics, and other materials for sewing. I observed three class sessions with sixth, seventh and eighth graders. A thirty-minute interview was also conducted at the end of the sessions with the instructor.

Sampling

I purposefully sampled these makerspaces locations because they have access to diverse "technology" resources and offer lessons/instructions to students and facilitate the making process throughout the sessions. This was important to this study as the intention was to determine the pedagogical practices of these teachers in the makerspace and how they facilitate learning. According to Creswell (2011) purposeful sampling applies to both individuals and site and is appropriate when the researchers want to "learn or understand the central phenomenon" and specific group of individuals, or person's best informs this phenomenon (p. 206).

Participants

The participants for this study were adult instructors teaching in an informal and formal makerspace. Creswell (2007) states that a researcher can identify a group of individuals and define them as a collective case to study. A careful sampling plan must be executed by case study researcher to select informants and case that provide important insight to the study (Creswell, 2007). The participants selected for this study provided diverse views and opportunity to learn about making and tinkering in the makerspaces (Creswell, 2007). The instructors were the ones offering instructions and lessons using the technology tools available within the makerspaces making them vital informants in this study (see Table 3.1).

As a result of the new nature of makerspaces as learning environments, participants for this study were purposefully sampled because they better informed the study goals of identifying the pedagogical practices in these unique spaces and how these practices contribute to learner's acquisition of the 21st century skills. The library and school provides for a diverse group of individuals who share makerspace experience.

Table 3.1

Participants' Demographic Information

Instructor	Demographic Information
Ms. Josephine*	Library Guide Age: 30 Years as a guide: 7 Users catered for: All age groups Program observed: 3D design and printing (3 classes) Guides: All age groups Age group observed: k-8th graders
Mr. Jackson*	Library Guide Age:30 Years as a guide:6 Users catered for: All age groups Program observed: Gaming-video game creation Guides: All age groups Age group observed: K-8th graders
Ms. Anne*	Art Teacher Age: 31 Years teaching:7yrs Years teaching in a makerspace: 2yrs Grade level: 6, 7th & 8th (middle school) Classes observed: 3 Art making sessions
Mr. Mike*	STEAM science Teacher Age: 31 Years teaching: 5 yrs. Years teaching in a makerspace: 2 years Grade level: All grades (Elementary through high school) Classes observed: 4 middle school classes (Two with 7th graders, 2 with 6th graders)
Ms. Ashley*	Library guide Age: 29 Years as guide: 5 Programs: Art and designing Age group: All ages No observation done

Note. All teachers were interviewed but only four were observed as they taught in their Makerspaces.

* Pseudonyms used at all times.

Gaining Access

I submitted a research request with the library and middle school explaining the purpose of the study, the process that the study was to include, data collection procedure, time frame, and adjustments if needed. I visited the sites to establish rapport with the instructors, administrators and discussed my role and research goals and what that involved in the classes/sessions. This was a great opportunity to establish scheduling and when the instructors were comfortable having me in the classes depending on activities at hand. Once the approval letter was obtained, I sought University of Northern Colorado Institutional Review Board (UNC IRB) approval for data collection to commence. After UNC IRB approval, I met with the instructors again to work out final plan and went over the purpose of the study, data collection procedures and my role in the classroom as an observer. The instructors and administrators were issued copies of the documents such as purpose of study and consent forms. The first week on site was strictly used to gain rapport with the instructors in the makerspace learning environments. This time allowed for an observation of the culture, norm, and practice of the makerspace studios as well as an opportunity to interact with the instructors and guides and see the flow of things in the space. As Creswell (2007) advises, on first day of observing have "someone introduce you if you are an outsider, start with limited objectives, take few notes and simply observe transitioning gradually from an observer to an active observer" (p. 135). On the first day of observing at all locations, I let the instructors introduce me as it seemed appropriate and less disruptive for their students. My only request was to let the students or users know that I was someone who was there to join them in their tinkering and just observe the class and learn from them. This took away the "power imbalance between me as a researcher and participants" as they were less attentive to me and what I was doing and continued to tinker and make as they would daily (Creswell, 2007, p. 124). This turned out to be critical in helping me interact with them later in their making process.

Data Collection Procedure and Tools

Multiple rigorous data are vital in any qualitative case study to help the researcher build an in-depth picture of the case (Creswell, 2007). In this study I employed multiple, rigorous data collection procedures using observations, interviews, students, and instructor's artifacts, as well as open ended questionnaire to better inform the research questions and gain better understanding of practices in the makerspaces (Creswell, 2007; LeCompte & Schensul, 1999, p. 2; see Appendix B). Triangulation of theses multiple data helped inform this study and ensure credibility of data collected.

Observations

Instructors and students were observed during the rich technology integration lessons for a period of approximately six months. According to Creswell (2007), observation in case studies offers the researcher "possibility on a continuum from being a complete outsider to being a complete insider" (p. 132). The observation process was in twofold. I first shadowed the instructors as they prepared the classroom or studio for activity to see how they set up at the makerspace, how they design their activities, and the decisions that goes into the activities. Shadowing them through this process helped me be part of the process and see from their lens the planning process. I took field notes during this process.

Secondly, I observed the instructors during sessions as they taught, guided, and helped students/users with making, and tinkering. During this time, I also observed the users/learners as they interacted with and used technology in the makerspace. I mainly looked at how they were making, what were they making, what questions, goals drove their design and how much help did they seek from both peers and instructors. During this observation process, I took field notes and as well as used Creswell (2007) Observation protocol matrix to record some descriptive and reflective notes. These were later transcribed and analyzed in the results (see Appendix A). Creswell (2007) divides the observation notes into Descriptive and Reflective notes. The "descriptive notes" were used to summarize and record chronological description of activities while the "reflective notes" were used to record the reflection and summary conclusion about the activities" Creswell 2007, p.138).

Interviews

In addition to observing, I conducted interviews with the instructors in the makerspace. These interviews were very crucial in this study as they allowed me to make connections with what I observed in the space and instructors goal, perceptions, and thoughts on their instruction strategies. The interviews lasted from twenty to forty minutes. Non-structured interview question guided the interview process. The sessions were audio recorded and transcribed for analysis. All interviews were conducted in the makerspaces after the last observation as requested by the instructors.

Artifacts

I also collected artifacts from both instructors and students. From the students, photographs of their completed works as a result of technology integration in the makerspaces were acquired. Any identifiable data from student's work were stripped off and could not be traced back to the students. These were mainly pictures of their products that they created using available technology in the makerspace. From the instructor's mentor texts, lessons plan and pictures of the space itself were collected. I also took pictures of the space itself and how the setup looked like.

Field Notes

Field notes were collected from the entire study as I observed interviewed and interacted with the group in the makerspace environment. I wrote everything down on a notepad. The field notes entailed mostly what I observed in the makerspace setting, the verbal responses from the instructors and students in the space, as well as commentary notes such as general feelings while observing, reactions, hunches, initial interpretations as well as working hypothesis (Merriam, 1998). Included in the notes were direct quotes, description as well as comments seen in the spaces. After the session, these were typed out in a word document as soon as I got home. According to Merriam (1998), an investigator should dictate type and write full notes immediately or as soon after the observation is complete.

Personal Journal

In addition to field notes, I kept a journal I used to record questions, tentative interpretations, and integrative memos to assist me in making decisions and plans for the next observation (Creswell, 2007). This journal was used to reflect on my prior experiences as an instructor who has technology knowledge and how that influenced the observation if at all. Using the journal allowed me to reflect on the sessions and stay objective during the consecutive observations. Using this journal helped me further address ethical issue that arose during the study and how I addressed them to increasing the credibility of the study. One big one was interaction with the student's users in the space. How long could I stay passive in the space when I was called upon often to assist.

Data Handling and Analysis

Data Handling

Before any data analysis procedures began I took some steps to prepare it for analysis. Throughout the study, I kept all field notes, artifacts (mental texts, images of student work, images of the space itself) and journal in password protected folder. All data were organized and named by date and topic they represent for easy retrieval and analysis access.

Data Analysis

Qualitative research data analysis entails "preparing and organizing the data, reducing the data into themes through process of coding and condensing the codes, and finally representing the data in figures, tables or discussions" (Creswell, 2007, p. 148). Having organized the data, retrieval for analysis was made easier. Data analysis began with first transcribing the recorded interviews and observation sessions. I then designed a data analysis matrix to help organize my analysis process (see Appendix C). I employed within-case and cross-case analysis (Creswell, 2007; Merriam, 1998). I specifically chose these because I observed and collected data from multiple cases, three to be precise, as these better informed my research questions (Merriam, 1998). In addition, I used Glaser and Strauss (1967) constant comparison analysis technique.

Constant Comparison Analysis

Glaser and Strauss (1967) stated that in constant comparison data that is gathered from multiple data sources is written and recursively analyzed. As I observed and collected field notes, I constantly read and reread the notes identifying and noting initial codes that come up. This process was repeated after each observation.

Within-case Analysis

As Merriam (1998) stated, in a multiple case study the process of data analysis is in two folds, within case analysis and cross-case analysis. Using within-case analysis first, I looked at each case as "comprehensive in and of itself" (Merriam, 1998, p. 196). I analyzed the field notes transcripts, journal observation protocol transcript, interview transcript and artifacts collected from each case independently and recorded these. Looking at each case independently was vital in identifying the local dynamics within each case and understanding the "contextual variables" in each situation (p. 194). The coding process followed that stated by Creswell (2007) of developing "lean codes" which are short number of codes and then expand these categories as data review continued. These individual codes from all data were then compared to the original codes gained from constant comparison analysis. Once all the lean codes were gained I then used focused coding technique to further seek out the codes that are most significant and frequent (Creswell, 2007). From the coding step, data analysis process moved to the classifying stage where the information was analyzed for "dimensions, themes, and categories after which both textural and structural description of these were written" (Creswell, 2007, p. 153).

Cross-case Analysis

Once within-case analysis was completed, I used cross-case analysis method as stipulated by Merriam (1998) to "build abstraction across the three cases" (p. 195). I wanted to identify any similarities or differences and any patterns that transcends across the cases. By identifying the underlying codes across cases I refined the codes and come up with themes across the data that were part of the results.

Ethical Consideration: Personal Stance, and Trustworthiness

Researcher personal stance. Merriam (2009) outlined the importance of maintaining a reflexivity as a researcher since they are the primary agents for data collections. She noted that it was nearly impossible for a researcher to entirely separate their values and beliefs to reduce influence in their research. For this reason, researchers should strive to provide a clear explanation of their beliefs, biases, and assumptions to help readers understand how they arrived at interpretations and conclusion (Merriam, 2009). As an instructor and educational technologist and student I share some similar classroom behavior and practices with my participants. I, however, made a conscious note to myself to distance my own practices and beliefs during the study using epoche technique as well as keeping a journal after each observation (Creswell, 2007; Merriam, 2009).

Trustworthiness. In any qualitative study, the researcher must ensure a non-biased representation of views, opinions, and experiences of the informants. Many researchers have suggested reflexivity and careful note taking of the process of the study and conducting the investigation in an ethical manner (Creswell, 2007; Merriam, 1998; Wolcott 1990). There exist some ethical issues that researchers must consider and be cognizant of when using any qualitative research. Because I was in the field observing and collecting data for six months I carefully addressed and negotiated entrance with instructors ahead of time, exited the site gradually once my data collection reached saturation, interactions with participants and students in the space were initiated once an okay was obtained from teachers and students.

Due to the qualitative nature of this research, as the sole investigator, I conducted the study by carefully following ethical standards set in a qualitative study. Merriam (1998) suggested that qualitative researchers can ensure trustworthiness of their study through "triangulation technique, member checks, long-term observations, peer-examinations, participatory or collaborative modes of research and identifying researcher biases" (p. 205).

This study employed multiple sources of data to confirm emerging findings, peer-examination was sought, as well as qualitative expert review. This study also involved long-term repeated observation on sites. As the sole researcher and education technology instructor I identified my bias and tried as much to separate that from the process. Techniques such as epoch (suspending Researcher's biases), graphic diagrams and reclassification of categories into themes were employed (Merriam, 2009).

Theoretical Framework

Constructivist and Papert's Constructionism theory guided this study. Constructivist learning framework holds that learning takes place through actively engaging the learners in meaningful activities, that learning is an active process of meaning making gained in and through experience and interactions with the world, that learning opportunities arise as people encounter cognitive, challenge, or puzzlement, and through naturally occurring as well as planned problem-solving activities, that learning is a communal activity involving collaboration, negotiation, and participation in authentic practice of communities, learners taking responsibility of their learning by setting their own goals and regulating their own learning, and finally that assessment is embedded naturally within the learning activities (Driscoll, 2005; Duffy & Cunningham 1996; Reiser & Dempsey, 2012; Vygotsky, & Cole 1978). The goals of constructivist learning entail problem solving, reasoning, critical thinking, active and reflective use of knowledge and rather than emphasize product of learning, this learning theory emphasizes process of learning (Driscoll, 2005; Papert, 1993a). Piaget proposes that learners gain knowledge through engaging in personally meaningful experiences (Driscoll, 2005). Despite its cognitivist angle, Piaget's theory acknowledges that learning does not entirely happen in the head of the student but rather is also influenced by external factors (Driscoll, 2005).

Papert's (1993a) constructionism theory builds on constructivist framework and goes beyond building knowledge to incorporate learners consciously building and constructing a "public entity or artifacts" (p. 142). Papert's learning framework established learning through making. The approach helps educators understand how different media can be used to express and transform multiple ideas in different context (Ackermann, 2001). To Papert, learning happens when the learner's thinking is worked out through the making of external artifacts that "can be shown, discussed, examined, probed, and admired" a distinction from constructivist where leaner build knowledge (Papert, 1993a, p. 142). Learning is as such the central focus of constructionism as it intends to determine how we learn by constructing, making, and doing (Papert, 1993b). To Papert (1993b), therefore, we learn when we make knowledge and artifacts that portray this knowledge.

Making in the makerspace involves interactions with peers, instructors, mentors, technology, and materials available in the spaces, creating artifacts, as well as collaboration, problem solving, and guided instructions. The process of making and tinkering is fairly explained by constructionism and constructivist theoretical frameworks. I used the tenets described in these theoretical frameworks to understand making in the makerspaces, the pedagogical practices that occur and how learning occurs in these environments from instructors' points of view.

Limitations of the Study

This study had few limitations to it. In determining learning in the makerspaces, I was not able to interview students and use that as part of the data. All data represented as evidence were from instructor's perspectives and what was observed in the space. Future studies must find more statistical and empirical results from students to further strengthen evidence of learning in the makerspace.

CHAPTER V

PEDAGOGICAL PRACTICES OF MAKERSPACE INSTRUCTORS

To be submitted to a top Journal in Technology Education
Specific Information withheld for Journal Blind Review
Process Single Author Manuscript

Introduction

Many educators have called for the need for education to move beyond the 19th century teaching and learning habits and instead adapt strategies and mindset that not only help students master content they need to, but also the 21st century skills to help them succeed academically and globally (P21, 2009; Wagner, 2008; Washor & Mojkowski 2013). The call for teachers to create learning environments that help students be critical thinkers, problem-solvers, effective communicators and work efficiently with others in a vast globally world cannot be emphasized enough (P21, 2009). Makerspaces are such learning environments that proponents argue will help educators tackle part of this issue and hopefully reform education (Dougherty, 2013; Honey & Kanter 2013; Martinez & Stager 2013; Petrich et al., 2013). Defined as spaces where individuals can freely make, tinker, innovate and create, makerspaces are becoming quite a phenomenon (Dougherty, 2013). Makerspaces call for educators to foster the maker mindset among learners, the mindset that they can turn ideas into creative realities, they can use the knowledge gained to be innovators (Honey & Kanter, 2013). Making and tinkering mindset within these spaces strive to help learners learn through making. As rising phenomenon, Makerspaces are positively pushed for by the need for our learning environments and education to provide environments that brings out and sustains the curiosity of young minds instead of stifling it by extrinsic goals and expectations as mostly called for in schools setting (Honey & Kanter, 2013). As learning environments, makerspaces are designed to be supportive, challenging, and engaging learners in meaningful activities which in turn can rekindle their natural motivation to learn (Honey & Kanter, 2013). Pure Instructionism pedagogy has worked in equipping students with the set of skills it needed to but with the evolution of learning spaces and technology integration, skills required of learners has changed. With Instructionism pedagogy there exists two set of students, ones who succeed academically in areas they were told they were good at limiting them to explore and reach their full potentials, and one that struggle in those specific confines and have given up due to the harsh judgments not allowing them to explore new skills, and capabilities to reach their full potentials (Martinez & Stager, 2013). Making in the makerspaces strives to remedy this and provide opportunity for growth in one's full potential. With the evolving technology, not only has opportunities for integration become imminent, making and tinkering has also become much easier.

Past studies have focused on the impact and influence makerspaces have on learning, but little research has looked at the strategies and methods used by makerspace instructor that make them so successful. In this study, I asked the question how exactly are makerspaces instructors helping learners make? What teaching strategies are makerspace instructors using in these spaces that allows for such transformative learning?

As an educator, I wanted to keenly observe learning and teaching in a makerspace environment to identify exactly how pedagogy in such space helps learners take on the maker mindset. Through multiple observations and interviews with makerspace instructors, I looked keenly at their teaching strategies in the space, the resources available in space and interaction between the instructors and their learner and how these fostered the learning that most educators are calling for. The purpose of this qualitative case study henceforth, was to examine the pedagogical practices of makerspace instructors in both formal and informal makerspaces. Four makerspace instructors were observed and interviewed for a period of six months. All sessions occurred within the makerspaces.

Literature Review

A thorough review of the literature was conducted to understand the breadth and depth of current research in makerspaces as well as showcase how pedagogy has evolved and influenced teaching and learning in innovative learning environments, case in point Makerspaces.

Learning Theoretical Frameworks and Their Contributions to Pedagogy

Pedagogy has evolved over the years mostly influenced by the learning theories including but not limited to behaviorists, cognitive information processing, situated cognition, constructivist, and constructionist learning theories (Driscoll, 2000; Gagné, 1977). Pedagogy involves selecting strategies and methods to use in a learning environment that best meets the learners learning needs and learning objectives set. For us to understand pedagogy and best conditions to provide for learning objectives to be met, we must first understand the learning theories, what needs to be learned, and the learners themselves.

Behaviorist

According to this theory of learning, we acquire new knowledge by responding to reinforcements, both positive and negative, from the environment and this shape our behavior (Driscoll, 2005; Keller, 2010). Teachers for years have and continue to employ behaviorist principles to manage learning and behaviors in the classrooms and individualized instructions. Most often teachers use behaviorist principles in classroom managements situations by reinforcing certain desirable behaviors from the students, identifying and clearly stating instructional objectives and determining achievements from observable behavior after instructions (Driscoll, 2000; Gagné, 1977). Based on this theory of learning instructor role in the teaching and learning environment is that of the dispenser of knowledge most often and students understanding is checked through change into the desired behavior outcome which is most often teacher directed/determined.

Cognitive Information Processing Learning Theory (CIP)

Unlike the behaviorist, CIP proponents believed that not only did external or environmental aspects influenced our learning but between the behavior and environment, the learner processed the information they obtained in their brain like a computer processor (Atkinson & Shiffrin 1968; Ausebel, Novak, & Hanesian, 1978; Driscoll, 2005; Gagné, 1977). That the information we sense is stored in memory, retrieved when needed and output in the form of learning outcome desired. In understanding the learners CIP, teachers can design instruction and employ strategies that reduce cognitive overload and instead helps learners process new information all the way to the long-term memory for retrieval and connection making. These strategies include organizing and scaffolding learning if learners are to make sense of the new information, signaling what information is important to increase selective attention, using multimodal resources, creating learning environment that allows for “perfect practice” and context where these can be applied, and help learners be more metacognitive of their learning process and self-regulate (Driscoll, 2005; Gagné, 1977). Teachers must also activate learners’ prior knowledge so they can relate to the new knowledge being learned providing better chances for long term memory. Using CIP teaching strategies, instructors also emphasize on reducing learners cognitive overload if learning is to be meaningful.

Situated Cognition Learning Theory

In this framework, learning is defined as happening in the sociocultural setting as opposed to individual (Driscoll, 2000). That we acquire knowledge from our interactions with other people in our society (Bruner 1997; Driscoll 2005; Vygotsky, 1978). This framework influence in pedagogy ranges from the need for teachers to provide apprenticeships opportunities as well as “projects in which the instructors can models desired skills and coaches’ learners as they attempt to follow suit” (Driscoll, 2000, p. 175). In addition, teachers can provide real world problems that students can solve, and instead of being the knowledge dispenser they work collaboratively with the students to meet the learning goals set. In this class, the classroom becomes a learning community where students can bring their interests and experiences and teachers provide support and resources to help learners through this process. Assessments are also defined in this framework. No longer are summative testing enough to determine students' success in the social practice but instead the teacher employs formative assessment throughout the course period by identifying progress during activity, collaboration with peers and learning in the class community.

Constructivist

Other theoretical frameworks influenced learning for a long time and by the time constructivist learning theory come into the picture instruction in the classroom was being redefined. Constructivist is like a mash from multiple scholars, psychologists, and education pioneers. To this framework learning occurs as learner "construct knowledge as they attempt to make sense of their experiences" (Driscoll, 2000, p. 376). In contrast to behaviorist learners are "not empty vessels waiting to be filled but rather are active organisms seeking meaning" (Driscoll, 2000, p. 376). For learning to occur as per constructivism theory, certain conditions must be provided by the teachers in the learning environment. These conditions according to Driscoll (2005) could range from;

> Embedding learning in complex realistic and relevant environments, providing social integration as an integral part of learning, supporting multiple perspectives and the use of multiple modes of presentations, encouraging ownership in learning and finally nurturing self-awareness of the knowledge construction process. (p. 393)

Teachers as such can integrate multiple teaching strategies to meet the conditions and help learners learn. They need to provide rich student-centered learning environments where authentic experiences are emphasized, creating a safe learning environment where learners can collaborate and work together freely, design effective goal- based and problem-based learning allowing learners to pursue think critically, and problem solve and work through tasks efficiently.

Constructionism

Constructionism builds on to constructivist learning theory and emphasizes learning through making. Constructionism goes beyond building knowledge to incorporate learners consciously building and constructing a "public entity or artifacts" (Papert, 1993a, p. 142). Constructionism helps educators understand how different media can be used to express and transform multiple ideas in different context (Ackermann, 2001). To Papert, learning happens when the learner's thinking is worked out through the making of external artifacts that "can be shown, discussed, examined, probed, and admired" a distinction from constructivist where leaner build knowledge (Papert, 1993a, p. 142). To Papert (1993b), we learn by doing and teachers need to redefine success in the learning environment as learning is a process and iteration is key. Collaboration while making, as well as seeing technology as a tool to create and build, plays a big role in successful learning. Teachers as such must provide innovative learning environments where students can create and make and identify ways to assess this learning process. Martinez, and Stager (2013) stated that teachers can use constructionism principles to implement constructivist learning.

Gagné's Theory of Instruction

Gagné proposed conditions of learning that teachers and educators must allocate if learning is to be successful. He identified multiple learning outcomes desired, verbal, intellectual, cognitive, attitudes, and motor skills (Gagné, 1977). Once a teacher has identified these then they must provide learning conditions that helps learner be fluent in those learning outcomes (Gagné, 1977). He designed nine events of instructions that teachers have referenced to and used for years. These include, gaining attention, informing the learner of the objective, presenting stimulus, providing learning guidance eliciting performance, providing feedback, and assessing performance (Driscoll, 2005; Gagné & Medsker, 1995). For years Gagné's theory of instruction has been used by teachers and instructional designers to effectively design instruction that are learner centered.

Teaching in the Makerspace

Teaching in the makerspace has been influenced by all these frameworks and instructional theories. Dougherty (2005) referred to makerspaces as publicly-accessible places to design and create. They are mainly characterized by informal spaces where people of all ages can go to learn "tinker" and "make;" terms synonymously used to refer to act of "designing and producing things for sheer pleasure of figuring out how things work and repurposing them at will" (Honey & Kanter, 2013, p. 5). Makerspaces are in both formal and non-formal environments such as museums, libraries, and schools. Resources in makerspaces often vary depending on the facility space and funding available but quite common ones in any space are microcontrollers, 3D printers, other fabrication tools, Video and media tools, robotics tools which individuals use for fast prototyping, and explore questions, fail, and retry, bounce ideas off one another and build something together. Because the makerspace learning environment is not like traditional classroom, teachers must redefine their teaching strategies and what learning looks like in the setting. Many makerspaces researchers have referenced constructionism as guiding framework in these learning spaces and have further pinpointed teaching methods as proposed by Papert to be effective in a makerspace (Dougherty, 2013; Honey & Kanter, 2013; Martinez & Stager 2013; Petrich et al., 2013). Martinez and Stager (2013) referred to makerspace classrooms as “active classroom” where students are engaged and often working on multiple projects (p. 83).

Research Question

The following research question guided this qualitative case study**:**

Q1 How does pedagogy manifest itself in a technology rich makerspace environment?

Methodology

Framework For study: Case Study

Qualitative Methods

This study followed case study methodology tenets as stipulated by Creswell (2007) and Merriam (1998). I treated each makerspace location as an individual case. My goal for the study was to extensively understand the makerspace itself and how the makerspace instructors teach within the space. To do so thoroughly case study lent itself appropriate for my methods. In case study, the researcher pays attention to “the process rather than the outcome, in context rather than specific variable and in discovery rather than confirmation” (Merriam, 1998, p. 19). As a researcher, I wanted to understand in depth the process, context and the discovery that happens in the makerspace.

Setting

This study took place at three sites library makerspace and two middle schools makerspace in the Rocky mountain region (Pseudonyms used at all times).

Library makerspace. The library makerspace is unique and referred to as studio by the library guides. The library specifically promotes creativity, innovation, including other library goals. The library is among seven others in the county serving a population of 368, 652 users and 60 librarians (excluding other staff; Library Research Services, 2016). This makerspace is open to various programs or sessions ranging from 3D design and printing, sewing, gaming and game design, programming, and stop motion animation. Tools available in the space include Makerbot 3D printer, sewing machines, digital photography lab with multiple digital SLR cameras, three mac desktop computers, about twenty laptop computers, software programs like Sploder for videogames and 3D model designs, toys for younger age groups such as KIBO, and other supplies for DIY crafts and textile projects. Except for the laptop computers, the rest of the tools were strategically located around the room. Up against the wall were most resources, in the middle of the room were three tables and chairs. Laptop computers were always set on the tables and users would work from these computers. They would freely move around the space to access the resources if they needed to. The studio itself is walk in and open to any age groups.

First middle school. The second makerspace was in a middle school in the rocky mountain region. According to the National Center for Education Statistics (2015), there were 988 students with 16.65 teachers, a ratio of 16.03. Among the 988, 837 were Hispanic, 90 were white, non-Hispanic, 47 black, non-Hispanic, 7 were two or more races, 6 Asian/Pacific Islander and 1 American Indian/Alaska native. This makerspace was the biggest among the three observed. It had four sections. First section was the classroom study area with round tables and chairs facing the smartboard and teacher desk. The other section was an office, then a student display and work in progress station, a small library with reference resources, a secluded area with 3 desktop computers and workout space and finally a computer lab with about thirty-three individual desktop computers facing the teachers station. Apart from the desktop computers, the space also had Makerbot 3D printers, laser cutter and engraving tool, cart system iPads, software for design, gaming, and coding. This makerspace is used in the school's "Advanced Robotics", "Science/Technology", "Computer Science", "Introduction to Engineering", "Digital Media", and "Electronic Publications" courses. Students had access to all these resources. For safety reason, the teachers monitored access and gave okay for high end tools.

Second middle school makerspace. This final makerspace was also located in a middle school in the rocky mountain region. The school according to the National Center for Education Statistics (2015) has a total of 284 students and 20.25 teachers, with a Student/Teacher Ratio: 14.02. Among the 284 there are 95 Hispanics, 1 Asian/Pacific Islander and 188 white, non-Hispanic. There were 95 sixth graders, 92 seventh graders and 97 eighth graders. This makerspace is in an arts classroom. The room had tables and chairs in the middle space where students would seat and work, these faced the teacher’s projector, tools, and resources all strategically located close to the walls around the room. There was one cart iPad system, painting resources, class station with all pottery materials, pottery throwing tools, sewing stations with fabrics, and other materials for sewing.

Participants

Participants for this study were adult makerspace instructors from both formal and informal makerspaces. There were four makerspace instructors, two from same library and two from middle school makerspaces that were observed and interviewed and one library guide was only interviewed and not observed. Of these three were female and two were male. The adult instructors were all observed during sessions in their spaces and later interviewed (see Table 4.1).

Data Collection

To understand the instructor's practices in the makerspaces, multiple data were collected. These ranged from observation, interviews, artifacts, journal, and field notes.

Observations. This was an integral part of the data collection to see making and tinkering in action and how these instructors interacted with the space students, and technology**.** According to Merriam and Tisdell, (1997), observation together with other data collection documents like interviews allows a researcher "a holistic interpretation of the phenomenon being investigated" as they are in the setting and can witness and record the events and phenomena as they happen (p. 111). Observing the makerspace instructors in their natural environment while they guided and taught allowed me a firsthand experience and view of the phenomenon in the space. I observed total of three sessions at the library; two 3D modeling and printing and one video game creation and 3D modeling together. I then observed four classes at the first middle school makerspace which involved two 3D modeling session with 7th graders, and two engineering class with 6th graders. My last observation was the second middle school where I observed three classes with 6th, 7th and 8th graders art class in the art makerspace. All observations were recorded down as field notes using Observation protocol as proposed by Creswell (2007; see Appendix A). I immediately typed and transcribed these on the same day when they were still fresh on my mind. This was crucial in helping me to monitor the process of the data collection and identify codes that jumped out in that specific observation through constant comparative.

Table 4.1

Participants' Demographic Information

Instructor	Demographic Information
Ms. Josephine*	Library Guide Age: 30 Years as a guide: 7 Users catered for: All age groups Program observed: 3D design and printing (3 classes) Guides: All age groups Age group observed: k-8th graders
Mr. Jackson*	Library Guide Age:30 Years as a guide:6 Users catered for: All age groups Program observed: Gaming-video game creation Guides: All age groups Age group observed: K-8th graders
Ms. Anne*	Art Teacher Age: 31 Years teaching:7yrs Years teaching in a makerspace: 2yrs Grade level: 6, 7th & 8th (middle school) Classes observed: 3 Art making sessions
Mr. Mike*	STEAM science Teacher Age: 31 Years teaching: 5 yrs. Years teaching in a makerspace: 2 years Grade level: All grades (Elementary through high school) Classes observed: 4 middle school classes (Two with 7th graders, 2 with 6th graders)
Ms. Ashley*	Library guide Age: 29 Years as guide: 5 Programs: Art and designing Age group: All ages No observation done

Note. All teachers were interviewed but only four were observed as they taught in their Makerspaces.

* Pseudonyms used at all times.

Interviews. In addition to observations, I also interviewed the instructors on their pedagogical practices in the space. The interviews lasted approximately 28 to 45 minutes. Each interview was recorded and later transcribed for analysis. For the library, the interview ended up being a focus group session with four library guides. For both the middle school interviews were done with just the teachers after the classroom sessions. During the interview, open ended questions were posed to the participants to allow for a discussion and probing to occur but still using the questions to ensure we did not entirely lose track of the purpose. I further used my observation notes and knowledge from the classes observed to guide some questions that I wanted to prompt further. Creswell (2007) and Merriam (1998) state that interviews are necessary to help the researcher find out about behaviors, feelings and past practices that cannot be observed.

Artifacts. Artifacts collected included space photographs, instructor's notes, mentor texts, and student created work. Any student identifiable data were removed from all these materials.

Field notes and journal entry. Through the process, I wrote field notes and recorded on a reflective journal allowing me to stay reflective through the data collection process. Keeping the field notes allowed me to reflect on the events of the day and identify habits, areas and categories that needed to be further explored.

Data Analysis

Data collected was analyzed throughout the study a strategy that helped me make sense of the data and ensure coding was continuous process. Creswell (2007) states that data analysis in qualitative research entails “preparing and organizing the data, reducing the data into themes through process of coding and condensing the codes, and finally representing the data in figures, tables or discussions" (Creswell, 2007, p. 148). Using this guideline, I analyzed the data throughout the study duration on regular basis following qualitative data analysis guidelines.

Constant comparative method. I started data analysis immediately when I started the observations. My initial data coding was on the field notes, journal entries and artifacts as I collected them followed by the interview transcripts as those were collected at the end of the observations. Continuously looking and coding the data into categories was vital in helping me describe the process, context and the discovery that happens in the makerspace. Codes were written out as I read and reread the data and compared to the previous codes each time to identify relationships, gaps and provided for insight to probe and look further to answer the research questions.

Within case analysis. At the end of data collection, I employed within-case analysis method as proposed by Creswell in analyzing data from more than one case. Using this method allowed me to keenly look at each makerspace as a case to better understand the phenomenon and process and uniqueness of each case. In this stage, I used Creswell's (2007) lean and focused coding method to recode the data and identify relationships with codes from the initial constant comparative coding method. When these initial coding were completed I identified the common themes that came out and I believed answered the research questions posed. This process was repeated for each case.

Cross-case analysis. After I concluded this process in the within-case analysis, I wanted to look at the relationships in the focused codes and themes that arose, similarities and differences across cases. I looked at these relationships and nonexistence of the same as well across cases.

Results

The following themes were identified and presented in the results after a thorough analysis of the data: (a) some scaffolding and structure; (b) multiple pathways/entryways to activities; (c) Do It yourself a self-taught mindset; (d) More about the student less about the teacher- Paradigm shift; (e) Teaching Iterative process; (f) Encouraging artifacts creation through iteration; and (g) Feedback. These themes represent teaching strategies these specific makerspace instructors use in their individual spaces.

Some Scaffolding and Structure

This was true on all instructors observed. Instructional scaffolding occurs when an instructor provides supportive tools, resources, guidance as they construct knowledge, gain new skills to meet the learning objective (Vygotsky, 1978). Instructors provided some sort of prompts, and setup of the projects at hand for the users and students. This gave students some basis entry to the projects and gave them ideas allowing room for enhancements. I noticed that this basis helped the users to relate easily and find some starting point. Some built on those starting points and some deviated and explored their own pursuits and ideas and this was just as welcomed in the space. The guidance provided at the beginning of these session played a major role in helping learners find their bearing in the sessions as they could be seen exploring freely on their own afterwards. In each session, there were introductions done, mentor texts provided, as well as scaffolding. In the library makerspace, the instructors provided multiple avenues to the projects to cater for the varied abilities in the space. So, students that are advanced can dig in and start where they want while first timers can follow through the guides to get where they want to be. In one instance Ms. Josephine commented;

> It is a good way to get people through those mental blocks to be really successful at one thing and ones they can attach something to their Gmail then we can talk about all other things on Gmail, but they need to know that they are capable of doing it so whether that's finishing the first section of stitching a project or I guess that's a good example or if we are doing embroidery project they got their first color of red embroidery done, they got their stich done and when they are beginning to feel like they are kinda hitting their groove and so it's like making it feel like formal instruction for that first bit but we are doing it instead of seating in front of the class on a okay now do this, now do this, so we are kinda pushing them a little further into the pool before you shove them into the deep end.

In the art class makerspace, the instructor provided a painting image projected on the whiteboard after the students settled in class. They reflected on the image identifying every element that stood out for them, what they noticed and why this was important. Students then had the opportunity to share their observations with class and this led to discussion on hues, dimensions, story narrative of the art. After this, the students broke into their individual projects and they had to ensure that their work incorporated some of the elements they discussed from the painting if they did not already have them. If their work did have these elements already they had to reflect on what that meant for their overall project and it was upon them to polish on those skills.

I asked her why she did so and her response;

> It is important for the students to see work of art out there and look keenly at the pieces that bring the art work out and how this might help inspire them in the paying attention to little details and elements in their own creation as makers.

Mr. Mike started his classes by posing questions to the students about their previous class sessions after which he projected that day's sessions activity guidelines on board. Students were then given go ahead to start on their projects. Using these guideline, the students were given the cue to create their 3D models and CubeSats to meet the objectives. For the 6th grader's CubeSat sessions the learners were guided through the problem which was create a CubeSat to help the National Aeronautics and Space

Administration’s (NASA’s) mission of making the world a better place. Students were given five themes to choose from after which they selected their own goals and designed CubeSats that meet those goals. However, they designed these were up to them. If the CubeSat served that objective, survived the tests of the fall then they were allowed freedom of design.

The library guides did similar process. In the library, there is a starting time and end time as well, however, users can come as go as they wish. At the beginning of every sessions the guides provided a little, about five minutes, introduction to the sessions what the sessions was about, the stations set and how printing 3D modeling and gaming design worked. Once this was done users created what they wanted and the instructors answered questions asked.

These little starting nuggets varied between the makerspaces obviously due to formal and informal nature of both spaces. Through scaffolding, instructors could model strategies for brief moments leading students into taking control of the rest of the design and practicing them in their projects. Through fading into a guide and facilitator, instructors allowed for students to rise from novice to apprentice to experts almost in their creation becoming more autonomous.

Multiple Pathways/Entryways to Activities

The instructors set up the makerspaces in ways that allowed learners to create differently using multiple resources and techniques in the space. They set up the space to be flexible to multiple activities but rigorous at the same time. The library instructors for instance employed this technique a lot as they get people from varied age groups and abilities. To meet the creating needs of these diverse groups that come into the space, they laid out multiple tools, ways to get to a project and create. This gave users much flexibility in the space. For instance:

> We have a really form of informal learning in the studios and we pick things that are interesting to different age groups. So, something like 3D printing if I was just teaching a class I am going to teach it differently if its teens or adults even if they come in, am going to teach it a lot differently. But a lot of things is having an understanding of what is the easy entry points to this project. So, if it's a tote bag project to sewing and crafts day, the very easy entry point is coloring on it with markers or fabric crayons, the next step is maybe adding working on stitching, maybe sewing in their first buttons. And then you have different kids that are doing a very elaborate design rather than marker and stitchery. And then you have adults that are comfortable with sewing and really just having a good time and are at a completely different self-guided level and adults can fall anywhere in that same spectrum. But I think having projects that are easily adaptable so a lot of time we have skills we want to teach but the projects are the starting points for easily adaptable.

In another instance one library instructor described a scenario where they are creating video games but there was a user that wanted to sew instead. In creating multiple avenues, that user was still able to sew while interacting and collaborating with the users creating video games in the same space. This account was reported by Mr. Jackson below.

> And you know that reminds me, we did, I had a videogame program it was really fun, we had a lot of people creating video games and someone came in and said I wanna work on a dress for my daughter. And I don't have much experience with sewing but we did have someone in hand to help actually Beth* was there to help out and it was this crazy experience because we had a parent working on a dress while next to people working on this completely different thing and talking to each other and engaging in a different weird way, I don't think they would have otherwise been doing that, it's a weird melting tot sometimes.

Same observation as above was made by Ms. Ashley who said:

> A lot of, like we have a theme for every open studios, but being able to adjust and be flexible on who shows up, and what skills levels, sometimes I would have a theme but someone shows up but they brought their own project that kinda relate to that but it's not what I was kinda thinking about so then being able to just jump

> in and go with that and that inspires somebody else um I think that's something to strive for kinda that virtual experience, so people are self-teaching and creating on their own without that really guided help.

In this instance, the flexibility in the space allowed users to find different pathways to projects. Users could create and invent multiple projects and even though some were not related, they could discuss, talk to one another, and share ideas. In addition to multiple pathways, this flexibility provided a safe environment for the students to create comfortably and take charge in this endeavor.

Do It Yourself, a Self-taught Mindset

Makerspace were founded on the concept that everyone can learn, make and tinker and given the right environment, guidance, and resources we can all be innovators. Across all cases observed none of the adult instructors could say they had any experience prior to starting their makerspace teaching. That meant they had to constantly be reading, researching, reevaluating and troubleshooting technical difficulties themselves outside and during sessions. According to Mr. Mike, a teacher in the middle school makerspace, it was a constant learning curve and he had this to say:

> Last year I was basically told here are the names of classes you are teaching, good luck. Huh. My background is biology so things like computer science and engineering like I got some knowledge about, like that's not what my schooling is about so I have had a lot of learning. . . . But there is a lot of great things online as far as what other teachers are doing but I have had pretty limited connections with other teachers.

During my first observation in a 3D modeling and printing session, the instructor Ms. Josephine's attention was called by one of the student who had already designed their 3D model on tinker card, the software used by all instructors to teach 3D modeling, they sent it to print in one of the printers and it was not printing as the instructor was not getting the feed. She immediately started troubleshooting the computer and 3D printer, she could not figure out what went wrong, she searched online for solutions on fixing it and discovered the 3D printer base was not working she dug deeper in forums and found a solution within 20 minutes and started printing the user's model. I found out later that this was a common occurrence where they had to troubleshoot most things themselves in the space. She further went on to explain that part of one thing they learn fast is that anything can go wrong in the space, but experience teaches you to be ready to figure it out, find resources, stay calm and hopefully use that as a teachable moment even for the students as innovation is never easy. These instructors are constantly learning on their own, digging through resources to troubleshoot, and learn new ideas to make the space more interactive, engaging and learner centered.

In addition to the above, they teach the students this concept and try to empower them to understand that they can take charge of their learning and help each other figure out things through research and determination.

More About the Student Less About the Teacher/Paradigm Shift

Within each of these spaces, teacher-student role shifted. The instructors worked towards granting more control, responsibility, and urgency to the learner a strategy that allowed these users and students to push their understanding and ideas through making and tinkering. The spaces become safe environments where the users and students could be guided through their ideas when they need guidance and instructors become facilitators rather than managers. Within the library makerspace, making and tinkering is very informal and users come and go as they wish and sometimes come in with a different project idea than what is being offered. In one instance Mr. Jackson had this exact incidence in his making session and disclosed this in the interview:

> And you know that reminds me, we did, I had a videogame program it was really fun, we had a lot of people creating video games and someone came in and said I want to work on a dress for my daughter. And I don't have much experience with sewing but we did have someone in hand to help actually Beth* was there to help out and it was this crazy experience because we had a parent working on a dress while next to people working on this completely different thing and talking to each other and engaging in a different weird way, I don't think they would have otherwise been doing that, it's a weird melting tot sometimes.

In another instance, Ms. Josephine stated that:

> And I think that's what's nice about the studio, we all have things we are interested in and different expertise we have but knowing that we don't have to be the experts and I think a lot of the patrons here identify that we are going to help them find the resources to become the experts themselves but they are not leaning on us to help them in every step but we can point them to different directions. You know okay Sewing machine is showing this error, okay let's look up online what is that error mean, kinda showing people means to become successful yeah.

The instructors' strategies further involved helping users and students learn by being experts themselves through guiding them out of the structured learning system they were and are used to as noted by Ms. Ashley:

> And I think that's a challenge we run into coz a lot of people did grow up with that structured setting and they come in here and expect that you are going to go step by step and project and it is something we want people to have that experience.

These instructors as such shared control of learning in the space and gave the students and users more ownership of their learning as they assumed more responsibilities and the level of engagement in the space with their own personal projects was exhilarating to say the least. In this regard, Ms. Anne said:

> I have also learned a lot that having choice in the curriculum gives students more engagements, that's in itself is a structure is a lot better. I have had the students write objectives. For about the last year and half I went to a conference and the teacher there had the students write objectives and I was like 'why am I doing all the work? Why am I trying to write overarching objective that had nothing to do with their projects, so then that's when I was introduced to the studio habit of mine. Why do not we utilize these for their objectives?

Having students write and pursue their own learning objective for their projects was something different from what you would see in a regular classroom. Students had to think critically about what they wanted to do and create in conjunction with available resources and tools in the space. They worked harder, smatter, were more driven to be successful in seeing their goal completed. They asked questions and were more engaged in the process resulting in authentic learning.

Teaching Iterative Process

These instructors' goals were to help their learners and users understand that creation and innovation takes time. Using the space as a safe place to try and retry, make mistakes, and retrace their steps the instructors guided the users in the space through making and helped them move forward through their tinkering constantly evaluating their progress themselves. It was important for the users to understand that you cannot get innovation perfect the first time it takes trial and trial and the instructors provided those conditions that helped the learners succeed through this process, time, help and resources. The library makerspace users come and they make whatever they wanted using the material provided this meant two people could be making something entirely different using similar materials or something similar but personal twist to it. It also meant that varied abilities and age group needed varied help and guidance and so the instructor's goal in this instance also focused on helping users understand that failure is part of the making process. Within the space, success is defined and not looked as completion of task but rather success is what you want it to look like and what it means to you. It is very individual oriented and users redefine that for themselves depending on the project they are working on.

Mr. Jackson on this noted:

> Yeah, what I found to be really interesting about this structure is, I think, yeah I guess I couldn’t make a general statement about anyone but I think this is kinda a safe space to experiment and I think sometime failure is part of that, sometimes you have certain expectations you don’t necessarily meet. I think part of it is also coaching people on defining success in what they are working on. So, have someone say ooo I thought this was gonna be that well, you this is still this is still something, but let’s do the next one. And I think that has really been fun too to see that. And I think some people are but yeah, some people are just some individuals aren’t just coached on. I don’t know what the word am looking for how to view the success afterwards and define the success.

By helping users understand the iteration process, the instructors focus on guiding them through passing those mental blocks of what perfect success looks like.

Ms. Josephine further echoed this sentiment by saying:

> They are looking for only the perfect success or the perfect project and so little that we do deal with that. It makes me think of what you are saying about when I did teach helping general and people were so terrified of they are gonna break the computer. And I go are you gonna throw it out the window on the streets, coz if not think we are okay. But there is just the fear of I don’t know what am doing how do I start? Yeah that’s kinda, it’s a mental block for a lot of people.

Ms. Ashley also shared similar views regarding helping users learn to view success differently through positive reinforcements:

> Exactly, and I think just also teaching them ways to define what they are seeing rather than saying ooh I made this thing is a failure, you could say, what did you make, a 15 second thing you told a story with it, or you made a playable game with a clear ending, and once they have those words to define it instead of when they explain it to somebody's else is another way to describe it.

Mr. Mike who is one of the middle school makerspace further echoed this strategy of ensuring learners understand that making process is messy and does not come out perfect on the first run:

> To a degree and it’s something we have explicitly said and agreed on as a class. You know we talked about the first time we made the CubeSats, do we expect them to fail, choral respond yes, is that okay yes, what are the things we learn if they fail, my favorite response is, ‘we learned what not to do’ so we are talking

> about it, but am not sure for every kid it translates to prototyping. But we practice that message over and over, yeah, its prototype yeah, it's the first time let's go with it and see what happens.

So, did Ms. Anne:

> And it is okay to fail. I mean I want a quality product at the end, but it's okay that the color mixing over here in 8th grade it didn't work but in a sense of failure it was a fail, but then what did we learn from that mistake? Okay we learn that I need to ask help from Ms. Anne, and Ms. Anne was able to give me a suggestion and now I can try this suggestion.

In addition to redefining success and learning that mistake in making is okay, the instructors further fostered the understanding that learning takes a process and it can be such a wonderful exploration. Ms. Anne for instance noted that:

> And that's another thing that's a hard thing for the new kids coming in from the elementary, because elementary its teacher directed, and am not saying that's wrong, am just saying it's a huge transition from that to this environment and they wouldn't want to take those risks, they wouldn't feel comfortable with that. They would just wanna rush rush rush, and am to get it done, and am like wait wait art is a process it takes time to go through this. I know you have a great start, and it's a wonderful sense of exploration, but now let's go back and refine and put our best into it. And so that can be a challenge, because they are middle schoolers and they are always just like we wanna be done, right we just gotta slow down a little bit and focus, the key word there is FOCUS.

Encouraging Artifacts Creation
Through Iteration

Every session observed involved users and students creating and making something either tangible or digital that they could share and reflect on. Instructors guided their users and students towards achieving just that. Even though this was not something new from the space as learners and users come to the space with the preconception of what they want to make and create the instructors worked with them through guidance and encouragement to help them make something be it a 3D print, digital video game, stop motion, art, CubeSat or sewing.

In the library makerspace users left space with something tangible and digital that they created. These ranged from 3D model design they created that were printed out for them or video game they made that they would share with friends and family. This ownership and sense of fulfillment from their creation made them come back often to learn more and create more. The same happened in the middle school makerspace, even though the making was not one session but over multiple sessions students still had access to their designs and creations that were shared. One way sharing of artifacts in the space was through art galas, show casings days where the students work would be displayed to the entire library and school community and students get to discuss and talk about their designs. Instructors encouraged students to participate in these to share their creations and obtain feedback and ideas on their designs:

> I think that’s a working progress right now, but we have like an annual art gala, third quarter we would do an art show in conjunction with the high school and it’s like a band choir and art show together, so when their pieces are judged and they get the reviews is a big profound moment and that on a grand scale.

Ms. Ashley said in reference to this:

> So, another element is we got a new display system in the hallway, yeah walker display system, very expensive but very pleased with it, worth it. Before I was confined to this little bulletin board and displaying system in the cafeteria, and I was like, it’s too hard to choose what piece of art goes up, and what if I repeat a student’s art work then another student doesn’t get a chance to celebrate their art work, and it was just like this is not gonna work and we are no longer doing the same thing of a guided drawing and am gonna choose the best one. I want every voice to be out there, and if it’s out there and you are like ooh my God am slightly embarrassed. Then maybe that’s telling you that there is something you need to go back and address. Right, but if you are like this is mine this is me, and the teachers comes to you and say hey you know what you did a great work of art on this one there. It’s more of a dialog, right you are going to be accountable.

Feedback

Providing constant feedback. This happened through the iterative process. Making and tinkering is a continuous process and the instructors created an environment where peer to peer feedback as well as instructor feedback was always happening. Instructors are often asking questions and offering suggestions here and there that helps the learners through their making process. Within the school setting, these makerspace instructors used both summative and formative assessment to guide students' learning. Feedback varied from person to person, some students asked questions, others needed some probing and guidance, others worked through walking around and finding inspiration through peer to peer conversations while others seemed afraid to ask for assistance. In all these scenario, the instructors still provided a safe environment allowing imagination and creation to take place through feedback.

Mr. Jackson while discussing some users needing guidance referenced how this guidance and feedback occurs in the library makerspace:

> They are afraid to ask for help sometimes, I use an almost delusional amount of enthusiasm I found that that usually helps, I think I always respond with ooo what is that, and just if you hit somebody with that you can kinda go I lead into asking things I think.

Students and users also gave each other feedback facilitated by the instructors. They shared their creation whatever level they were in and discussed ways to make changes and ideas the other could try.

> And then the Self-assessment has a section where they do a class critique; And basically, that means they have their artwork and assessment with critique side by side and we all come around and write a sentence, I appreciate your use of color and value, Ms. Anne, then on the critique side, have you considered adding texture to your composition? Ms. Anne. And then that way the students have something to think about, it's not giving them like you have to do this, but it's a choice.

In addition, they created a learning space that gave students opportunities to self-reflect on their learning process and their creations. By using Seesaw mobile application in the classroom, Ms. Anne gave students a way to track their progress and reflect on it. It also provided a way for her to give constant feedback. She noted regarding this:

> Students documenting their artwork. Beginning, middle and end of their art work. Seesaw app I use. So, they are all in the same class. They scan the code. They take a photo of their artwork and they assign it to their name. They can also add a caption, here is what I'm working on and go here is what I am really succeeding in and here is what we are struggling in. And so, it helps me to say I can give you feedback and help guide you with your struggling but also help celebrate your strength. So, I try to do that and I require them to do a posting on it 3 time in their project, beginning middle and end.

In another instance, feedback is provided during iteration process where the instructor holds students finished artwork in class, without interrupting progress, and shares that with everyone to help inspire each other.

> But I also think like when I was holding the, drawing of a car up for the students to look at I think it kinda gave them a chance to see at it in a different new eyes and say hey am headed at the right direction, this is good and hearing the wow from the other students is encouraging, and just knowing that some students like our robot student who creating a robot with paint the fact that he is willing to seek criticism and constructive feedback is huge for him. So that's the moment of hey Ms. Ashley could you let me know that you appreciate what I have done? Absolutely, I say rock on good work, now how can you go back and refine it, well this is the most paint I have used, okay well I get that can you let it dry and clean up some of your edges. So, things like that so applauding what they do but also suggesting and we do that with the critique, so like I really appreciate this is cool.

Self-instructor assessment. Every instructor observed and interviewed commented highly on this. Because everyone had been teaching in the makerspace for less than three years they constantly assess and reevaluate their strategies for the space and make improvements as well as learn from each encounter. Instructors had to constantly identify their progress and how that helped making and tinkering for the learner, what worked, what did not and how could they make the next year sessions better were some of the questions they voiced. All instructors agreed that yes it was a learning curve and they are constantly improving and adjusting.

Mr. Mike noted:

> So you know last year was a lot of coming up with stuff for the first time and seeing what worked and what didn't and so this year I have a little bit better idea and I can guide them more but I am kinda seeing where the spread is as far as student abilities , what kind of scaffolding they do need, so like in developing more cohesive unit lesson plans this year, what you saw is pretty much teaching everybody and it's not broken much by individual student needs, but am really developing a lot of curriculum this year, and once I have all that my goal for next year will be , to have like computer science for example, would be to have a whole unit buildup of materials then I could just set kids on their next project coz they will already have all the instructions and resources available and huh, so that way they can kinda pace themselves right now am not quite there yet so.

Ms. Anne noted as well:

> I have gotten better at asking questions, I have gotten better at helping them scaffolding the thinking from here is a concrete notion of football, how can we take it more abstract. What is it that do you like about football? Hang out with friends. Okay I can respect that's awesome. Why are friends important? How is that friendship impacting your field playing on football. Okay how do we show this in your piece? And am not gonna lie, there are moments I go, ooh my God I had an awesome idea ever, but the moment I voice my idea I take away their ownership and ideas. So, I have to focus at editing myself, am like don't say it, don't say it (laugh).

Conclusions and Implications

Schools must evolve with the evolving learning needs and makerspaces highlight just that need. Instructors in the makerspaces put forth activities and learning goals that are learners centered, and interesting to various learning needs. They design and create a learning environment that safeguards learners to experiment with ideas, their own goals, materials and iterate learning in the process to redefine what success and failure means, becoming inventors and pioneers in creations that are big and small.

In a traditional classroom, students have less chance to refine and tune the struggles in each project as feedback is mostly summative either as percentage or words like “need more evidence,” and teachers move onto next project, segment with the expectation that the learner will improve on the next project, but little is done on previous struggle to ensure meaningful learning process through these hard parts. In addition, most often the students check out of the projects once it was submitted and graded and rarely have time to reflect and rework those pieces and move on to the next with less time to problem solve their previous struggle with that assignment. In makerspaces, this is completely different as instructors work with learners constantly on the ground using both formative and summative assessments to help students through these hard parts, they guide iteration process and provide a learning space that allows for reflection and opportunity to experiment and rework those hard segments.

Instructors in these spaces provided activities to learners that helps broaden their minds and put into practice what they learn in classroom or their imagination into reality by fostering creativity, problems solving through iteration and transfer those skills across to a very different form of learning. Paradigm shift was a significant aspect as learning responsibility is distributed throughout. Learners take ownership of their creations and have more autonomy in return. Teachers facilitate and share in the responsibility. Through emphasizing iteration, learners can grow and problem solve as they tinker, create, and make. Instructors further identify the variability in skills in the space and provide for multiple pathways to projects that allow students to further iterate, share ideas and experiment.

There are several implications of this study**.** Educators need to revisit their teaching strategies if we are going to prepare our students for the global world. Create learning environments that allows for creativity, problem solving, critical thinking and a safe place for students to work through these learning process as called for by P21 (2003a).

Most teachers sometimes think the fancier and bigger the tool the better outcome and teaching I can do but necessarily not the case as teachers in this study used cardboard, tape, and straws to achieve meaningful learning. Teachers must, therefore, select strategies that would effectively integrate available resources to help meet learning goals and engage their students. Makerspaces encouraged students to experiment and create while still learning and acquiring those important skills using not only technology but also other non-expensive tools available every day. Teachers can as such borrow from this and be ready to design lesson activities using resources available to them to help learners meet not only content skills but also 21st century skill and reimagine their classrooms. Teachers must provide supportive learning environment through guidance to allow students to take ownership of their learning which in turn helps them critically think and problem solve throughout their design process. Administrators must also support teachers who are willing to venture out of the old teaching zone, teachers that are ready to reinvent the learning and provide them with resources, guidance, support, and education opportunities to see through successful makerspaces within their classroom. Revise and revisit is a consistent skill needed if teaching strategies and experimentations with new strategies are to be fruitful. Constantly assess your own teaching strategies against learning goals and skills learners are gaining.

References

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of Learning Group Publication, 5*(3), 438-448.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory. A proposed system and its control process. In J. Spense & K. Spence (Eds.), *Psychology of learning and motivation* (Vol 2, 89-189). New York, NY: Academic Press.

Ausebel, D. P., Novak, J. D., & Hanesian, H. (1978). E*ducational psychology: A cognitive view* (2nd ed.). New York, NY: Holt, Rinehart and Winston.

Brahms, L. J. (2014). *Making as a learning process: Identifying and supporting family learning in informal settings* (Order No. 3582510). Retrieved from ProQuest Dissertations & Theses Global. (1609201673)

Bruner, J., S. (1997). Celebrating divergence: Piaget and Vygotsky. *Human Development*, 40, 63-67.

Cavalcanti, G. (2013). *Is it a hackerspace, makerspace, techshop, or fablab*? Retrieved from http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-techshops-and-fablabs/

Creswell, J., W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage publication Inc.

Dougherty, D. (2005). *Maker faire founder Dale Dougherty on the past, present, and online future of the maker movement*. Retrieved from https://goo.gl/wRkKxF

Dougherty, D. (2013). The maker mindset. In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Driscoll, M. P. (2000). *Psychology of learning for instructions* (2nd ed.). Needham Heights, MA: Allyn & Bacon.

Driscoll, M. P. (2005). *Psychology of learning for instructions* (3rd ed.). Boston, MA: Pearson Education Inc.

Gagné, R. (1977). *The conditions of learning*. Boston, MA: Thomson Learning.

Gagné, R. M., & Medsker, K. L. (1995). *Conditions of learning: Training applications*. Belmont, CA: Wadsworth Publishing.

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Keller, J., M. (2010). *Motivational design for learning and performance: The ARCS model approach*. New York, NY: Springer.

Library Research Services. (2016). *Public library statistics and profiles*. Retrieved from https://www.lrs.org/data-tools/public-libraries/annual-statistics/

Merriam, S., B. (2009). *Qualitative research: A guide to design and implementation*. Hoboken NJ: John Wiley & Sons**.**

Merriam, S. B., & Tisdell, E. J. (1997). *Qualitative research: A guide to design and implementation.* San Francisco, CA**:** Jossey-Bass**.**

National Center for Education Statistics (2015). *Schools statistics*. Retrieved from https://nces.ed.gov

Papert, S. (1993a, February 1). Obsolete skill set: The 3Rs--Literacy and literacy in the media ages. *Wired Magazine*. Retrieved from http://www.wired.com/1993/02/1-2-papert/

Papert, S. (1993b). *The children's machines: Rethinking schools in the age of computers.* New York, NY: Basic Books.

Partnership for 21st Century Learning. (2003a). *Framework for 21st century learner*. Retrieved from http://www.p21.org/

Partnership for 21st Century Learning. (2003b). *Learning for the 21st century.* Retrieved from http://www.p21.org/storage/documents/P21_Report.pdf

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 50-70). New York, NY: Routledge.

Vygotsky, L. (1978). Interaction between learning and development. In M. A. Gauvin (Ed.), *Reading on development of children* (pp. 34-40). New York, NY: Scientific American Books.

Vygotsky, L. S. & Cole, M. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wagner, T. (2008). *The global achievement gap: Why even our best schools don't teach the new survival skills our children need--and what we can do about it*. New York, NY: Basic Books.

Washor, E., & Mojkowski, C. (2013). *Leaving to learn: How out-of-school learning increases student engagement and reduces dropout rates* [Kindle reader]. Portsmouth, NH: Heinemann.

CHAPTER VI

INSTRUCTORS PERSPECTIVES ON LEARNING IN THE MAKERSPACEF

To be submitted to a top Journal in Technology Education
Specific Information withheld for Journal Blind Review
Process Single Author Manuscript

Introduction

Makerspaces, making and tinkering, as a rising phenomenon has brought about a lot of questions regarding its contribution to learning especially for young age groups in K-12. Some of the questions asked are 'Is it learning or just play? Can we justify that during making and tinkering sessions students are actually learning? What really are they learning? How can we assess and determine learning in a makerspace environment? Not only does the innovation of technology influences and change how we interact, learn, and teach, technology use in makerspaces is completely revolutionizing how we perceive learning and teaching. Defined by Dougherty (2005) as spaces where individuals freely come in to make and tinker using available resources, Makerspaces have become quite common in both informal learning spaces and formal learning spaces. Educators for a long time have challenged how learning and teaching occur in K-12 environment and have called for teaching strategies that engage students and equip them with not only specific content area knowledge, but also skills that would make these students successful in the 21st century global world.

Makerspaces as innovative learning environment are providing opportunities for educators to achieve just that as it continues to be implemented in learning spaces to provide a place where students, teachers, faculties, and staff can tinker, create, prototype, try out solutions, and hear input from colleagues with similar interests and learn (Educause, 2013). In 2009, former President Obama called for the need for education to embrace hands-on, project based learning to encourage students to be makers and not just consumers. When launching his Educate to Innovate campaign he said:

Students will launch rockets, construct miniature windmills, and get their hands dirty. They will have the chance to build and create and maybe destroy a little to see the promise of being the makers of things and not the consumers of things (Obama, 2009).

This call for action from Obama saw the rise of many maker initiatives to provide students with makerspaces that enhance their innovation. One such organization is the Maker Education Initiative (MEI; 2016), a non-profit organization whose goal is "Every child a maker" and works to establish makerspaces in K-12 schools and afterschool settings to develop hands on projects for young people as well as recruiting mentors who are willing to share their passion and expertise with young mentees. Quinn and Bell (2013) observed that makerspaces as informal learning environments have the potential to provide stimulating learning experiences, promote voluntary and differentiated learning as well as providing avenues to use classic and new advanced learning technologies.

There is potential and benefit in learning through making, and even though this mindset does make sense to educators and learning communities there is lack of research and empirical evidence to this effect and how we can attribute making as something that influences students learning (Anderson, 2012; Honey & Kanter, 2013; Litts 2015; Martinez & Stager, 2013; Sousa & Pilecki, 2013).

Educators must as such reevaluate what constitutes learning as makerspaces and other innovative learning environments bring new dimensions in education. This study intended to determine how learning occurs in the makerspaces from extensive observations, interviews, and artifacts of making and tinkering in both schools and library setting. The following research question was examined:

Q1 How does learning happen in a technology rich makerspace?

Literature Review

Learning

Learning and how we learn has been the focus of research for decades. Several learning theoretical frameworks have been designed to help us understand how we learn and what learning entails. From behaviorist, all thing in between, to constructivist framework how we learn vary from age, person, and materials available to help us learn. Despite the differences in tenets among all learning theoretical framework, there exist a fundamental definition of learning. To all these frameworks, learning is seen as the persistence change in human performance as they interact with the world and environment (Driscoll, 2005). Constructivist learning framework holds that learning takes place through actively engaging the learners in meaningful activities, and that learning is an active process of meaning making gained in and through experience and interactions with the world (Driscoll, 2005; Merriam, 2009; Papert, 1993b; Reiser & Dempsey, 2012). To constructivist, learning opportunities arise as people encounter cognitive challenges through naturally occurring as well as planned problem-solving activities (Driscoll, 2005;

Merriam, 2009; Papert, 1993a; Reiser & Dempsey, 2012). Learning is a communal activity involving collaboration, negotiation, and participation in authentic practice of communities and it involves learners taking responsibility of their learning by setting their own goals and regulating their own learning with assessment is embedded naturally within the learning activities (Driscoll, 2005; Merriam, 2009; Papert, 1993a; Reiser & Dempsey, 2012). In addition, Constructionism learning theory holds that making an artifact is a crucial part of learning (Papert 1993b). This is the heart of what making and tinkering in the makerspace learning environment aims to achieve. The question," What contributions are makerspaces providing towards students learning and acquisition of 21st century skills," can be answered using the lenses of constructivism and constructionism learning theories. Learning, as defined by these frameworks goes beyond product and grades and looks at learning in the aspect of process (Merriam, 2009). If we look at makerspaces under these lenses, we can to some degree, answer the question 'what learning occurs in makerspaces'? To determine how learners within the makerspaces are learning and acquiring 21st century skills, I used the learning framework and definitions as proposed by these frameworks to identify what learning looks like in this environment.

Learning Dimensions in Making and Tinkering

Petrich, Wilkinson, and Bevan (2013) introduced three learning dimensions (see Table 5.1) for identifying how learning could potentially look like in a tinkering process. Using the framework for k-12 science education established by National Research Council in 2011, Petrich et al. (2013) designed this guideline to help educators identify learning within a makerspace environment (Petrich et al., 2013).

Table 5.1

Original List of Learning Dimensions as Visible in Makerspace Learning Environment

Learning Dimension	Indicator
Engagement	• Duration of participation • Frequency of participation • Work inspired by prior examples • Expression of joy, wonder, frustration, curiosity
Intentionality	• Variation of efforts, paths, work • Personalization of projects or products • Evidence of self-direction
Innovation	• Increasing efficiency/fluency gained with scientific concepts, tools, processes • Evidence of repurposing ideas/tools • Evidence of redirecting efforts • Complexification of processes and products
Solidarity	• Borrowing and adapting ideas, tools, approaches • Sharing tools and strategies; helping one another to achieve one’s goals • Contributing to the work of others

Note. Learning categories as identified by Petrich et al. (2013, p. 66)

To Petrich et al. (2013), designing engaging making and tinkering activities to support learners “engagement, intentionality, solidarity, and innovation” puts the students in a learning path “that is matched to their (and evolving) interests, capacities and commitments” (p. 66). I referenced to this learning dimension throughout my study as a reference point on what I observed and heard during the making and tinkering sessions in the makerspaces.

The Framework for 21st Century Learning

In addition to the above tenets expounding on how we view learning, the Framework for 21st Century Learner, here in P21, was established in 2003 to help educators equip learners with skill that would help learners succeed in the 21st century global world. This framework was geared towards updating the skills students were expected to be fluent in at the end of their educational experience from the three Rs, reading, writing, and arithmetic, alone to more interweaving skills relevant to succeed in the 21st century. Established through collaboration with educators, business groups, community and government entities, P21 entails well defined elements that capture skills today's students need to be skilled, and proficient in as well as the support system that can help them achieve this. These skills, as seen in Figure 5.1., are broken into categories; "life and career skills, information media and technology, learning and innovation skills, content knowledge and 21st century themes" (P21, 2003a). These skills are not mutually exclusive as they work together to ensure students preparedness.

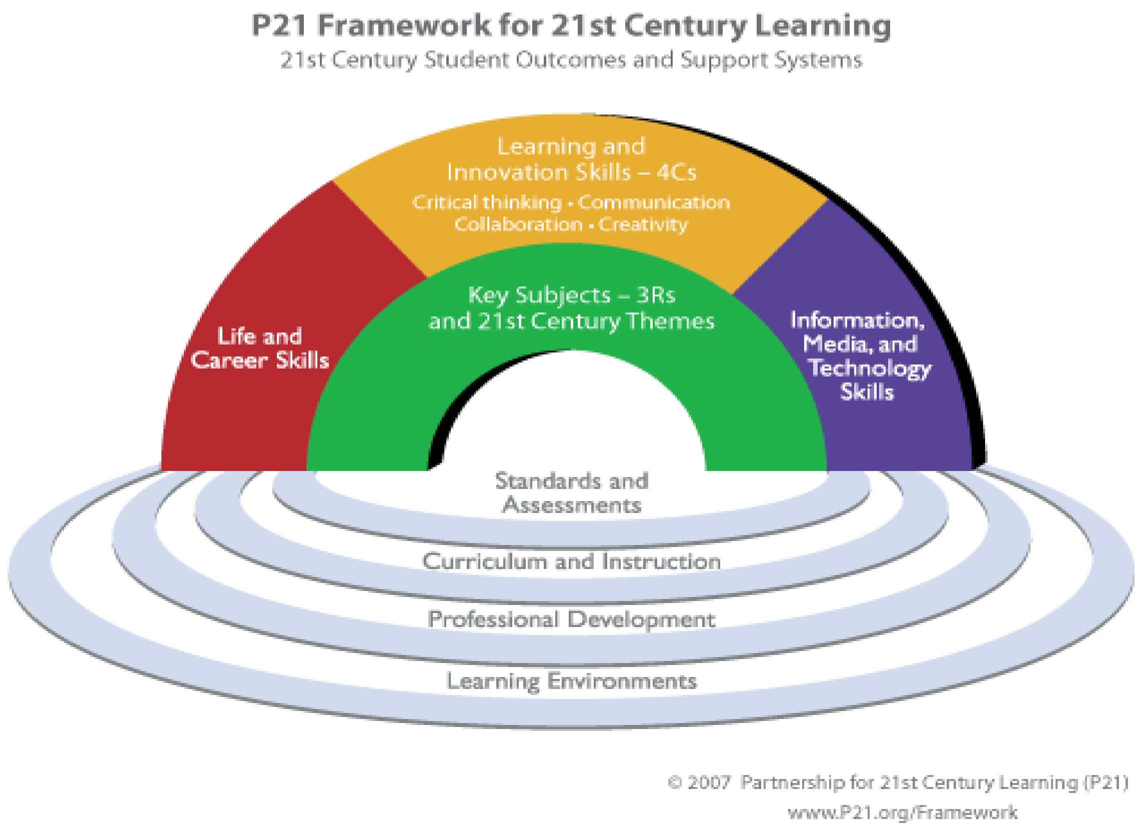

Figure 5.1. Partnership for 21st Century Learning framework for 21st century learning. Reprinted with permission from P21©2009 http://www.p21.org/.

Partnership for 21st Century Learning (P21) stipulates that students must have knowledge and be experts in the core subject areas as stipulated in their curriculum as well as in civic, health, financial and global literacy to meet the content knowledge and 21st century themes skills (P21, 2003a; P21, 2015). Teachers must provide and create learning environments that helps student gain life and career skills if they are to successfully navigate the challenging global, career environment. These skills call for students to be cognizant of the diverse rich cultures of today, be “flexible,” “adaptive, “responsible” as well as take “initiatives” (P21, 2003b). These skills are all not mutually exclusive and work together to ensure students preparedness. Learning and innovation skills, according to P21 (2003b), are geared towards equipping students with the four Cs (4 Cs); Communication, collaboration, creativity, and critical thinking skills. Today's students need to master the four Cs, in addition to the other set of skills earlier mentioned, if they are to be successful in the 21st century global community.

Critical thinking and problem-solving skills. Partnership for 21st Century Learning (2015), defined this as the ability of a learner to "reason effectively both inductively and deductively as appropriate to the situation, ability to use system thinking, make judgments and decisions as well as problem solve" (pp. 9-10). Teachers today must strive to teach their students problem solving skills if they are to compare evidence, evaluate competing claims, inquire, and make sensible decisions in everyday life (Wagner, 2008). Problem solving and critical thinking skills provides the avenue for learners to develop improved thought processes, in depth analytical skills, higher level of concentration, systemic perspectives, and curiosity (P21, 2003a; Wagner, 2008). If these students are to be competitive in the global market, they must possess critical thinking as today workforce require their employees to problem solve and think critically of ways to better serve customers, develop better products and most importantly continually better themselves within the ever-changing global economy (P21, 2003a). With the dramatic change in corporations over the last twenty years, a learner's specialty is no longer enough to define work, but rather the task or challenge worker is to solve and the end goal intended become part of the learner's specialty. As such the workers must use critical thinking and problem-solving skills to find these solutions making this skill one of the most important competencies needed to succeed in the workforce (Wagner. 2008).

Critical thinking and technology. Teachers and educators have constantly employed different methods in teaching and learning to help equip learners with critical thinking and problem-solving skills. Pray (2001) reported that online discussion forums have the potential to tailor learning to meet the diverse learning style and needs of students. Those asynchronous discussion forums provide the opportunity for learners to think through their contributions, discuss approaches to complex issues, apply theory to learning, and develop skills in appropriate critiquing of peer's work (Pray, 2001). In their study, Chiang and Fung (2004) reported that online chat forums provide a learning environment for discussion and problem solving among students as they can post their topics, thoughts and viewpoints and collaborate in being problem solvers with teacher assuming the coach role to guide, provide suggestions in steering a problem, and interactively joining the discussion. The learners together think of different ways to solve the issue and problems that come by building on to each other's knowledge (Chiang & Fung 2004).

Communication. This skill is defined by P21 (2003a), as the ability of students to communicate clearly by "articulating their thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of contexts and forms, listen and effectively decipher meaning, communicate effectively in a diverse environment and use communication to inform instruct, motivate and persuade" (P21, 2003b, p 15). The ability of individuals to clearly express their views in a democracy as well as communicate effectively across culture is a prerequisite in global economy (Wagner, 2008). According to North Central Regional Educational Laboratory (NCREL) and the Metiri Group, (2003), to succeed in today's global world, students must possess effective communication skills and technology can facilitate this need. North Central Regional Educational Laboratory (NCREL) and Metiri Group (2003) further acknowledge that the presence of various information and technology tools require learners to be competent in communication skills to succeed in the 21st century global economy. Wagner (2008), added that students must also be able to access and analyze information from multiple sources, discern meaning from them, and effectively communicate and relay this meaning.

Communication and technology. Many Web 2.0 tools can be integrated in the classroom setting to help students master communication skills. Previous studies reported that blogs are a good avenue for communication and interaction and their interface allows for self-expression and recounting of personal events to the blogger community, allowing teachers to facilitate learning communication skills through dialog and storytelling as students are free to express and support their own ideas and opinions fluently (Huffaker, 2005; McGrail, & Davis, 2011; Otieno, Schulz, Tankovich, Wang, & Gall, 2013). Social media tools, for instance twitter, Facebook, Pinterest, when effectively integrated can help students master oral, written, and reading skills in the classroom as students need to think strategically how they convey and receive information with and from peers (Foote, 2013). Other studies reported that students use social networking sites to communicate and discuss academic issues, and meet their academic goals both formally and informally (Greenhow & Robelia, 2009; Mazer, Murphy, & Simonds, 2007; Otieno et al., 2013).

Collaboration. This set of 21st century skill has been defined by P21 (2003a) as the ability of the student to be able to “work effectively and respectfully with diverse team, exercise flexibility and willingness to be helpful in making necessary compromises to accomplish common goal, as well as ability to assume shared responsibility for collaborative work, and value the individual contributions made by each team member" (P21, 2003b, p. 21). Students must learn to work together with peers to produce "extremely inclusive and valuable resources" (P21, 2003b, p. 20). Because of globalization and rise of technology, this skill has not only become necessary but vital as it generates a more holistic result and intelligent decision necessary to succeed in today's global society (P21, 2003a). According to Wagner (2008), various multinational corporations today require workers to be proficient in working with networks of people from different cultures as well as across boundaries. This skill works hand in hand with global awareness to ensure students are conscious of the diverse nature of today's global environment (P21, 2003b).

Collaboration and technology. Teachers have used the many web 2.0 resources like, wikis, blogs, discussion forums, videos, and podcast to help learners collaborate and build this skill (Boling, 2008; Huffaker, 2005; Miller & Shepherd, 2004; Otieno et al., 2013). In a study conducted by Churchill (2011) the use of blogs in the classroom was found to enhance student collaboration. The researcher reported that students shared their reflections, give, and receive constructive feedback freely and willingness to make corrections based off these feedbacks (Churchill, 2011). Wikis, another web 2.0 tool, have also impacted teaching positively in terms of teaching student's collaboration skills (Boling, Castek, Zawilinski, Barton, & Nierlich, 2008; Doult, & Walker, 2014; Huang & You-Lin, 2011; Otieno et al., 2013; Warschauer & Grimes, 2007). Other studies also reported the use of social networking tools to equip learners with collaborative skills (Lampe, Wohn, Vitak, Ellison, & Wash, 2011). By connecting students in informal learning environment, social networking sites allow students to learn through the process of collaborative sense making (Lampe et al., 2011). In addition, previous studies have reported the use of mobile devices and mobile apps in helping improve learners' collaboration (Ciampa & Gallagher, 2013)

Creativity. Defined as the ability of the learner to "think creatively, work creatively with others and implement innovation" this skill requires teachers to equip their students with the ability to regularly innovate and create to succeed in a professional and personal capacity. (P21, 2003a, p. 26). Soulé and Warrick (2015) referred to these skills as one that plays an important role in the framework as learners are required to use wide range of idea creation techniques in today's world to succeed in the workforce. Not only do they need to put their creative caps on, but students should also be able to effectively and efficiently communicate these new ideas to others, work creatively together to reiterate, develop, and implement such ideas as well as demonstrate responsibility, self-direction, and productivity in the workplace (Soulé & Warrick, 2015). Students need to be ready for the global world that currently requires individuals who are self-starters, ones that take initiatives and are entrepreneurial (Wagner, 2008). In a study to determine the relationship between technology and creativity among students, Jackson et al. (2012) found that educational videogames had a role in helping students perform better in creativity assignments. Integration of mobile games applications have been seen to create a learning environment that allows for healthy competition among teams which in turn are motivational and engaging to the students allowing them to creatively work with their peers (Ciampa & Gallagher, 2013).

Different technologies have been used to help learners enhance their 4 Cs as evident from the above accounts, however, little research exists that shows how makerspaces achieve similar results if any. For this reason, this study focused on identifying how ‘learning’ as defined by these tenets occur in the three makerspaces observed.

Methodology

Qualitative Case Study Methods

Using qualitative case study guidelines as stated by Merriam (1998) and Creswell (2007), I provided in depth recount of the experiences of my participants throughout this study. As I observed three different makerspaces locations in both formal and informal learning spaces, case study method was the best fit for this research. Using case study as a qualitative framework for this study allowed me to pay close attention to “the process rather than the outcome, in context rather than specific variable and in discovery rather than confirmation” (Merriam, 1998, p. 19).

Setting

Three makerspaces were studied. Among these was one makerspace studio in a library, and two makerspaces in middle schools in the Rocky mountain region (Pseudonyms used at all times).

Library makerspace. This makerspace, sometimes called a studio, hosted several library programs facilitated by different library guides. This makerspace is equipped with Makerbot 3D printers (three), Digital photography lab with multiple digital SLR cameras, sewing machines, Supplies for Do It Yourself (DIY) crafts and textile project and personal laptops and three desktop computers. The library is among seven others in the county serving a population of 368, 652 users and 60 librarians (excluding other staff; Library Research Services, 2016). The makerspace hosts various programs or sessions that utilizes the tools in the space. These included but were not limited to 3D design and printing, sewing, game design, programming, and stop motion animation pictures. The programs are tagged for age level but are not restricted on that age and as such open to anyone from varied age groups. This space was opened only when there was a program or when a user requested to use the space. During these open sessions, users could walk in and out freely to use the space.

Middle school makerspace #1. This makerspace was in a middle school in the rocky mountain region. This middle school served 988 students with 16.65 teachers, a ratio of 16.03. Among the 988, 837 were Hispanic, 90 were white, non-Hispanic, 47 black, non-Hispanic, 7 were two or more races, 6 Asian/Pacific Islander and 1 American Indian/Alaska native (National Center for Education Statistics, 2015). This makerspace is equipped with tools such as 3D printers, CAD (computer-aided design) software, professional video production and editing equipment/software, Laser cutter and engraving tool, iPad, and desktop computers for the students. This makerspace is used schoolwide for "Advanced Robotics", "Science/Technology", "Computer Science", "Introduction to Engineering", "Digital Media", and "Electronic Publications" courses taught by one teacher. Students have access to the space during regular class time allotted to the STEAM, 45 minutes. They can also access the space individually by asking permission from the teacher and with supervision.

Middle school makerspace #2. This makerspace was also located in a middle school in the rocky mountain region. This school served a total of 284 students and 20.25

teachers, with a Student/Teacher Ratio: 14.02. Among the 284 there are 95 Hispanics, 1 Asian/Pacific Islander and 188 white, non-Hispanic (National Center for Education Statistics, 2015). There were 95 sixth graders, 92 seventh graders, and 97 eighth graders (National Center for Education Statistics, 2015). This makerspace was used exclusively for art classes and by the art teacher. The space is equipped with cart system iPads, art, and craft supply materials such as clay and pottery materials, paint and brushes, fabrics, and yarn, as well as sewing machines. Students access the class during regular class periods, forty-five minutes slot time. They can also access it privately with permission and supervision.

Participants

For this study, the participants included adult instructors of makerspaces in both formal and informal learning spaces, as well as students and users attending these spaces. Five instructors were interviewed, four were observed several times as they facilitated and taught in their makerspaces (see Table 5.2). Students were only observed as they made and tinkered in the space.

Data Collection

To identify learning and how learning occurs in the space, multiple data were collected. These ranged from observation, interviews, artifacts, journal, and field notes.

Table 5.2

Participants' Demographic Information

Instructor	Demographic Information
Ms. Josephine*	Library Guide Age: 30 Years as a guide: 7 Program observed: 3D design and printing (3 classes) Guides: All age groups Age group observed: k-8th graders
Mr. Jackson*	Library Guide Age:30 Years as a guide:6 Program observed: Gaming-video game creation Guides: All age groups Age group observed: K-8th graders
Ms. Anne*	Art Teacher Age: 31 Years teaching:7yrs Years teaching in a makerspace: 2yrs Grade level: 6, 7th & 8th (middle school) Classes observed: 3 Art making sessions
Mr. Mike*	STEAM science Teacher Age: 31 Years teaching: 5 yrs. Years teaching in a makerspace: 2 years Grade level: All grades (Elementary through high school) Classes observed: 4 middle school classes (Two with 7th graders, 2 with 6th graders)
Ms. Ashley*	Library guide Age: 29 Years as guide: 5 Programs: Art and designing Age group: All ages No observation done

Note. All teachers were interviewed but only four were observed as they taught in their Makerspaces.

* Pseudonyms used at all times.

Observation. Multiple observations were conducted throughout the study duration to identify and pinpoint how learning if any occurred as students tinkered and made. Using observation together with other multiple data allowed me to gain “a holistic interpretation of the Makerspace phenomenon” as they I was in the setting and witnessed and recorded the events and phenomena as it happened (Merriam, 1998, p. 111). To identify how students were gaining new knowledge or experiences, I observed making and tinkering firsthand in the natural environment. Four classes were observed at the library makerspace; three 3D designing and printing and one game design class. Two middle school Makerspaces were also observed. In the first one four classes were observed; two of those were 3D design with 7th graders and two were engineering CubeSat with 6th graders. The second middle school makerspace was an art makerspace and here three classes were observed with 6th -8th graders. All observations were recorded down as field notes and using Observation protocol as proposed by Creswell (2007; see Appendix A). I immediately typed and transcribed these when I got home on the same day.

Interview. One on one interviews were conducted with the middle school makerspace instructors to further identify their views on learning within the space and what that entails. With the library makerspace instructors, a focus group with four instructors was conducted. Open ended questions guided the interviews and focus group to elicit discussion without veering off intended goal. The interviews and focus group was audio recorded and later transcribed for analysis.

Artifacts. Another source of data was artifacts from the space and instructors. These included space photographs, instructor's notes, mentor texts, and student created work.

Field notes and journal entry. To stay reflective throughout the process, I wrote field notes at each observation. In addition, I kept a personal reflective journal. Keeping the field notes and journal allowed me to reflect on the events of the day and identify habits, areas and categories that needed to be further explored.

Data Analysis

Creswell (2007) stated that data analysis in qualitative research entails "preparing and organizing the data, reducing the data into themes through process of coding and condensing the codes, and finally representing the data in figures, tables or discussions" (Creswell, 2007, p. 148). Using this guideline, I analyzed the data throughout the study duration on regular basis.

Constant comparative method. Data analysis was a continuous process throughout this study. Field notes, journal entries and artifacts were the first data collected continuously and as such coded continuously after each session observed. This was then followed with the interviews and then focus groups that were coded. and those codes looked up against initial codes from the other data collected. I constantly read and reread the data as I collected them and coded them comparing new codes from new data to previous codes each time to identify relationships, gaps and provided for insight to probe and look further to answer the research questions. It was important to continually code and look at the data throughout the study as it assisted me in better describing the process, context and the discovery that happened in these makerspaces.

Within case analysis. This analysis technique is called for by Creswell especially when a researcher has multiple cases. Because this study involved three makerspace cases I first analyzed the data collected after the study completion, by looking keenly at each case and identifying codes as they arose from the data. I treated each case as an independent case and doing so allowed me to better understand the phenomenon and process and uniqueness of each case. I coded everything using Creswell's (2007) lean and focused coding method. This was vital in identifying the relationships with codes from the initial constant comparative coding method. When these initial coding were completed I identified the common themes that come out and I believed answered the research questions posed. Each case went through this process.

Cross-case analysis. After I concluded this process in the within-case analysis, I wanted to look at the relationships in the focused codes and themes that arose, similarities and differences across cases. I looked at these relationships and nonexistence therein if any across cases.

Results

After thorough analysis of the data collected, common themes arose that reinforces the need for educators to reconceptualize what learning is. As Petrich, et al. (2013) stated learning can be looked as, in addition to traditional definition, "engaging in practices that draw on facts and skills to advance valued and purposeful activity" (p. 69). These themes were (a) sharing and designing collaboratively, (b) learning to problem solve, (c) Creativity through making and tinkering, (d) learner taking charge of their own learning

Sharing and Designing Collaboratively

Students ability to work well with peers either in group projects or seek advice from peers on individual projects and readily help others is an important skill in the 21st century learning environment (P21, 2003a). Collaboration in the makerspaces observed in this study occurred naturally. In the sessions where students were working on their own individual projects they were free to engage with peers in the space, ask questions and see what they were designing, help solve design problems as they arose and brainstorm new ideas together. In one instance in the gaming class at the library makerspace, students were designing games using Sploder software. Each student was designing their own games and starting at the easy level, they would then ask the person sitting next to them to play it and help them make the game better. Conversations that ensued from such collaborations were so natural. The expectation was that the other student would give similar feedback to either that student or any other that needed it. This was similar in the middle school makerspaces as students collectively worked together. Rarely was the question, I am done what do I do now? Those students that were finished early with their projects would naturally offer to help their colleagues and give them feedback on what they were working on.

In fostering collaboration, instructors gave the students support, tools and resources as well as space and opportunities to become natural facilitators to one another. Students learn to share not just ideas but also resources and the space. They further shared improvisation skills when resources were being used. Ms. Ashley in her art makerspace encouraged what she called ‘choice based collaboration’. What that looked like in the space was in two folds, before students embarked on the project after brainstorming their ideas and during making, tinkering designing session. In the initial stage after students came up with an idea of what they wanted, the class sat in conversation group and shared their ideas. This helped students hear aloud their ideas and gave the group a chance to refine and share feedback. Collaboration happened in the second instance during making as students were free to interact with each other and assist as they needed help from peers or the instructor. She states;

> We also do something called *Conference critique.* Basically, before they start their project, we all get together in a group and we share our plans. Students are in charge of giving ideas and feedback. Hey, a heart is on the band symbol list, so what's another symbol you can use. Well I don't know am kinda stuck on that. Well what if you wanna try this, or what if you do this.

She further emphasized that;

> Then if they are really struggling then they can go hey Susan, can you help me, so that's where collaboration comes in with the problem-solving technique. I don't stress so much the collaboration process as choice based I have done in my previous years, because I want my students to choose that path.

At the library makerspace, students and users worked together as well in a very natural impromptu manner. Users could be seen sharing their design process, ideas and asking questions on their models. Ms. Anne noted in this regard;

> Mark who is one of our sidekick started 3D printing one week and was signed up for my class next week and he had kinda learned everything by then, and he kinda become my informal sidekick because he would be like that is cool, here is what else we can do. And people wanted to see what he was doing coz he was kinda in that next level so by having a room with varied abilities people starts to have that interest the desire to share their knowledge but also the desire to figure out to get to the next level because they have seen it.

And it is very impromptu. Impromptu is the key word there. When people think collaboration, they think in a school a group project or something like that. You are forced around the table and you are working together no matter what and it was not like that. You know maybe you are working by yourself or in a small group or then small group combined, and people come and go and you may collaborate for a few minutes then go split off again then go in different directions and that was where having, especially in our open studios programs there is so much freedom to come and explore for five minutes with someone else, and then completely collaborate with everyone for the whole time.

Learning to Problem Solve

One of the highlights for any makerspace instructor is the iteration process, when students are exploring different ideas, testing these ideas, responding, and implementing feedback and seeing how their products change and evolve as they create (Martinez & Stager, 2013). In the spaces observed students were seen going through this learning iteration process naturally. As students create they go through this cycling process of iteration, starting with an idea, experimenting with that idea, implementing feedback trials and error until they achieve and create something they are proud of and happy with. Ms. Ashley noted that students are constantly problem solving as they create, they are constantly having to rethink, strategize, and troubleshoot their ideas especially when they get stuck on something.

> That (referring to the space) becomes a space where they can say okay am willing to take a risk Am gonna try this, ok that didn't go so well, what can I do differently to change it and that's where problem solving comes.

Same feedback was shared by the library instructors whose focus was to facilitate the problem solving and not on the forefront of it. Students were in charge of the problem solving; Ms. Anne noted;

> We trick people to problem solve, and it's very careful phrasing and using everything that goes wrong in the space as a teachable moment and just kinda instead of fixing it just coaching people with it. So ooo well that's not working quite right so let's take a look at some of those stuffs going on here and see if we

> can, and Janet, former team guide was talking about troubleshooting 3D printing with the team, so like alright guys let's trace this back, let's see what's going on let's find what's making that noise. So, I think a lot of the problem solving, if we are involved I think we are kinda leading the process for it but we are not doing it, if that's makes sense, facilitating would be the right word.

Mr. Jackson also state regarding this;

> Yeah a lot of it has to do with how you set out the project too I haven't done it too much but , it started with sort of a random thing where we set out a like program beans for pixel while you are doing 3D modeling and then every now and then some groups will find weird overlap between how the pixels come together and how 3d model can be designed , and then after that it become something like what if I leave something weird here, something else here and see how it goes and that. We had people, participants designing background for stop motion movies pictures, it's really fascinating if you set out two things, and that's not necessarily more of the early stages for me that has been a way to kinda problem solve. Not even introducing but finding an opportunity then they and how they use the opportunity.

Instructors further selected tools that help student's problem solve. This can be seen in Ms. Anne's response when asked how problem solving looks like in the space;

> I think with some of the younger kids especially with the maker programs we do a lot of is open ended things, so when we think of young kids is open ended toys vs one answer toys so say we have Kibbo playing music you can only hit a 3D printing software from so many computers at a time and so am thinking some other 3 dimensional we could do but everything you do with Kibbo playing is problem solving its design, it's how do I make this something that is not the same structure I have seen before, how do I make it taller, how do I make it strong enough to be that tall, how do I get the black pair especially librarians are mean and won't let me stand on the chair, true story, they will eat you huh and so kinda having really smart people, and having really quality tools, we have a wide variety of both and it's kinda place for both but having those activities that maybe they can learn a skills like counting but also how do I get them together.

Creativity Through Making and Tinkering

Makerspaces are designed to be safe places where people can come in and create. This environment provides learners with resources and support system they need to engage in creating. Learners observed were creating artifacts that were either inspired by a problem they wanted to solve or something they have always wanted to learn to make (see Figures 5.2, 5.3, 5.4 and 5.5). Combining problem solving, an understanding of iteration process and that creation is messy and needs time, learners are prepared to think and do like they would be needed to in a workforce or global environment. Students have better grasp that hard work pays, what working with peers effectively achieves and understanding that there are several ways to approach an issue and get good output. That they can be creators and makers. In one instance Mr. Mike in one of 3D classes had a project for the student that involved creating something for their peers to solve a problem the peer was experiencing.

> So, what they did last year, they worked in pairs, so nothing went out of the classroom. They identified a problem small problem that they had in their daily lives or some quacks, sort of subtle annoyance maybe, and then they told their partner about it and the goal was to design something for their partner that would solve the problem for their partner. They did all the planning and designing on the 3D prototypes and we printed them out. Some of them turned out pretty well some of them didn't, but I was like that's what happens when you prototype, but then we did showcase them, it was our first showcasing night.

Another example was of a five-year-old user at the library makerspace who wanted to make something to put his money in. One could say well buy a piggy bank, but where is the imagination there, this kid decided he wanted to create his own piggy bank and that was exactly what he did.

> Having stuff for our population is kinda almost a novelty but it takes the want stuff out of it, you know, I have something super cool that I made. We had a kid come in last week who just wanted to build a place to put his money, he was like what 5 probably, huh, and he was the one that ended up sewing on the button and he originally wanted to come in sew on this cool thing he saw before but he didn't know how to hand stitch and he thought what would make my life better, which is problem solving in its own, and then he learned how to sew a button which is a very tangible skills and very important in life.

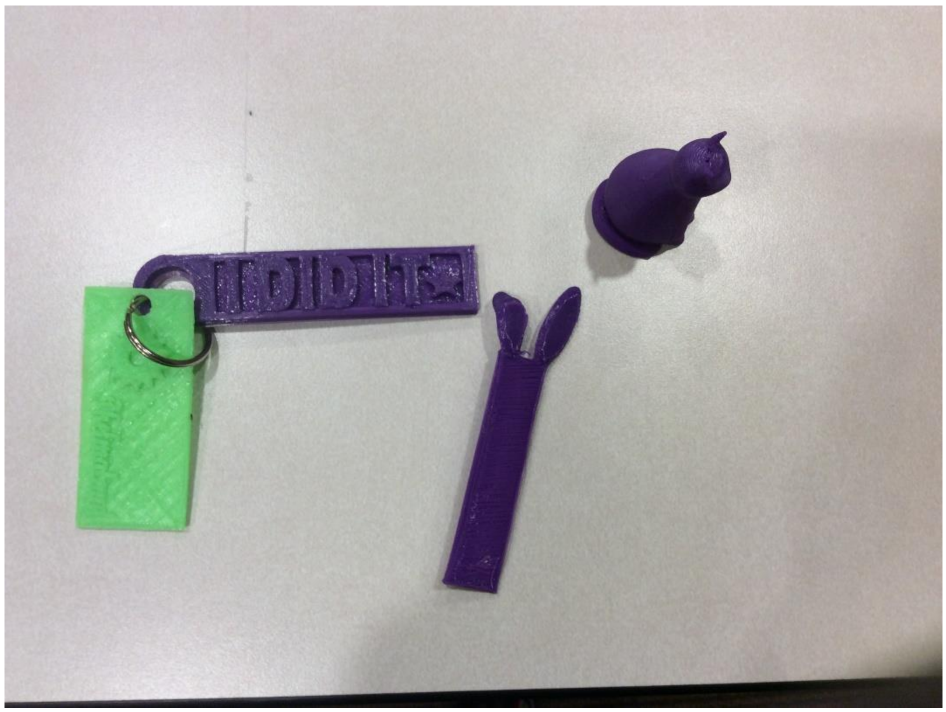

Figure 5.2. Student’s 3D printed keyholder. Examples of student’s artifacts. This is an example of student created work in the space that was designed and printed using the 3D printer at the library Makerspace.

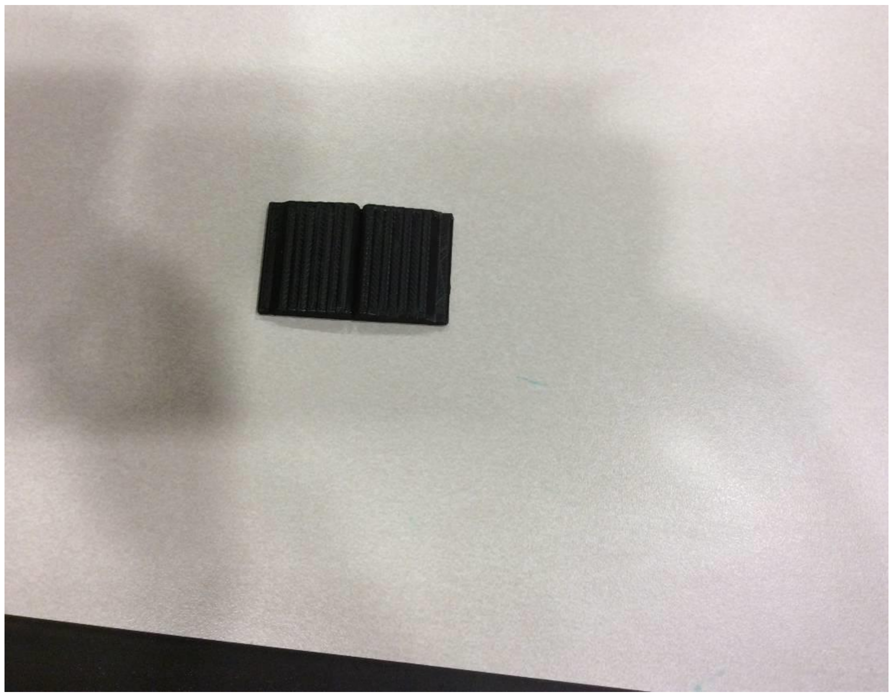

Figure 5.3. Student's 3D printed book figure. Examples of student's artifacts. This is an example of a mini book that one of the student's 3D designed and printed.

Figure 5.4. Student’s art piece in progress. Examples of student’s artifacts. This image shows a student’s work in progress in the Art classroom Makerspace.

Figure 5.5. Student's CubeSat in progress. Examples of student's artifacts. This is an image of students work in progress during an observation at the middle school Makerspace session. This student was designing a CubeSat to help NASA space exploration mission.

Learner Taking Charge of Their Own Learning

Theses makerspaces lent themselves as safe environments where students could experiment, iterate, and create without prescribed process. Within the space students took charge of their own learning goals and design and sought guidance when needed from both peers and instructors. Within the library space students come in with either predetermined idea of what they wanted to create or make, there was freedom to veer as needed from this initial pathway. By making resources and materials readily available in the space, learners could work through their ideas and set goals that they set by exploring these resources and in the process interacting with other peers sharing ideas. Students could problem solve and think critically through their making to meet their goals. They sought feedback freely from peers and instructors and made changes as they needed to.

One of the instructors Ms. Agnes* noted that one of her aim was to help students take more ownership of their creations by having them write out their goals and objectives and reflecting on how that design process would look like. In doing so students were more engaged, put more effort in creating, problem solving to see their goals come through. In addition, students creating artifacts gave them ownership and authentic audience. They were accountable for the work they created and given that these were mostly things they were passionate about, they valued their creation whether it was perfect or imperfect. Students would be heard saying, "I do not like everything about it I think I want to change this side on my next design' or 'I love it I am going to show it to my mom when I get home." Creating gave them a sense of pride and they learned to appreciate their hard work and designs.

Conclusions and Implications

Makerspaces as innovative learning environment are redefining how we see learning. Students are engaged, generating new ideas, iterating, sharing these ideas naturally with peers, as they make and tinker in the space. Learning goes beyond traditional definitions to incorporate these aspects. As framework for P21 (2003a) outlines, education must equip learners with not only content skills but also creative, problem solving, collaboration, communication skills so learners can succeed in the global environment. As observed in these makerspace students were picking on these skills naturally. Petrich et al. (2013) supports these findings as they found that learners took ownership of their learning by creating their own goals and developed these goals to maturity as they became familiar and confidence with the phenomena and materials. They further reported the iteration process of tinkering as learners pursued ideas, become frustrated, gain breakthrough through their own ingenuity and collaborations which enhanced problems solving, collaboration and creativity skills (Petrich et al., 2013).

Constructivist and constructionism both holds that learning takes place when learners are actively engaged in meaningful activities, making meaning gained in and through experience and interactions with the world, encountering cognitive challenges through naturally occurring as well as planned problem-solving activities learning occurs, and making an artifact (Driscoll, 2005; Papert, 1993a; Reiser & Dempsey, 2012). In the makerspaces, learners were actively engaged as they tinkered, designed, problem solved through the designs, experimented, and implemented changes and feedback to their designs. Most of the student designs were created because they had a problem they wanted to solve, like a place to put my money, a gift to a friend, a color for their pet, a nail polish holder, a part for my toy that broke or design a video game that I always imagined and wanted to play. Regardless of the purpose, the iteration processes the students went through as they created encompassed creativity, collaboration, problem solving and communication. These findings are consistent with those of Blikstein (2013) who reported that making and tinkering in the Makerspace increased the process of "ideation and invention" as students through the iterative process of imagining, making, remaking and remaking again were committed in refining their designs and engaged in the process something they would not otherwise be doing from reading a manual on the design (p. 7).

Students go through this iterative process that is part of learning and as they do so they are developing a better understanding of their design requirements, the tools, and materials choices they need to make, tradeoffs in design options and implementation of changes and feedback for the prototype they are creating. As they are going through this process the teacher who role is guiding and facilitating in the space can see them through this process and ensures they are making progress to their intended goals while still providing constructive feedback to help them with the process.

Educators as such need to provide learning environments that allow students to be creative, engaged and provide resources that could potentially help learners be makers rather than consumers of contents. Teachers must create learning spaces that allow students to go through learning process through guidance. Teachers must also provide engaging activities for learners that are relevant to their everyday needs. They must also share responsibility of learning and be ready to give up some ownership of learning so learners can be accountable. We as educators and teachers must also reinvent and redefine success for the learners so they can be encouraged to follow through and keep inventing and discovering. Administrations must support teacher’s efforts in establishing these spaces through funding, professional developments, resources if they are to reinvent their teaching space.

References

Anderson, A. C. (2012). *Makers: The new industrial revolution*. New York, NY: Crown Business.

Blikstein, P. (2013). Digital fabrication and “making” in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.). *FabLabs: Of machines, makers and inventors* (pp.1-21). Bielefeld, Germany: Transcript-Verlag Publishers.

Boling, E. (2008). Learning from teachers’ conceptions of technology integration: What do blogs, instant messages, and 3D chat rooms have to do with it? *Research in the Teaching of English, 43*(1), 74-100.

Boling, E., Castek, J., Zawilinski, L., Barton, K., & Nierlich, T. (2008). Collaborative literacy: Blogs and Internet projects. *Reading Teacher, 61*(6), 504-506.

Chiang, C. A., & Fung, P. I. (2004). Redesigning chat forum for critical thinking in a problem-based learning environment. *Internet and Higher Education, 7*(4), 311-328.

Churchill, D. (2011). Web 2.0 in education: A study of the explorative use of blogs with a postgraduate class. *Innovations in Education and Teaching International, 48*(2), 149-158. doi:10.1080/14703297.2011.564009

Ciampa, K., & Gallagher, T. L. (2013). Getting in touch: Use of mobile devices in the elementary classroom. *Computers in the Schools, 30*(4), 309-328.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage publication Inc.

Dougherty, D. (2005). *Maker faire founder Dale Dougherty on the past, present, and online future of the maker movement*. Retrieved from https://goo.gl/wRkKxF

Doult, W., & Walker, S. A. (2014). “He gone and wrote over it:” The use of Wikis for collaborative report writing in a primary school classroom. *Education 42*(6), 601-620. doi:10.1080/03004279.2012.752022

Driscoll, M. P. (2005). *Psychology of learning for instructions* (3rd ed.). Boston, MA: Pearson Education Inc.

Educause. (2013, April 9). *7 Things you should know about Makerspaces*. Retrieved from https://library.educause.edu/resources/2013/4/7-things-you-should-know-about-makerspaces

Foote, L. M. (2013). Honing crisis communication skills: Using interactive media and student-centered learning to develop agile leaders. *Journal of Management Education, 37*(1), 79-114. doi:10.1177/1052562912455419

Greenhow, C., & Robelia, B. (2009). Old communication, new literacies: Social network sites as social learning resources. *Journal of Computer-Mediated Communication, 14*(4), 1130-1161. doi:10.1111/j.1083-6101.2009. 01484.x

Hackerspace. (2015). *Hackerspaces*. Retrieved from http://hackerspaces.org/

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Huang, C., & Lin, C. (2011). Enhancing classroom interactivity and engagement: Perceptions of the application of Web 2.0 technology. *British Journal of Educational Technology, 42*(6), 141-144. doi:10.1111/j.1467-8535.2011. 01219.x

Huffaker, D. (2005). The educated blogger: Using weblogs to promote literacy in the classroom. *AACE Journal, 13*(2), 91-98.

Jackson, L. A., Witt, E. A., Games, A. I., Fitzgerald, H. E., von Eye, A., & Zhao, Y. (2012). Information technology use and creativity: Findings from the children and technology project. *Computers in Human Behavior, 28*(2), 370-376. doi: 10.1016/j.chb.2011.10.006

Lampe, C., Wohn, D. Y., Vitak, J., Ellison, N. B., & Wash, R. (2011). Student use of Facebook for organizing collaborative classroom activities. *International Journal of Computer-Supported Collaborative Learning, 6*(3), 329-347. doi:10.1007/s1 1412-011- 9115-y

Litts, B. K. (2015). *Making learning: Makerspaces as learning environments* (Order No. 3672348). Retrieved from ProQuest Dissertations & Theses Global. (1651611969)

Maker Education Initiative. (2016). *Every child a maker*. Retrieved from http://makered.org/

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

Mazer, J. P., Murphy, R. E., & Simonds, C. J. (2007). I'll see you on "Facebook:" The effects of computer mediated teacher self-disclosure on student motivation, affective learning, and classroom climate. *Communication Education*, *56*(1), 1-17.

McGrail, E., & Davis, A. (2011). The influence of classroom blogging on elementary student writing. *Journal of Research in Childhood Education, 25*(4), 415-437. doi:10.1080/02568543.2011.605205

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Merriam, S., B. (2009). *Qualitative research: A guide to design and implementation*. Hoboken NJ: John Wiley & Sons**.**

Merriam, S. B., & Tisdell, E. J. (1997). *Qualitative research: A guide to design and implementation.* San Francisco, CA**:** Jossey-Bass**.**

Miller, C. R., & Shepherd, D. (2004, July). *Blogging as social action: A genre analysis of the weblog. Into the Blogosphere: Rhetoric, Community, and the Culture of Weblogs*. Retrieved from http://blog.lib.umn.edu/blogosphere/blogging_as_social_action_a_genre_analysis_of_the_weblog.html

National Center for Education Statistics. (2015). *Education statistics*. Retrieved from https://nces.ed.gov

Obama, B. (2009, November 23*). Remarks by the President on the "Education to Innovate" campaign*. Retrieved from https://www.whitehouse.gov/the-press-office/remarks-president-education-innovate-campaign

Otieno, C., Schulz, L. J., Tankovich, W., Wang, X., & Gall, J. (2013). *Teacher perceptions and use of web-based tools for student collaboration in K-12 education*. Paper presented at Presented at The Annual Convention of the AECT Sponsored by the Research and Theory Division Anaheim, CA. Retrieved from http://www.aect.org/publications/proceedings/2013.asp

Papert, S. (1993a, February 1). Obsolete skill set: The 3Rs--Literacy and literacy in the media ages. *Wired Magazine*. Retrieved from http://www.wired.com/1993/02/1-2-papert/

Papert, S. (1993b). *The children's machines: Rethinking schools in the age of computers.* New York, NY: Basic Books.

Partnership for 21st Century Learning. (2003a). *Framework for 21st century learner*. Retrieved from http://www.p21.org/

Partnership for 21st Century Learning. (2003b). *Learning for the 21st century.* Retrieved from http://www.p21.org/storage/documents/P21_Report.pdf

Partnership for 21st Century Learning. (2015). *P21 framework definitions*. Retrieved from http://www.p21.org/storage/documents/docs/P21_Framework_ Definitions_New_Logo_2015.pdf

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 50-70). New York, NY: Routledge.

Pray, J. L. (2001). Enhancing critical thinking and professionalism through use of the discussion forum in social work practice courses. *Journal of Technology in Human Services, 18*(1-2), 65-75. doi:10.1300/J017v18n01_06

Quinn, H., & Bell, P. (2013). How designing, making, and playing relate to the learning goals of k-12 science education. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 17-34). New York, NY: Routledge

Reiser, R., A & Dempsey, J., Y. (2012). *Trends and issues in instructional design and technology* (3rd ed.). Pearson, Saddlebrook, NJ, Soulé, H., & Warrick, T. (2015). Defining 21st century readiness for all students: What we know and how to get there. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(2), 178-186. doi:10.1037/aca0000017

Sousa, D. A., & Pilecki, T. (2013). *From stem to steam: Using brain-compatible strategies to Integrate the arts.* Newbury Park, CA: Corwin Publisher.

Wagner, T. (2008). *The global achievement gap: Why even our best schools don't teach the new survival skills our children need--and what we can do about it*. New York, NY: Basic Books.

Warschauer, M., & Grimes, D. (2007). Audience, authorship, and artifact: The emergent semiotics of Web 2.0. *Annual Review of Applied Linguistics*, 27, 1-23. doi:10.1017/ S0267190508070013

CHAPTER VII

A LOOK INTO THE SPACE ITSELF: MAKERSPACE

To be submitted to a top Journal in Technology Education
Specific Information withheld for Journal Blind Review
Process Single Author Manuscript

Introduction

Makerspaces as innovative learning environments are becoming a phenomenon both in formal and informal learning spaces. Makerspaces are defined by Honey and Kanter (2013) as informal spaces where people of all ages can go to learn "tinker" and "make;" terms synonymously used to refer to act of "designing and producing things for sheer pleasure of figuring out how things work and repurposing them at will" (p. 5). Makerspaces as a term first appeared in 2005 coined by Dale Dougherty. It emerged from the technology-driven "maker movement and culture," associated with Make magazine and the Maker Faires started by the founder Dale Dougherty (2005). The maker movement, which saw the birth of makerspaces, was mostly motivated by the majority interest in DIY (do it yourself) culture which saw individuals make and tinker materials on their own outside formal learning spaces; these spaces have been referred to as makeshops, hackerspaces, makerspaces, techshops, and fablabs (Honey & Kanter, 2013). Dougherty (2005) referred to makerspaces as publicly-accessible places to design and create.

To better understand makerspaces itself, photographs of three Makerspaces in formal and informal learning environments were taken and represented here. This was crucial in giving readers glimpse of the space and what factors they need to consider when setting up a Makerspace of their own. Many factors must be considered when setting up a makerspace. These include but are not limited to space, available resources, funding, and users. Any makerspace regardless of the tools and resources available must be students and user centered. If they are to work effectively, these spaces must provide accessibilities that balance creation, safety, and security. Martinez and Stager (2013) encourages the need for any Makerspace to afford flexibility and functionality. They defined functionality of the space as the physical design, how much space, organization of resources within the space and safety from harm within the environment (Martinez & Stager, 2013). Flexibility of the space is the ability of the space to be used for multiple projects and ability of users to feel free to navigate the space itself (Martinez & Stager, 2013).

In this study, three makerspaces were observed and image of these spaces were collected to highlight how these can look like in different learning environments. The first Makerspace was in a library serving all age groups in the rocky mountain region, second makerspace was in a school serving kindergarten to eight graders, and the final Makerspace was in a middle school in the rocky mountain region in an art class.

There were similar features across spaces such as flexibility, functionality, security, and safety, as well as storage. Each space design was unique to each teacher but all these factors were present. When it comes to space functionality, all three makerspaces were designed to be useful in making and tinkering. They were not too small, or too crowded. They had working organization of tools, resources to allow students to work efficiently. Good lighting, room to move around and design. In addition to functionality these spaces were flexible. Instructors designed the spaces to allow for multiple projects at the same time, resources organized and accessible so students can explore, experiment with multiple ideas. Flexibility was also evident in the design as students could collaborate easily, or work independently on their own, share resources and tools while working, brainstorm and iterate. The more flexible choices users have in the space the better they are at creating freely.

To better represent the Makerspaces studied, images of these Makerspaces were taken and analyzed with other data collected to showcase the space itself and how the space enhances pedagogy and learning.

Results

After thorough analysis of the photographs and data collected, the results of this study demonstrated aspects in Makerspace that can be adapted by any teacher. These Makerspaces worked to ensure functionality and flexibility of the space. Martinez and Stager (2013) defined functionality as the space ability to allow users to tinker freely. Functionality in these spaces was characterized by the size, resources available, safety and security and access. Functionality in these spaces were seen as the ability of the space to allow for multiple entry points to the activities, the ability of the space to allow users to embrace the functionality of the space and feel free to take charge and create, access resources and work collaboratively in their making and tinkering. Safety and security is also important in any makerspace as an aspect of both functionality and flexibility. Students and users must feel safe to create, safe from harm when operating tools, safe to move around easily, and work together freely and naturally in the space. Depending on the tools and equipment being used, safety of all parties throughout making and tinkering is essential. Allow students buy in and share precautions, safety rules, cleanup, expectations and common rules in the space. Coordinating with other staff members and administration was another way these instructors ensured safety in the space. One thing observed that was different in spaces was access to a security personnel that come often in the library makerspace and ensured things were going well without interrupting the creating progress. This was quite different from the school makerspaces where responsibilities fell solely on the teacher. In this chapter, I provide photo examples of how these makerspaces were designed to help make and tinker.

Makerspaces Learning Environment:

Informal Learning Environment:
Library Makerspace

This space was designed to meet the making and tinkering needs of the library users of all age groups within the area. For this reason, the space features are flexible and can be rearranged to meet specific program and users making needs. Identifying and creating a makerspace that fits your users' needs is crucial if your space will be functional and flexible (Martinez & Stager, 2013). Desk and chairs were always in the middle of the room allowing for free easy movement around the space. All 3D printers, cabinets, sewing equipment and media station were situated conveniently on the sides of the room for easy access. Instructors could easily move around the room to help students through their making.

In creating a safe making environment, this library invested in the space and allowed for flexibility (see Figures 6.1 and 6.2).

Figure 6.1. Library Makerspace. Images of the library makerspace showing available resources in the room. From top left mac computer, top right cabinet storage for supply, bottom right flat screen tv for demonstrations and viewing media work, bottom left is the work station area with tables and chairs all of which users' access during sessions to complete their projects.

Figure 6.2. Images of the library Makerspace. Images of the same library Makerspace. From left table setting with computer laptops ready for session, and bottom right some pen 3D design materials ready for a session.

Formal Learning Environment

Middle school #1: Makerspace for science technology engineering mathematics learning. This space was designed with students in a school setting in mind. The space mainly served kindergarten through eighth grade students. The instructor had more freedom to design the space to meet the learning need of his students. This room was bigger than the library and tools were permanently in the room. Students access the space during art lesson periods only. The class would run regular forty-five-minute time slot. This space had several sections. In the middle of the room tables were set up with chairs for group works as well as individual work facing the projector, there was a small library space where students could access reference books, a display section for artifacts, a corner with plugged in iPad cart system, 3D printers laser cutter tool, office, a small section with books and three computers and space for students who want to work alone, and a computer lab with about thirty three individual computers, teacher projector, and smartboard.

These photographs collage represents the space itself. On the top left is the small library section, followed by top right the work space, lower left picture is the students work space facing the projector screen, then students work station (see Figure 6.3 and 6.4).

Figure 6.3 Makerspace in first middle school. Clockwise top left, small library with books for students, corner space for individual student to work in, and bottom right back view of the student space with tables and chairs facing main entrance, and finally bottom left is the students work space facing instructors podium.

Figure 6.4. First middle school Makerspace more space area. The second image below further represents the space, top left supply shelves as well as students' artifacts, top right 3D printers, bottom right iPad cart system and finally bottom left is the computer lab.

In addition to the above, this space also had mentor texts, cues, and motivational nuggets across the room (see Figure 6.5). These were vital for classroom management in the room where students would reference the rules of the class if they needed to without constantly asking the teacher.

Examples:

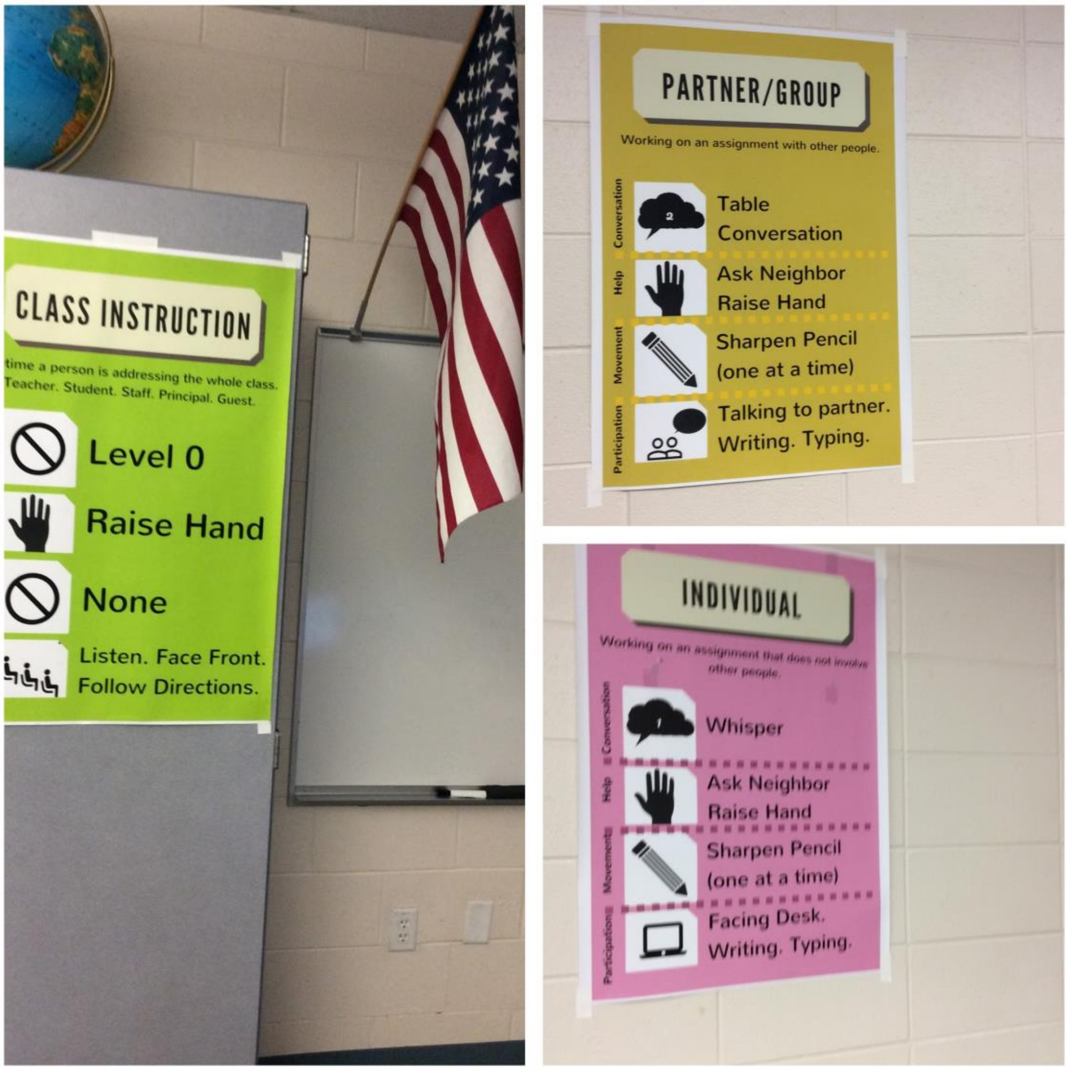

Figure 6.5 Mentor texts in the space. Images showing mentor texts with space rules around the room, these helped students in reference capacity and self-guiding in terms of space rules improving functionality.

In addition, these mentor texts played a motivational role (see Figure 6.6). These were aspects that defined the space itself. The room had five events that happen in the room to encourage students and make them aware of the space potentials.

Figure 6.6. Mentor texts 2. These images show making and tinkering motivational cues to help the student create freely improving flexibility of the space and showing the iteration process.

There was also a student's work in progress station where students could store their projects they were working on. Having this allowed the students to save their work as they still had the rest of the day of school, and prevented lost projects or interrupting their work stages and just the relief that they did not have to worry about it and or lose it if they took it with them. They came back and continued from where they left off. These were easily retrievable for next class and it also allowed for work in progress display demonstrating the iteration process for the students and the teacher as well (see Figure 6.7).

Middle school #2: Makerspace for art education. This was an art education classroom Makerspace specifically for sixth-eighth graders. Like the other makerspace, the instructor had much freedom in design and the layout of the space. This instructor also worked on grants to supply some of the resources and technology in the room. The classroom could host a capacity of twenty students with the material in the space. Unlike the library most things are fixed in specific corners of the room and the students space is in the middle of the room (see Figure 6.8). This setup allowed students to move freely and access the different resources for creating and making. While creating, students were observed sharing materials and collaborating to help each other with the projects. Students had flexibility in choosing how collaboration looked like as they designed and created. They could work with something on their project or sought help from someone for their own projects as well as helped others on these projects.

Figure 6.7. Students work-in-progress station. These images represent student's designs that they were still working on left safely in the room for the next session.

Figure 6.8. Second school Makerspace. These photos showcase the School Art classroom Makerspace.

Like the first middle school spaces, there were mentor texts across the room as well as on students' folders (see Figure 6.9). For this makerspace, these mentor texts were quick teaching aid tips of different art techniques for the students. These were strategically placed around the working space where they were easily visible and accessible.

Figure 6.9. Classroom mentor texts. These pictures represent the mentor texts in the classroom Makerspace for students to access.

Through their making and tinkering students individual space varied as their projects varied. Spaces were messy, creative if you may, as students created. They were more focused and experimented with multiple tools, equipment for their work as represented in Figure 6.10 below.

Figure 6.10. Student’s work space. These images showcase students work spaces and how they created in their spaces.

To celebrate student's innovation and creations, students' artifacts were displayed around the room, and school corridors (see Figure 6.11). This not only motivated students, but also held them accountable to their work. According to Honey and Kanter (2013) providing a platform for students to showcase their work helps them take ownership and boosts their confidence to create and make more, therefore, enhancing the "maker mindset."

Conclusion

Makerspace and how they are set up mostly depends on the teachers and their students. What was similar across all these makerspaces is that they still have students and users in mind. Creating a space where students, makers, and users, feel comfortable, safe and supported to experiment, tinker and make is and should be the goal of any makerspace. Makers must find a haven in your space if they are going to freely create and bring their imagination to life. The space must inspire and challenge them through iteration, interaction, resourcefulness, and creativity (Martinez & Stager, 2013). Functionality and flexibility can as such be achieved in the space regardless of resources and space size. Identifying how users will use the space and designing the space to be functional and flexible can be the make or break in any Makerspace.

Starting a makerspace is dependent on a lot of factors like support, users, space size, teacher, budget, equipment, and tools. It is possible for a teacher who believes in the transformative learning that makerspaces and technology affords learning to venture on starting a makerspace than one that does not. Teachers can start makerspaces in their own classroom using resources they have access to and later transform into high end technology. Regardless of the scenario, makerspace must put into consideration access, flexibility, safety, and functionality.

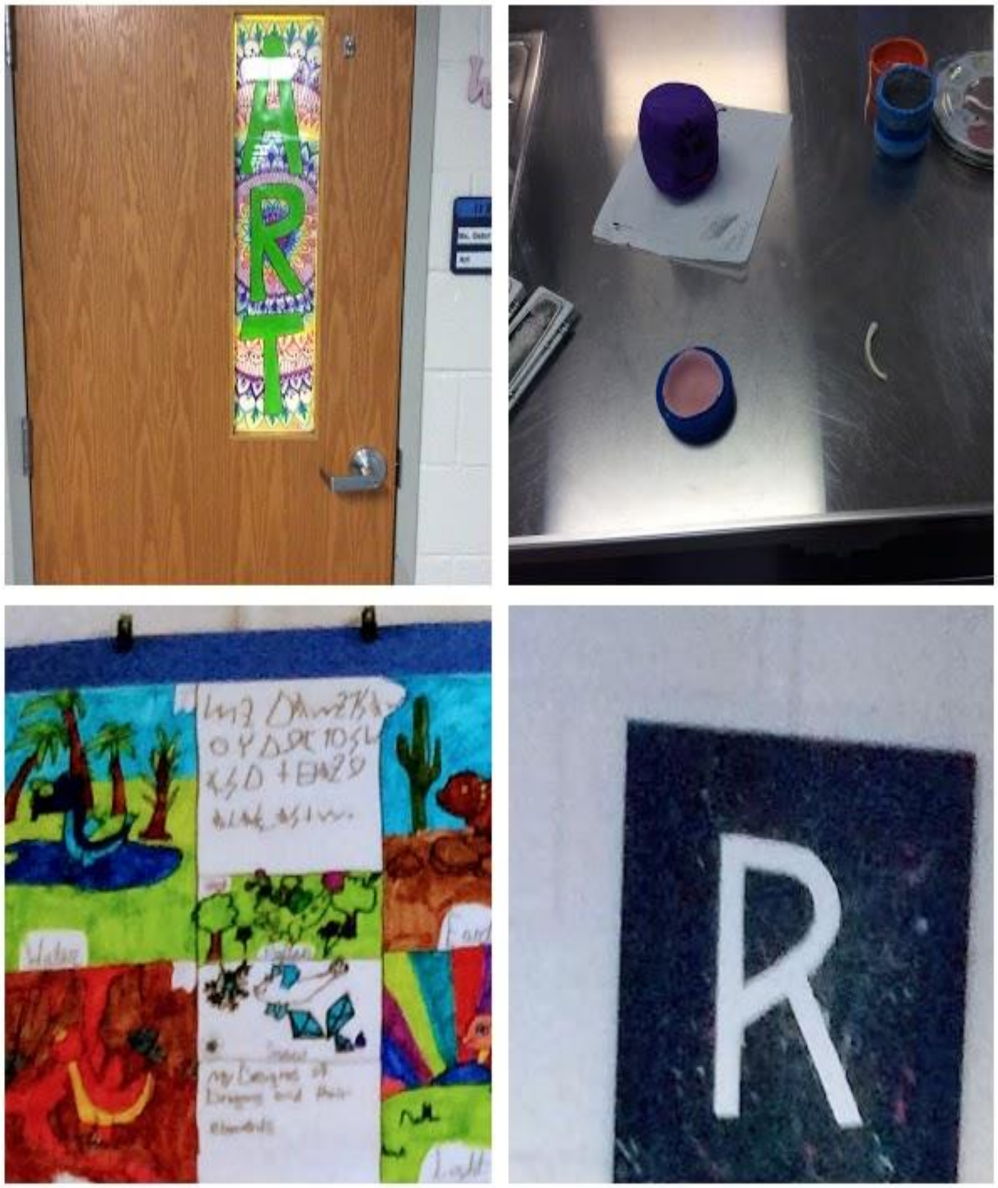

Figure 6.11. Student's artifacts display. These images represent the display of students work around the school corridors and cafeteria.

References

Dougherty, D. (2005). *Maker faire founder Dale Dougherty on the past, present, and online future of the maker movement*. Retrieved from https://goo.gl/wRkKxF

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

CHAPTER VIII

CONCLUSIONS

In this study, I investigated making and tinkering in the makerspaces to determine how instructor's pedagogical practices manifests itself in the space, how this practice enhances making and tinkering, how learning happens in the space and finally looked at the space itself from photo elicitation. The three makerspaces observed in this study represents the diverse and unique nature makerspaces present as innovative learning environments. The following research questions guided this study;

Q1 How does learning happen in a technology rich makerspace?

Q2 How does pedagogy manifest itself in a technology rich makerspace environment?

All three articles presented in this dissertation (pedagogical practices of makerspace instructor, instructors perspectives on learning in the makerspace, and a look into the space itself) as well as the initial three chapters aim at providing insight and contributing to the literature on makerspaces, making and tinkering and how educators must reimagine in addition to original definition of learning what evolution of technology and innovative environments really look like. The articles presented hope to provide educators with resources on the benefits of makerspace and their contribution to learning.

In highlighting the pedagogical practices of the makerspace instructors this specific article hopes to inform all educators in K-12, administrators, and makerspace pioneers on teaching strategies that enhances maker mindset and helps create makerspaces where learners and users can create, tinker and maker efficiently. Due to the unique nature of makerspaces, instructors need to provide engaging activities with multiple pathways, facilitate and guide these engaging activities and redefine what success means as students create and tinker. In sharing these instructor's practices in the space, and how instructors facilitate learners learning I hope to show that teachers can borrow from teaching strategies in makerspace in a regular classroom. Some of these teachers used simply materials to help student be designers.

Makerspaces are further redefining learning. The second article in this dissertation is geared towards displaying that. Students in the makerspace can be seen learning through iteration, sharing ideas, strategies, problem solving, and being innovators in both formal and non-formal makerspaces. Learning in the makerspaces are not linear step by step as seen in most traditional classroom, instead it is nonlinear, packed with problem-solving opportunities through iteration, a lot of collaboration opportunities that are choice based and happens naturally, engaging and users can pursue their own learning goals. This article is geared to help teachers, educators, administrators, and policy makers in K-20 learning environments see the possibilities makerspaces have in transforming learning and teaching. It is intended to provide evidence of learning in the space and can be done to help educators provide the resources and materials that will enhance this. This article further shows that educators can adopt makerspace principles and tenets in a regular classroom to enhance their students learning.

To understand how makerspaces, look like, the third article in this dissertation provides educators and teachers a look into a makerspace itself through photos of the different makerspaces. Makerspaces designs are unique to the space, funding, instructors, students, and users. To design a space that works for both parties, equipment and tools, instructors must consider all these factors. Regardless of the situation one is in, a makerspace must be user friendly, organized and haven for students to work, make and tinker in.

Implications

Several implications can be drawn from this study that can help teachers, instructors and those considering a makerspace mindset. The paradigm shift in the space was something to behold. Instructors become facilitators and guides of knowledge. They provided a learning space where some ownership of learning was transferred to the learners and this allowed for learners to pursue their own goals with the instructors nurturing these innovative, making and tinkering minds. Instructors created space and provided materials and resources where students naturally had to stretch their thinking, creative mindset and problem-solving skills. Seeing student’s creation and seeing them through iteration process instructors had more professional fulfillment and confidence in the activities they created.

Students and users in the makerspace valued their works as designers, innovators especially if they created something to solve an issue they had. This ownership of learning further builds their interest and engagement to the learning process giving them ownership of the knowledge they gained. Makerspaces further provide students opportunity to share their ideas in the space. One of the skills called for in the 21st century. Is ability for learners to work together effectively. In a makerspace working collaboratively come natural in the environment where students worked individually or in groups. Either way they freely shared their ideas with peers in such a natural way through aiding, asking each other questions and feedback on their designs. Instructors provided multiple pathways to activities and guiding students through their creation provided autonomy and time for the students to think through their designs and some ended up in different pathways but this allowed students to trust themselves to be problem solver.

Future Research

After completing this study, I see opportunities for future research. This study specifically focused on makerspaces activities for middle school students a larger and more wider population group could be studied to determine the benefits across K-20. In addition, looking at more makerspaces in K-12 classroom where specific teachers have turned their classroom into makerspace would be beneficial to relate benefit with specific content areas in K-12.

REFERENCES

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of Learning Group Publication, 5*(3), 438-448.

Anderson, A. C. (2012). *Makers: The new industrial revolution*. New York, NY: Crown Business.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory. A proposed system and its control process. In J. Spense & K. Spence (Eds.), *Psychology of learning and motivation* (Vol 2, 89-189). New York, NY: Academic Press.

Ausebel, D. P., Novak, J. D., & Hanesian, H. (1978). E*ducational psychology: A cognitive view* (2nd ed.). New York, NY: Holt, Rinehart and Winston.

Berland, M. W. (2008). *VBOT: Motivating computational and complex systems fluencies with constructionist virtual/physical robotics* (Order No. 3307005). Retrieved from ProQuest Dissertations & Theses Global. (304479699).

Berland, M., & Wilensky, U. (2006). *Constructionist collaborative engineering: Results from an implementation of PVBOT*. Paper presented at the Annual meeting of the American Educational Research Association, San Francisco, CA.

Blikstein, P. (2013). Digital fabrication and "making" in education: The democratization of invention. In J. Walter-Herrmann & C. Büching (Eds.). *FabLabs: Of machines, makers and inventors* (pp.1-21). Bielefeld, Germany: Transcript-Verlag Publishers.

Boling, E. (2008). Learning from teachers' conceptions of technology integration: What do blogs, instant messages, and 3D chat rooms have to do with it? *Research in the Teaching of English*, *43*(1), 74-100.

Boling, E., Castek, J., Zawilinski, L., Barton, K., & Nierlich, T. (2008). Collaborative literacy: Blogs and Internet projects. *Reading Teacher*, *61*(6), 504-506.

Brahms, L. J. (2014). *Making as a learning process: Identifying and supporting family learning in informal settings* (Order No. 3582510). Retrieved from ProQuest Dissertations & Theses Global. (1609201673).

Brahms, L. J., & Werner, J. (2013). Designing makerspace for family learning in museums and science centers. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 71-94). New York, NY: Routledge.

Bruner, J., S. (1997). Celebrating divergence: Piaget and Vygotsky. *Human Development*, 40, 63-67.

Cavalcanti, G. (2013). *Is it a hackerspace, makerspace, techshop, or fablab*? Retrieved from http://makezine.com/2013/05/22/the-difference-between-hackerspaces-makerspaces-techshops-and-fablabs/

Chiang, C. A., & Fung, P. I. (2004). Redesigning chat forum for critical thinking in a problem-based learning environment. *Internet and Higher Education, 7*(4), 311-328.

Churchill, D. (2011). Web 2.0 in education: A study of the explorative use of blogs with a postgraduate class. *Innovations in Education and Teaching International, 48*(2), 149-158. doi:10.1080/14703297.2011.564009

Ciampa, K., & Gallagher, T. L. (2013). Getting in touch: Use of mobile devices in the elementary classroom. *Computers in the Schools, 30*(4), 309-328.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage publication Inc.

Creswell, J. W. (2011). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Boston, MA: Pearson Education Inc.

Dougherty, D. (2005). *Maker faire founder Dale Dougherty on the past, present, and online future of the maker movement*. Retrieved from https://goo.gl/wRkKxF

Dougherty, D. (2013). The maker mindset. In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Doult, W., & Walker, S. A. (2014). “He gone and wrote over it:” The use of Wikis for collaborative report writing in a primary school classroom. *Education 42*(6), 601-620. doi:10.1080/03004279.2012.752022

Driscoll, M. P. (2000). *Psychology of learning for instructions* (2nd ed.). Needham Heights, MA: Allyn & Bacon.

Driscoll, M. P. (2005). *Psychology of learning for instructions* (3rd ed.). Boston, MA: Pearson Education Inc.

Driscoll, M. P. (2012). Psychological foundations of instructional design. In R. A. Reiser & J. Y. Dempsey (Eds.), *Trends and issues in instructional design and technology* (3rd ed., pp. 35-44). Saddlebrook, NJ: Pearson.

Duffy, T. M., & Cunningham, D. J. (1996). *Constructivism: Implications for design and delivery of instruction*. Retrieved from http://www.aect.org/edtech/ed1/pdf/07.pdf

Educause. (2013, April 9). *7 Things you should know about Makerspaces*. Retrieved from https://library.educause.edu/resources/2013/4/7-things-you-should-know-about-makerspaces

Farr, N. (2009, August 25). *Respect the past, examine the present, build the future* [Web blog posting]. Retrieved from http://blog.hackerspaces.org/2009/08/25/respect-the-past-examine-the-present-build-the-future/

Foote, L. M. (2013). Honing crisis communication skills: Using interactive media and student-centered learning to develop agile leaders. *Journal of Management Education, 37*(1), 79-114. doi:10.1177/1052562912455419

Gagné, R. (1977). *The conditions of learning*. Boston, MA: Thomson Learning.

Gagné, R. (1985). *The cognitive psychology of cognitive learning*. Boston, MA: Little Brown.

Gagné, R. M., & Medsker, K. L. (1995). *Conditions of learning: Training applications*. Belmont, CA: Wadsworth Publishing.

Gagné, R. M., & Merill, M, D. (1990). Instructional psychology. *Annual Review of Psychology,* 31(*4*) 381-418.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine Publishing Company.

Greenhow, C., & Robelia, B. (2009). Old communication, new literacies: Social network sites as social learning resources. *Journal of Computer-Mediated Communication, 14*(4), 1130-1161. doi:10.1111/j.1083-6101.2009.01484.x

Hackerspace. (2015). *Hackerspace*. Retrieved from http://hackerspaces.org/

Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York, NY: Routledge.

Huang, C., & Lin, C. (2011). Enhancing classroom interactivity and engagement: Perceptions of the application of Web 2.0 technology. *British Journal of Educational Technology, 42*(6), 141-144. doi:10.1111/j.1467-8535.2011. 01219.x

Huffaker, D. (2005). The educated blogger: Using weblogs to promote literacy in the classroom. *AACE Journal, 13*(2), 91-98.

Istance, D., & Kools, M. (2013). OECD work on technology and education: Innovative learning environments as an integrating framework. *European Journal of Education, 48*(1), 43-57. doi:1111/ejed.12017

Jackson, L. A., Witt, E. A., Games, A. I., Fitzgerald, H. E., von Eye, A., & Zhao, Y. (2012). Information technology use and creativity: Findings from the children and technology project. *Computers in Human Behavior, 28*(2), 370-376. doi: 10.1016/j.chb.2011.10.006

Kalil, T. (2013). Have fun-learn something, do something, make something. In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (12-16). New York, NY: Routledge.

Keller, J., M. (2010). *Motivational design for learning and performance: The ARCS model approach*. New York, NY: Springer.

Lampe, C., Wohn, D. Y., Vitak, J., Ellison, N. B., & Wash, R. (2011). Student use of Facebook for organizing collaborative classroom activities. *International Journal of Computer-Supported Collaborative Learning*, *6*(3), 329-347. doi:10.1007/s1 1412-011- 9115-y

LeCompte, M., D., & Schensul, J., J. (1999). *Designing and conducting ethnographic research*. Lanham, MD: Altamira Press.

Lee, V., G. (2006). *Reading experiences of adolescent boys as they navigate the multiple discourse and social context of school, home, and rural community: An ethnographic case study* (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (305293689).

Library Research Services, (2016). *Public library statistics*. Retrieved from https://www.lrs.org/data-tools/public-libraries/.

Litts, B. K. (2015). *Making learning: Makerspaces as learning environments* (Order No. 3672348). Retrieved from ProQuest Dissertations & Theses Global. (1651611969)

Maker Education Initiative. (2016). *Every child a maker*. Retrieved from http://makered.org/

Martinez, S. L., & Stager, G. (2013). *Invent to Learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

Mazer, J. P., Murphy, R. E., & Simonds, C. J. (2007). I'll see you on "Facebook:" The effects of computer mediated teacher self-disclosure on student motivation, affective learning, and classroom climate. *Communication Education*, *56*(1), 1-17.

McGrail, E., & Davis, A. (2011). The influence of classroom blogging on elementary student writing. *Journal of Research in Childhood Education, 25*(4), 415-437. doi:10.1080/02568543.2011.605205

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Miller, C. R., & Shepherd, D. (2004, July). *Blogging as social action: A genre analysis of the weblog. Into the Blogosphere: Rhetoric, Community, and the Culture of Weblogs*. Retrieved from http://blog.lib.umn.edu/blogosphere/blogging_as_social_action_a_genre_analysis_of_the_weblog.html

National Center for Education Statistics (2015). *Schools statistics*. Retrieved from https://nces.ed.gov

North Central Regional Educational Laboratory & Metiri Group. (2003). *21st century skills: Literacy in the digital age*. Retrieved from http://pict.sdsu.edu/engauge21st.pdf

Obama, B. (2009, November 23*). Remarks by the President on the "Education to Innovate" campaign*. Retrieved from https://www.whitehouse.gov/the-press-office/remarks-president-education-innovate-campaign

OlPhen, M. V. (2008). TPCK: An integrated framework for educating world language teachers. In AACTE Committee on Innovation and Technology (Ed.), *The handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. 3-29). New York, NY: Routledge.

Otieno, C., Schulz, L. J., Tankovich, W., Wang, X., & Gall, J. (2013). *Teacher perceptions and use of web-based tools for student collaboration in K-12 education*. Paper presented at Presented at The Annual Convention of the AECT Sponsored by the Research and Theory Division Anaheim, CA. Retrieved from http://www.aect.org/publications/proceedings/2013.asp

Papert, S. (1993a, February 1). Obsolete skill set: The 3Rs--Literacy and literacy in the media ages. *Wired Magazine*. Retrieved from http://www.wired.com/1993/02/1-2-papert/

Papert, S. (1993b). *The children's machines: Rethinking schools in the age of computers.* New York, NY: Basic Books.

Partnership for 21st Century Learning. (2003a). *Framework for 21st century learner*. Retrieved from http://www.p21.org/

Partnership for 21st Century Learning. (2003b). *Learning for the 21st century*. Retrieved from http://www.p21.org/storage/documents/P21_Report.pdf

Partnership for 21st Century Learning. (2015). *P21 framework definitions*. Retrieved from http://www.p21.org/storage/documents/docs/P21_Framework_ Definitions_New_Logo_2015.pdf

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning? In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 50-70). New York, NY: Routledge.

Pray, J. L. (2001). Enhancing critical thinking and professionalism through use of the discussion forum in social work practice courses. *Journal of Technology in Human Services, 18*(1-2), 65-75. doi:10.1300/J017v18n01_06

Quinn, H., & Bell, P. (2013). How designing, making, and playing relate to the learning goals of k-12 science education. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 17-34). New York, NY: Routledge

Reiser, R., A & Dempsey, J., Y. (2012). *Trends and issues in instructional design and technology* (3rd ed.). Saddlebrook, NJ: Pearson.

Simon, M., & Brown, G. (2013). Raft: A maker palace for educators. In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (138-162). New York, NY: Routledge

Soulé, H., & Warrick, T. (2015). Defining 21st century readiness for all students: What we know and how to get there. *Psychology of Aesthetics, Creativity, and the Arts, 9*(2), 178-186. doi:10.1037/aca0000017

Sousa, D. A., & Pilecki, T. (2013). *From stem to steam: Using brain-compatible strategies to Integrate the arts.* Newbury Park, CA: Corwin Publisher.

Vygotsky, L. (1978). Interaction between learning and development. In M. A. Gauvin (Ed.), *Reading on development of children* (pp. 34-40). New York, NY: Scientific American Books.

Vygotsky, L. S. & Cole, M. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1993). *The collected works of L. S. Vygotsky. Volume 2*: In R. W. Rieber W. & A. S. Carton (Eds.), *The fundamentals of defectology (abnormal psychology and learning disabilities)* (1-93). New York City, NY: Springer.

Wagner, T. (2008). *The global achievement gap: Why even our best schools don't teach the new survival skills our children need--and what we can do about it*. New York, NY: Basic Books.

Washor, E., & Mojkowski, C. (2013). *Leaving to learn: How out-of-school learning increases student engagement and reduces dropout rates* [Kindle reader]. Portsmouth, NH: Heinemann.

Warschauer, M., & Grimes, D. (2007). Audience, authorship, and artifact: The emergent semiotics of Web 2.0. *Annual Review of Applied Linguistics*, 27, 1-23. doi:10.1017/ S0267190508070013

Wilson, F, R (1998). *The hand. How its use shapes the brain, language, and human culture.* New York, NY: Pantheon Books.

Yin, R. (1994). *Case study research: Design and methods* (2nd ed.). Thousand Oaks, CA: Sage Publishing.

APPENDIX A

OBSERVATIONAL PROTOCOL DOCUMENT
(Creswell, 2007, p. 137)

OBSERVATIONAL PROTOCOL DOCUMENT

Length of Activity 45 minutes each (7:50 am-10:50am) October 5th (PV M)	
Descriptive Notes	Reflective Notes
For this observation, I observed 3 classes back to back. 6th, 7th and 8th graders. Class started with an art projected on the board. Announcement of taking the loyalty pledge, all students up and recite pledge. Another announcement, a student called to office. Students then reflect on the image on the board on their work books (about 5 minutes) Then the teacher asks questions about what they see (About 10 min) "Jamie* observation please" "I see contrast" After they set off to continue on their projects. They work at the different stations (Painting, clay modeling, sewing, crafting, etc,) They are determining whether they are being subjective or objective Seemed very organized and students worked on their projects. Teacher went around probing, guiding and asking questions on the making process, why what how questions were posed. Same set up for all 3 classes	The teacher had very good rapport with the students while still maintaining that teacher authority balance. Students very engaged in their projects and asking help and feedback from peers and instructor when they needed more help. The pieces were very good, some were struggling but the teacher was very good at guiding.

APPENDIX B

DATA COLLECTION MATRIX

DATA COLLECTION MATRIX

Research Questions	Types of Data
1.How does pedagogy manifests itself in a technology rich makerspace	Interviews Observation Artifacts: teacher lesson plans, mentor texts, photos of work in the space, of space itself Journal entry Field notes
2. How does learning happen in technology rich makerspace	Interviews Observations of students in the space Artifacts; student work, teachers evidence of work Field notes

APPENDIX C

DATA ANALYSIS MATRIX

DATA ANALYSIS MATRIX

Research Question	**Data Collected**	**Analysis Method**
How does pedagogy manifest itself in a technology rich makerspace	Interviews Observation Artifacts: teacher lesson plans, mentor texts, photos of work in the space, of space itself Journal entry Field notes	Constant comparative analysis Within-case analysis Cross-case analysis
How does learning happen in technology rich makerspace	Interviews Observations of students in the space Artifacts; student work, teachers evidence of work Field notes	Constant comparative analysis Within-case analysis Cross-case analysis

APPENDIX D

INSTITUTIONAL REVIEW BOARD APPROVAL

INSTITUTIONAL REVIEW BOARD

DATE: July 14, 2016

TO: Catherine Otieno FROM: University of Northern Colorado (UNCO) IRB

PROJECT TITLE: [929223-1] Makerspaces: A Qualitative look into makerspaces as

Innovative learning environment from Instructors perspectives!

SUBMISSION TYPE: New Project

ACTION: APPROVAL/VERIFICATION OF EXEMPT STATUS DECISION DATE: July

14, 2016 EXPIRATION DATE: July 14, 2020

Thank you for your submission of New Project materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Catherine

Thank you for a clear and thorough IRB application for an interesting and relevant

study. Your application is verified/approved exempt. Please make the following two small changes to your consent form before use in participant recruitment and data

collection:

1) add a place at the for participants to initial the first page if it is a 2-page

consent form (e.g., Page 1 of 2 _____please initial); and

2) update the contact information verbatim in the last sentence of the last

paragraph as follows; If you have any concerns about your selection or

treatment as a research participant, please contact Sherry May, in the Office of

Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO

80639; 970-351- 1910."

These changes do not need to be submitted for subsequent review.

Best wishes with your research.

Sincerely,

Dr. Megan Stellino, UNC IRB Co-Chair

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Sherry May at 970-351- 1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.