EFFECT OF MAKERSPACE PROFESSIONAL DEVELOPMENT ACTIVITIES ON ELEMENTARY AND MIDDLE SCHOOL EDUCATOR PERCEPTIONS OF INTEGRATING TECHNOLOGIES WITH STEM (SCIENCE, TECHNOLOGY, ENGINEERING, MATHEMATICS)

Jennifer Renea Miller

Dissertation Prepared for the Degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF NORTH TEXAS

December 2016

APPROVED:

Gerald Knezek, Major Professor
Lemoyne Dunn, Co-Major Professor
Rhonda Christensen, Committee Member
Cathie Norris, Interim Chair of the
Department of Learning Technologies
Kinshuk, Dean of the College of Information
Victor Prybutok, Vice Provost of the Toulouse
Graduate School

Miller, Jennifer Renea. *Effect of Makerspace Professional Development Activities on Elementary and Middle School Educator Perceptions of Integrating Technologies with STEM (Science, Technology, Engineering, and Mathematics)*. Doctor of Philosophy (Learning Technologies), December 2016, 129 pp., 40 tables, 5 figures, references, 91 titles.

This study investigated a Makerspace professional development program, the Makers' Guild, provided to teachers within north Texas over the course of a semester. The research employed a constructionist approach delivered via 2D and 3D technologies during STEM instructional activities within a creative space. Participants reported statistically significant increases in self-reported competence in technology integration, confidence levels toward integrating World Wide Web, Emerging Technologies for Student Learning, Teacher Professional Development, and attitudes toward math, technology, science, and STEM careers.

ACKNOWLEDGEMENTS

I am grateful to many educators and organizations that supported my doctoral efforts. I wish to acknowledge my major professor, Dr. Gerald Knezek, co-major professor Dr. Lemoyne Dunn, and committee member Dr. Rhonda Christensen for their positive encouragement, constructive feedback, expertise, and support. Appreciation is extended to the National Aeronautics and Space Administration, NASA, North Richland Hills Pubic Library, the Makerspot community, and Birdville Independent School District for funding and supporting research associated with the Makers' Guild program. I would like to thank my children, Ezekiel Samuel Miller and Nolan Alexander Miller, for attending and participating in many STEM and Makerspace functions with me during the last five years, including teaching the public at NASA's Multiscale Magnetosphere student launch events. Your interpretations, perspectives, and representations inspired so many to consider new approaches to STEM public education efforts.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Problem Statement

The President's Council of Advisors on Science and Technology (2010) identified the importance of equipping both teachers and students with strong science, technology, engineering, and mathematics (STEM) career skill sets to assist in preparing a future workforce that will participate in a highly competitive global economy. In response to the knowledge era, schools will need to fundamentally shift approaches from a “paradigmatic knowledge environment in which knowledge is characterized as abstract or analytic to a situated cognition environment in which knowledge is understood as a narrative that is specific, personal, and contextualized” (Marsick, 1998, p. 126). Recent research highlights critical areas needed to improve STEM education efforts to include stronger partnerships between school districts, state, federal, and industry that center on improving training and retraining of K-12 teachers to fill current skill sets and knowledge gaps existing in STEM education (Batts & Lesko, 2011).

Transformative STEM learning spaces have grown rapidly in schools, libraries, and museums as “Learning Labs” or “Makerspaces.” These spaces are designed to encourage deep engagement with STEM-integrated content, critical thinking, problem solving, and collaboration while sparking curiosity (Koh & Abbas, 2015). Challenges facing educators interested in providing innovative STEM practice through a classroom Makerspace experience include standardized testing, lack of teacher preparation, and limited access to technology and resources (Hira, Joslyn, & Hynes, 2014).

According to the Congressional Research Service Report to Congress (Kuenzi, 2008), there is a confirmed concern regarding STEM preparation programs serving students, teachers, and practitioners. Literature identifies challenges in STEM professional development programs (Nadelson et al, 2013). Teachers do play a critical role in regard to student STEM perceptions. For example, Knezek, Christensen, and Tyler-Wood's (2011) MSOSW (Middle Schoolers Out to Save the World) findings indicated that gaps existed regarding the "perceptions towards science, technology, engineering, and mathematics held by middle school students versus those of their teachers" (p. 111). Findings suggested that the millennial generation's lower perceptions toward STEM and STEM careers versus older generation perceptions could result in a lower standard of living for the millennial generation.

Jang (2016) identified STEM skill sets to include critical thinking, reading comprehension, active listening, speaking, complex problem solving, judgement and decision making, writing, monitoring, active learning, time management, coordination, systems analysis, mathematics, social perceptiveness, systems evaluation, instructing, science, and learning strategies. Professional development programs often fail to include a focus on scientific knowledge and pedagogical experiences, and may produce teachers who have limited confidence regarding STEM skill sets (Murphy & Mancini-Samuelson, 2012). Few teachers engage in professional development activities to improve scientific teaching after receiving degrees (Cotabish, Dailey, Hughes, & Robinson, 2011). Without STEM prepared teachers who have positive dispositions towards STEM, how do we improve middle school student perceptions toward STEM and STEM career pathways?

Purpose of the Study

The purpose of this study was to explore how participation in a professional development experience involving Makerspace technology affects participants' attitudes and confidence level toward STEM and technology integration over the course of a semester. Determining factors that influence teachers' attitudes and confidence levels toward STEM and technology integration will provide valuable information to educators and the academic community. Findings can be used to guide STEM teacher preparation programs to improve teacher confidence and attitudes toward STEM and technology integration. According to Morales, Knezek, and Christensen (2008), "self-efficacy is defined as confidence in one's competence and is important to facilitating learning experiences" (p. 127). Other researchers reinforce the importance of teacher confidence levels along with teacher attitudes, defined as perceptions, toward STEM as both transfer to students' attitudes and confidence levels toward STEM (Nadelson et al., 2013).

Koh and Abbas (2015) research findings suggested that professionals working in Learning Labs or Makerspace programs receive training to include strong technology integration that addresses why technology is appropriate and which technologies will help to achieve desired learning outcomes. Makerspaces, defined as "informal sites for creative production in art, science, and engineering where learners blend digital and physical technologies to explore ideas, learn technical skills, and create new products" offer a new environment to explore STEM concepts (Sheridan et al., 2014, p. 505). Research is needed to further understand how people experience learning in Makerspaces and how this impacts self-efficacy and information behavior (Fourie & Meyer, 2015).

Significance of the Study

This research study addressed the need to explore professional development effects on teacher attitudes and confidence levels toward instructional technology and STEM. The proposed study was built upon previous STEM and technology integration research exploring teacher perceptions and confidence levels in STEM content areas and technology integration approaches, providing a continuation of previous research toward a new identified environment—Makerspace. Improvements in teacher professional development programs may increase the overall student STEM experience in lower and middle school programs. End results may lead to a highly confident and skilled STEM elementary and middle school education workforce while encouraging more students to consider entering a STEM career pathway.

Learning theories on how children and adults best learn are often deeply rooted in past experiences, personal perspectives shared within a wider community, and meaningful learning exchanges and discourse shared within a social context (Gilakjani, Lai-Mei, & Ismail, 2013). Traditional behavioral learning theories stress the importance of the instructor (Gilakjani, Lai-Mei, & Ismail, 2013). Knowledge is transmitted from the mind of the teacher through lectures and words to the student Gilakjani, Lai-Mei, & Ismail, 2013).. Active learning theories evolved from traditional approaches. Learners' actively construct a personal interpretation of thinking as a result of innate capacities interacting with personal experiences (Gilakjani, Lai-Mei, & Ismail, 2013). Constructivism, a cognitive theory proposed by Jean Piaget, proposes that learning takes place through discovery and is constructed by learners themselves while interacting within the environment (Tangdhanakanond, Pitiyanuwat, & Archwamety, 2006). Within discovery learning environments, teachers create situations, often using real world situations, to engage students to dialogue about a problem. Constructionism, a cognitive theory introduced by Seymour Papert (1993), takes Piaget's constructivism theory a step further (Tangdhanakanond et al., 2006). Papert expanded constructivist views to suggest that learning happens most effectively when people are active in making objects to share with a larger community (Papert & Harel, 1991). "Constructionist pedagogies require that teachers become a facilitator or guide, recognizing that students develop their own strategies to construct their own knowledge" (Salvo, 1998). This study employed a constructionist learning theory approach in which the learner collaborated with other participants, which required the learner to construct an artifact and share within a wider learning community.

Active learning through the art of a Makerspace design increases self-directed learning and provides a deeper learning experience (Sheridan et al., 2014). Through the process of designing, making, and creating an object, learners obtain feelings of satisfaction and develop a "myriad of interpersonal and technical skills" (Hira et al., 2014, p. 1). The Makerspace movement is built upon the foundation of constructionism, which is a "philosophy of hands-on learning through building things and is the application of constructivist learning principles to a hands-on environment" (Kurti, Kurti, & Fleming, 2014, p. 8). Constructionism aligns and extends constructivism to focus explicitly "on how the making of external artifacts supports learners' conceptual understanding" (Sheridan et al., 2014, p. 507). Makerspace areas provide for an authentic experience in which learners participate in a community, taking on leadership and teaching roles using diverse tools, materials, and processes to problem solve real world project-based learning scenarios (Smay & Walker, 2015).

STEM professional development research led by the i-STEM summer institute (Nadelson et. al., 2012) confirms that community space is an effective component to professional development. This finding is supported by additional research produced by the National Aeronautics and Space Administration (NASA) and California State University System's STEM K-12 professional development's Independent Collaborative Model, which centered on a common theme or NASA mission (Liddicoat, 2008).

Research Questions

This study focused on the following research questions.

1. To what extent do educators who participate in STEM Makerspace professional development activities increase their self-appraisal of competence in technology integration abilities?
2. To what extent do educators who participate in STEM Makerspace professional development activities increase in their confidence in integrating new information technology into pedagogical practice?
3. To what extent do educators who participate in STEM Makerspace professional development activities become more positive in their attitudes toward STEM?

Hypotheses

Hypotheses of this study include the following. Teachers will report an increase in attitudes toward instructional technology as a result of professional development. Teachers will report an increase in confidence levels toward instructional technology. Teachers who participate in a professional development program including targeted STEM professional development will improve their attitudes towards STEM.

Definitions

Definitions used in this dissertation follow.

2D Learning Technology: Computer-based technology used to create 2D artifacts such as the drawing of a mathematical flat shape as an aide in the learning process used for graphic design or quilting.

3D Learning Technology: Computer-based technology such as the construction of 3D shapes used for used to create a 3D artifact as an aide in the learning process used for 3D printing, origami, or virtual reality gaming.

Attitude: "Positive, negative, or neutral feeling toward an object or behavior. Attitude can vary in strength and direction, from extremely favorable to extremely unfavorable, or any point in between" (Pryor, B. W., Pryor, C. R., & Kang, R., 2016).

Confidence: Self-efficacy or "confidence in one's competence" (Morales et. al., 2008).

Fabrication: To construct, create, and assemble a part

Makerspace: Informal sites for creative expression in science, technology, the arts, engineering, and mathematics where learners blend digital and physical technologies and tools to include fabrication technology, digital art technologies, robotics, green screen technologies, digital audio, augmented reality, origami, and virtual reality to explore and expand ideas, problem solve, learn technical skill sets, and produce new learning artifacts or products that can be shared with a wider community (Sheridan et al., 2014)

Media Arts: Human communication through audio, photography, digital art, video, and interactive media

STEM: Science, technology, engineering, and mathematics

STEAM: Science, technology, engineering, the arts, and mathematics

Virtual Learning Environment (VLE): Web-enabled multimedia-driven learning system integrated with synchronous and asynchronous communication tools (Das, 2014)

CHAPTER 2

LITERATURE REVIEW

As renewed interest toward developing U.S. K-12 STEM curriculum advance a need for additional professional development research continues (Bouwma-Gearhart, 2012). Batts and Lesko (2011) highlight the continued critical need to improve STEM educational efforts. The Congressional Research Service Report (Kuenzi, 2008) to Congress further highlights K-12 professional development concerns regarding STEM preparation programs serving students, teachers, and practitioners. Primary goals of research targeting K-12 STEM education programs are to increase the number of students participating in STEM academic programs, enrich STEM learning experiences for both teachers and students, and to assist in increasing the number of students entering STEM career pathways (Bouvier & Connors, 2011). Literature confirms K-12 schools and professional development approaches will need to be revamped to include improved models to implement the Next Generation Science Standards (Brown, 2015). A challenge facing Makerspace environments is the considerable amount of STEM professional development needed to implement such programs (Hira et al., 2014). Often information professionals and librarians facilitate STEM Makerspace activities but many lack skills and competencies required to sustain Makerspace programs (Koh & Abbas, 2015).

History of K-12 STEM Professional Development Approaches

The current STEM career workforce shortage, which can be attributed to the lack of interest in STEM preparation programs (Knezek, Christensen, & Tyler-Wood, 2011), is not a new issue facing U.S. employers. Literature examined identified a long history exploring K-12 STEM professional development approaches. Lubinski and Benbow's (2006) longitudinal research findings, stemming from the 1971 Study of Mathematically Precocious Youth initiative, investigated STEM research encompassing 35 years and suggested "effective ways to identify potential for and to facilitate the development of scientific and STEM expertise" (p. 4). Findings highlight the importance of not basing STEM leadership programs on standardized testing but to tailor STEM professional preparation programs with participants (Lubinski & Benbow, 2006). The literature suggests that for students to be successful and engage in STEM career exploration, deep content knowledge and confidence is necessary (Moakler & Kim, 2014). Many programs have been developed to support STEM majors. However, barriers exist and there continues to be a lack of literature "focusing on improving STEM confidence and attitudes as a result of STEM program initiatives" (Huziak-Clark, Sondergeld, van Staaden, Knaggs, & Bullerjahn, 2015, p. 227).

Professional development programs often offer limited coverage of scientific knowledge, and pedagogical experience, and often produce teachers who have limited confidence regarding STEM skill sets (Murphy & Mancini-Samuelson, 2012). Teachers experience a lack of professional development activities focused on improving scientific teaching after completing undergraduate degrees and preservice programs (Cotabish et al., 2011). Sun, Finger, and Liu (2014) suggest that disconnects exist in regard to technology competencies and skills sets needed in postsecondary expectations that faculty design within an e-learning platforms. In addition, preservice teachers encounter no formal STEM training and a tight preparation program that typically lasts a year to include "general education studies, subject specific pedagogy, teaching practice in schools, and a service-learning component" (Teo

& Ke, 2014, p. 19). Faculty often fail to actually design and deliver effective instruction to promote social engagement and knowledge construction (Sun, et al., 2014).

Nadelson et al. (2012) suggested a lack of teachers' exposure to scientific inquiry in postsecondary programs corresponds to a lack of exposure to authentic inquiry models used to validate professional development. Elementary teachers are often the first to introduce students to the STEM pipeline (Nadelson et al., 2012). Unfortunately, research suggests that few elementary teachers engage in professional development to improve scientific instruction (Cotabish et al., 2011). Research that included over 300 primary instructors found strong relationships between scientific professional development and confidence levels in teaching science, suggesting that high quality and sustained professional development is needed (Murphy, Neil, & Beggs, 2007).

Technology Integration Professional Development Approaches

Despite having improved access to broadband and expanded infrastructure capabilities, educational technologies have yet to be effectively integrated into most K-12 classroom environments (Keengwe, Georgina, & Wachira, 2010). Teachers lack skill sets and expertise regarding how to use technology and lack pedagogical knowledge in regard to integrating it appropriately (Keengwe et al., 2010). Federal and education agencies continue to stress the need for teacher professional development programs to integrate technology into the classroom effectively and have promoted improved integration programs for over a decade (Keengwe et al., 2010).

In response to the failure of preservice teaching programs to integrate technology, the U.S. Department of Education issued the Preparing Tomorrow's Teachers to use Technology

(PT3) federal grant program that began in 2000-2001 (Polly, Mims, Shepherd, & Inan, 2010). Many PT3 programs reported successful outcomes in terms of the numbers of new teachers infusing instruction with technology" (Christensen, Parker, & Knezek, 2005, p. 188). PT3 research outcomes indicate that "teacher candidates that used technology during field experiences displayed higher attitudes toward integrating technology during instruction" (Bahr, Shaha, Farnsworth, Valerie, & Benson, 2004, p. 88). Christensen, Parker, & Knezek (2005) measured "technology skills used and strategies learned" through the U.S. Department of Education Preparing Tomorrow's Teachers to Use Technology Program (PT3) program in a comparative study investigating two university teacher preparation programs, with one providing a separate but required computer education course and the other integrating computer education within existing coursework (pp. 188-190). Research outcomes revealed that "methods employed in both university systems resulted in meaningful gains" and that preservice teachers who had the opportunity to develop multimedia presentations to share with a wider audience as part of this program resulted in a higher confidence toward integrating technology into the classroom (Christensen, Parker, & Knezek, 2005, p. 196). Christensen, Parker, & Knezek's (2005) research suggested that many approaches to integrating technology skills in teacher preparation programs are effective as long as authentic technology integration activities are well designed, participants have access to technology, and instruction is included on the use of technology tools. Perhaps an even more important contribution of PT3 funded programs is that for the "first time general teacher education faculty members became intensely interested in integrating technology into preservice teacher programs and courses" (Maddux, 2006, p. 152).

Additional research has investigated teacher progression through stages to further explore teacher barriers to introducing technologies into K-12 STEM professional development programs (Skaza, Crippen, & Carroll, 2013). Hooper and Rieber (1995) offer a framework to describe levels of technology adoption to include familiarization, utilization, integration, reorientation, and evolution. Nadelson et al. (2012) provide a strong argument linking learning and affective variables to include confidence, anxiety, and self-efficacy to teacher effectiveness. The authors stress the need for strong professional development to assist teachers to become more comfortable, thereby enhancing pedagogical contentment (Nadelson et al., 2012). Koh and Abbas (2015) highlighted the need for the American Library Association to update curricular competencies to address Makerspace library professionals. Findings suggest a critical need to introduce librarians and Makerspace professionals to approaches that facilitate learning and to improve understanding how to design user-appropriate and hands-on learning (Koh & Abbas, 2015).

Professional Development Models Supporting STEM Integrated Design

How are professional development models supporting STEM integration? Feldman and Pirog's (2011) Franklin County Research Academies for Young Scientists, STEM RAYS, program, an afterschool and summer National Science Foundation (NSF) research study initiative, identified a need for additional research in STEM professional development programs. STEM RAYS research findings suggested that it is necessary for STEM programs to include the involvement of high quality instruction. Teachers do not necessarily need extensive formal training in the sciences. However, teachers should possess a strong interest in teaching, learning, and doing science (Feldman & Pirog, 2011).

Baxter, Ruzicka, Beghetto, and Livelybrooks' (2014) research attempted to improve teacher STEM professional development, with the Excellence in Mathematics and Science Teaching (eMAST) project. The eMAST project supported active learning via face-to-face learning exchanges that was contextualized in authentic examples and problems, focusing professional development on scientific inquiry and problem solving strategies to support existing curricula. eMAST findings suggest that STEM professional development should center on mathematics and science assisting teachers in developing an improved and deeper understanding of STEM disciplines. The eMAST project produced positive changes in teachers' confidence and practice. Elementary teachers found it difficult not to generalize during scientific inquiry, highlighting a need for additional research. eMAST findings suggested that further research is needed on how to best facilitate collaborative discussion that focused on "epistemological and disciplinary distinctions" (Baxter et al., 2014, p. 111).

Professional development should encourage peer coaching, practice, and the ability to experience inquiry-based instruction at a minimum of 45 hours annually (Cotabish et al., 2011). Recent research investigated the impact of a three-day STEM professional development institute on elementary teachers' changes in attitudes, confidence, and self-efficacy (Nadelson et al., 2013). The study found significant evidence indicating that short periods of targeted STEM professional development can greatly influence and improve teacher confidence and self-efficacy (Nadelson et al., 2013).

A lack of research exists examining STEM knowledge base, STEM skill sets, and experiences necessary for teachers to implement STEM integrated instruction (Nadelson et al., 2013). Stohlmann, Moore, and Roehrig's (2012) explored factors affecting teachers' implementation of a national STEM education program, Project Lead the Way. Research included the following theoretical framework theory employing activities that "build on prior knowledge, organize knowledge around big ideas, include real world situations, foster social discourse, and include a social element" (Stohlmann et al., 2012, p. 30). Instructional activities should include "hands on approaches using manipulative, cooperative learning, discussion, questioning, writing for reflection, problem solving, appropriate integration of technology, and the use of assessment" (Stohlmann et al., 2012, p. 29).

Experiential Learning

Communication via Learning Technologies

Knowledge is "being actively constructed by the individual and knowing is an adaptive process within an experiential environment" (Karagiorigi & Symeou, 2005). Constructivism proponents argue that building knowledge occurs inside a learner's head (Stager, 2013; Tangdhanakanond et al., 2006). However, constructionists argue that knowledge transformation occurs as the learner is presented opportunities to build and "make an artifact with their own style" inspiring ownership (Papert & Harel, 1991). Papert (1993) proposed that learners must actively construct something tangible outside of the learner's head, presenting an artifact that is sharable and open to critique, promoting the ability to "show, discuss, examine, and reflect with others on cognitive artifacts and products created" (Tangdhanakanond et al., 2006).

Researchers have applied constructionist theories to investigate communication and learning technologies, which build upon designing and creating a tangible artifact of an idea (Sheridan et al., 2014). Constructionist pedagogies encourage teachers to act as a facilitator while “learning occurs as students develop new ideas through the making of some type of external artifact. Children become encouraged as they reflect upon and share a personalized representation to gain new knowledge via self-directed learning” (Kafai & Resnick, 1996, pp. 1-2). Constructionism was borne out of constructivism perspectives. Constructionism encompasses the idea that “learning is building a knowledge structure irrespective of the circumstances of learning, but adds to constructivism ideas in that learning happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity” (Papert & Harel, 1991).

The design process “focuses on a metarepresentational competence, using tools to support communication of an idea, in which learners problem solve, create a prototype, and assess how it works” (Sheridan et al., 2014, p. 508). As learners have opportunities to make a tangible object of interest, they build new knowledge and reinforce through sharing socially (Tangdhanakanond et al., 2006). Environments facilitating simulations employing exploratory learning enhance problem solving through an active learning and social context (Li, Cheng, & Liu, 2013).

The adoption of information and communication technologies by teachers develops through different stages from being aware, routine employment of technology, to creative use of technology (Mishra & Koehler, 2006). Research has shown the importance of teacher confidence for facilitating student learning (Morales et al., 2008; Hoy & Woolfolk, 1990; Henson, Bennet, Sienty, & Chambers, 2000; Moore & Esselman, 1992). Research by Morales et al. (2008) employed the Technology Proficiency Self-Assessment (TPSA) developed by Ropp (1999) to measure teacher technology confidence levels aligned to the International Society of

Technology Education's standards to over 978 elementary and middle school teachers from Mexico City and 932 middle school teachers in Dallas, Texas. Results indicated statistically significant findings to support that the TPSA provides a sound confidence level measure of technology proficiencies across languages and borders (Morales et al., 2008). Professional development is needed to support transformative learning methods and activities to challenge teacher beliefs while "simultaneously providing support so that teachers can manage feelings of incompetence and vulnerability" (Marsick, 1998).

Using Technology to Enhance Hands-On Instruction

How are technologies used to enhance pedagogical knowledge that incorporate constructionism? Alesandrini and Larson (2002) recommend teachers work collaboratively contextualizing, clarifying, inquiring, planning, realizing, testing, modifying, interpreting, reflecting, and celebrating to share artifacts and final accomplishments to a wider audience during professional development. President Obama's Educate to Innovate campaign stresses the importance of creative making experiences in which learning design promotes hands-on activities through informal learning spaces via museums, libraries, and community spaces (Sheridan et al., 2014). Sun et al. (2014) suggest incorporating instructional approaches that merge physical and virtual and offer a design eLearning approach via 3D printing. Digital tools that "develop, challenge, and expand prior thinking to become disrupted can lead to new understandings via a more effective pedagogical approach enabled through new technologies" (Sun et al., 2014, p. 210). Through "rapid prototyping," learners can employ digital fabrication to make anything imaginable, inspiring K-12 creativity, and has shown to positively affect attitudes towards STEM and STEM careers (Smith, 2014).

The TPACK framework supports the use of technology as a support for “content being taught and pedagogical strategies for successful outcomes or confidence” and provides a natural framework toward accessing STEM attitudes and beliefs (Smith, 2014). The Technological Pedagogical Content Knowledge (TPACK) framework (Figure 1) “builds on Lee Shulman's (1986, 1987) construct of pedagogical content knowledge (PCK) to include technology knowledge” (Koehler, Mishra, & Cain, 2013, p. 13). Based on Shulman’s (1986) theories, Mishra and Koehler (2006) developed an instructional model, TPACK, for 21st century learning environments investigating pedagogical knowledge, content knowledge, and technology knowledge (Matherson, Wilson, & Wright, 2014). A literature review revealsTPACK research is still in its infancy, with a need to explore TPACK competencies aligned to content domains, assessment of teacher TPACK competencies, and further development of TPACK instrumentation (Voogt, Knezek, Cox, Knezek, & ten Brummelhuis, 2013).

Digital fabrication technologies are classified into two areas to include 2D technologies in which subtractive techniques are employed to trim materials using paper or metal or 3D technologies that use silicone or plastic material excursions (Smith, 2014). The Smith (2014) case study employed the TPACK framework to address a lack of research exploring pedagogical practices integrating 2D digital fabrication technologies into language arts classrooms. The study did report an increase in motivation through hands-on creation of objects.

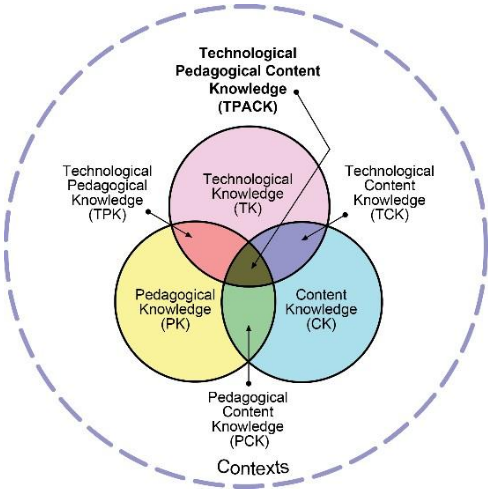

Figure 1. Technological pedagogical content knowledge (TPACK) framework (Mishra and Koehler, 2006).

Experiential Learning Enhances STEM Skill Sets

How can experiential learning activities enhance STEM skill sets? Research investigating Makerspace environments found that experiential learning activities via digital tools, wood working, electronics, circuitry, design, fabrication, music, art, transportation, and food through a creative space engages all ages, races, and populations and fuels access to just-in-time STEM experiences (Sheridan et al., 2014). Smith's (2014) study investigating experiential learning via 2D digital fabrication provides a digital learning framework in which learners clarify, visualize, prototype, implement, and reflect. Flowers, Raynor, and White (2012) highlight challenges facing STEM online teacher preparation programs and suggest that a wide array of methods for evaluation be incorporated to include student portfolios and STEM-based projects.

Learning Engagement via Media Arts

The study of media arts enjoys a long and evolving research history to include traditional technologies embracing print media, radio, and movies and newer forms of technologies to include web mediums, video games, blogs, and fabrication technologies (Bequette & Brennan, 2008). Learning opportunities to integrate digital media art often employ a three-pronged approach including the study of media arts as a process, expressive art, or hybrid art combining the old with the new (Bequette & Brennan, 2008). Creative use of learning technologies via media and digital art affects the types of activities available to students and teachers Black & Browning, 2011). Teachers overwhelmingly believe they do not have pedagogical support or technical support to assist in integrating digital arts and media into the classroom confidently (Black & Browning, 2011). Creativity is “innovation, discovery, curiosity, imagination, experimentation; and exploration and digital processes can allow for a transformation to occur from something known to a new idea, previously unknown” (Black & Browning, 2011, p. 20). The use of “digital arts is still in its infancy relative to other media familiar and available to artists today”, highlighting additional need for further research (Candy, 2007, p. 367).

Advantages and Disadvantages Integrating 2D and 3D Technologies

Spatial reasoning skill sets are highly desired in STEM careers that require a strong understanding of the relationship between 3D space and objects (Park, Kim, & Sohn, 2011). Spatial visualization tests suggest that spatial visualization skills decrease in levels of performance as learners age and can be improved through training (Park et al., 2011). Learning can be enhanced through the employment of materials to engage multiple sensory modality (Horowitz & Schultz, 2014). Research suggests that the transfer of learning between 2D and 3D contexts is highly complex, changing gradually during stages of cognitive development and requires careful consideration to best reduce cognitive overload or prevent disruptive learning experiences (Barr, 2010).

Improvements in 2D and 3D technologies have led to more commercially available modeling software and hardware, improved file format conversion processes and portable hardware, and have become relatively inexpensive (Horowitz & Schultz, 2014). Applications to the education setting leads some to consider how rapid 3D prototyping in design education could be leveraged to improve student spatial visualization skill sets (Park et al., 2011). Modeling and 3D printing require supervision along with training, but supervision could be supported through on-demand libraries or outreach centers (Horowitz & Schultz, 2014).

Teacher Perceptions on 2D and 3D Learning Technologies

Prain and Waldrip(2006) highlighted the many barriers facing teachers attempting to integrate 2D and 3D learning technologies into a science classroom. The exploratory case study identified weaknesses in teachers' ability to evaluate student reactions to different modes, in which completion of a modeling activity lacked true connection to learning (Prain & Waldrip, 2006). Daugherty and Custer's (2012) study investigating teacher perceptions in secondary engineering professional development suggests that teachers perceive a lack of resources, low importance from school organization, anxiety in regards to comfort level, and a lack of motivation to participate in 2D and 3D professional development. Research further highlights "problematic issues for researchers and curriculum developers in regard to different interpretations of STEM education and STEM integration approaches" (English, 2016, p. 2).

Future Research Trends

A study published by Nadelson et al. (2012) found a need for deeper examination of comfort, inquiry, and pedagogical discontentment, particularly for instructors who teach STEM. The Technology-Assisted Science, Engineering, and Mathematics (TASEM) summer STEM program offered through Michigan State University has a four-year-long history with exploring perceptions, providing workshops for kindergarten students to K-12 teachers (Varney et. al , 2012). Research conducted through this program found the attitudes of students who participated in TASEM improved along with averages in math, science, and citizenship with participants ranging across socioeconomic and cultural backgrounds (Varney et. al., 2012). TASEM outcomes suggest that there is a need to provide similar programs remotely, which would build a stronger community and support network between K-12 teachers, university postsecondary faculty, and K-12 student populations (Varney et. al., 2012). Despite all of the interest surrounding STEM integration, little to no research exists exploring Makerspace content and processes of learning (Sheridan et al., 2014).

A new approach to professional development exploring Makerspaces launched by the University of Nevada in 2016 employed a mobile Makerspace (Purpur, Radniecki, Colegrove, & Klenke, 2016). The pop-up mobile Makerspace research outcomes reported an increase in STEM enthusiasm and engagement for experimenting with new forms of technology (Purpur, Radniecki, Colegrove, & Klenke, 2016). Participants were exposed to three outreach events, each occurring for around a half an hour, in which participants were introduced to 3D printing, digital design literacies, and lendable technologies (Purpur et. al., 2016). This study will attempt to address the need for research exploring STEM professional development in Makerspace environments. Additional insight exploring teacher perceptions about 2D and 3D technology and confidence levels toward technologies highlight the need for this dissertation study.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

A review of literature reveals weaknesses in STEM professional development programs (Nadelson et al., 2012). Teachers do play a critical role in regards to student STEM perceptions and STEM career interests (Knezek et. al. , 2011). Professional development programs fail to include a focus on scientific knowledge and pedagogical experiences, and produce teachers who often have limited confidence regarding STEM skill sets (Murphy & Mancini-Samuelson, 2012). Few teachers engage in professional development activities to improve scientific teaching after receiving degrees (Cotabish et al., 2011).

Limited research exists examining STEM knowledge base, STEM skill sets, and experiences necessary for teachers to implement STEM integrated instruction. STEM professional development research by the i-STEM summer institute confirms that a community Makerspace is an effective component in professional development (Nadelson et al., 2012). This finding appears to be supported by additional research produced by NASA and California State University System's STEM K-12 professional development's Independent Collaborative Model, which centered on a common theme or NASA mission (Liddicoat, 2008). STEM professional development models delivered via STEM outreach were equipped with instructional activities, free science and technology resources, and learning technology equipment could be used to engage and peak teacher interest (Liddicoat, 2008).

Sample and Population

This study incorporated the Makers' Guild, a series of STEM and instructional technology professional development activities, over the course of the 2016 spring semester. The Makers' Guild program targeted six schools from a large north Texas public school district encompassing five cities and serving over 25,000 students. The Makers' Guild included a sample population of 57 elementary and middle school classroom teachers, campus principals, academic coaches, and librarians. Participating schools represented a variety of education settings. District leaders selected three elementary and three middle school campuses that were similar in population size. One elementary and one middle school was selected to represent one of three socio-economic income brackets, with one cluster representing low income students of whom 67% or more identified as economically disadvantaged (Texas Education Agency, 2015). The second cluster included one elementary and one middle school that serves middle income students, with 34 % identified as economically disadvantaged (Texas Education Agency, 2015). The last cluster represented one elementary and one middle school that serve higher income students, with 24% identified as economically disadvantaged (Texas Education Agency, 2015). The researcher worked with district leadership to select one elementary and one middle school that fed into each of the three high schools serving this large public school district during the fall of 2015. Participants were preselected by the campus principal. Campus leadership, as part of the program, identified a campus leader, Makerspace facilitator, and eight content teachers to participate in the Makers' Guild program. All participants were new to Makerspace environments, with only one of the six participating schools housing a campus Makerspace, which opened in the fall of 2015.

It is recognized that some participating teachers may have been exposed to STEM topics during previous training. To minimize the identified limitation, participants completing previous training were identified at the beginning of the study and noted during analysis and results. Teachers represented various grade levels serving kindergarten to eighth grade, represented all core curriculum areas, and included populations from a wide range of environments. It is understood that this statistically non-random sample is not represented of the nation, but it does provide insight and reflects a large demographic scope. Participants elected to enter the research study; therefore, results are only generalizable to this study's participants.

Research Questions

Three research questions were explored as part of this research study. Each is listed and discussed, along with the associated hypotheses.

> Research Question 1: To what extent do educators who participate in STEM Makerspace professional development activities increase their self-appraisal of competence in technology integration abilities?

According to literature, research is needed investigating a constructionism framework comparing different knowledge levels to learning motivation in regard to learning technologies (Li et al., 2013). Christensen (2002) suggest that teachers advance in regard to technology integration as attitudes toward technology improve.

> H1: After participation in a semester-long series of professional development activities, teacher perceptions to their ability to integrate technology will increase as measured by the Stages of Adoption of Technology.

Teacher confidence has been shown to be a primary factor in effective use of technology by students to assist in learning (Christensen, 2002). The ability to successfully integrate technology creatively occurs in part due to the teacher's willingness to "play with technologies and an openness to building new experiences for students to have fun in which learning is viewed as play" (Mishra & Koehler, 2006, p. 18). For this reason, the following research question was explored.

Research Question 2: To what extent do educators who participate in STEM Makerspace professional development activities increase in their confidence in integrating new information technology into pedagogical practice?

Makerspace environments provide an informal playground in which participants explore and create a production in art, science, and engineering blending digital and physical technologies to explore ideas and learn at their own pace (Sheridan et al., 2014, p. 505). Makerspace activities break down process and product-oriented practices building confidence toward integrating scientific and technical tools (Bevan, Gutwill, Petrich, & Wilkinson, 2015). Makerspace environments allow teachers to explore 2D and 3D fabrication technologies in an engaging format (Sheridan et al., 2014, p. 505)..

H2: After participation in a semester-long series of professional development activities, teacher confidence levels in their ability to integrate technology will increase as measured by the Technology Proficiency Self-Assessment for 21st Century Learning.

Enhancing the quality of K-12 STEM professional development is strongly linked to the quality of STEM education experiences, which can promote an increase in STEM career interest (Nadelson et al., 2012). Wang, Moore, Roehrig, and Park's (2011) findings suggest that teachers begin to actually integrate STEM in the manner they feel most comfortable, which is highly correlated to their attitudes toward STEM. For this reason, the following research question was explored.

> Research Question 3: To what extent do educators who participate in STEM Makerspace professional development activities become more positive in their attitudes toward STEM?

Makerspaces introduce an exploratory playground in which participants can improve STEM literacy, providing the opportunity to introduce STEM concepts that may improve STEM perceptions and confidence levels (Bevan et. al, 2015). This dissertation study aims to provide insight into the relationship of professional development on teacher confidence levels and attitudes toward STEM, with the expectation that confidence levels and attitudes will increase as a result of professional development.

> H3: After participation in a semester-long series of professional development activities, teacher attitudes toward STEM will increase based on results identified through the STEM Semantics Survey instrument.

Research Design

The researcher developed a quantitative study design that investigated the relationship between professional development and teacher's attitudes and confidence levels toward technology integration and attitudes towards STEM.

Participants took part in professional development activities over the course of a semester beginning in January 2016 and concluding in May 2016. Additional support was planned during the summer of 2016, with the expectation that teachers wouldl transfer learning to their classrooms the following year. Learning activities included curriculum content connections to include science, math, and the arts. Teachers were introduced to a series of professional development training experiences in STEAM activities integrating 2D and 3D technologies delivered in face-to-face training opportunities and one online training session. Course activities integrated programing, drafting programs, digital art, digital media, social media, and creation tools with a library Makerspace program targeting elementary and middle school core content areas. Activities incorporated hands-on constructionist approaches to themes geared to reading programs employed by all core content areas. The researcher partnered with the public library Makerspace community and met at the Makerspot, which served as the primary location for professional development. The public library's Makerspace community, along with district librarians delivered much of the professional development over the course of four months.

The purpose of the Makers' Guild program was to introduce participants to Makerspace environments, Makerspace design, constructionism, project-based learning, connecting Makerspace activities to content areas, and expose participants to 3D technologies, 2D technologies, media arts, virtual learning environments, and STEM. Participating schools were awarded Makerspace equipment through a NASA grant as part of the research study to be designed during professional development activities and open to students during the fall of 2016. Three face-to-face training sessions were held, along with one online training module delivered within Canvas (a Learning Management System), along with site visits to facilitate additional support to each participating school. The online project-based Canvas course, which is represented in Figure 2 below, facilitated community discussions, provided resources, and will continue to serve as a community repository to exchange Makerspace project-based learning activities.

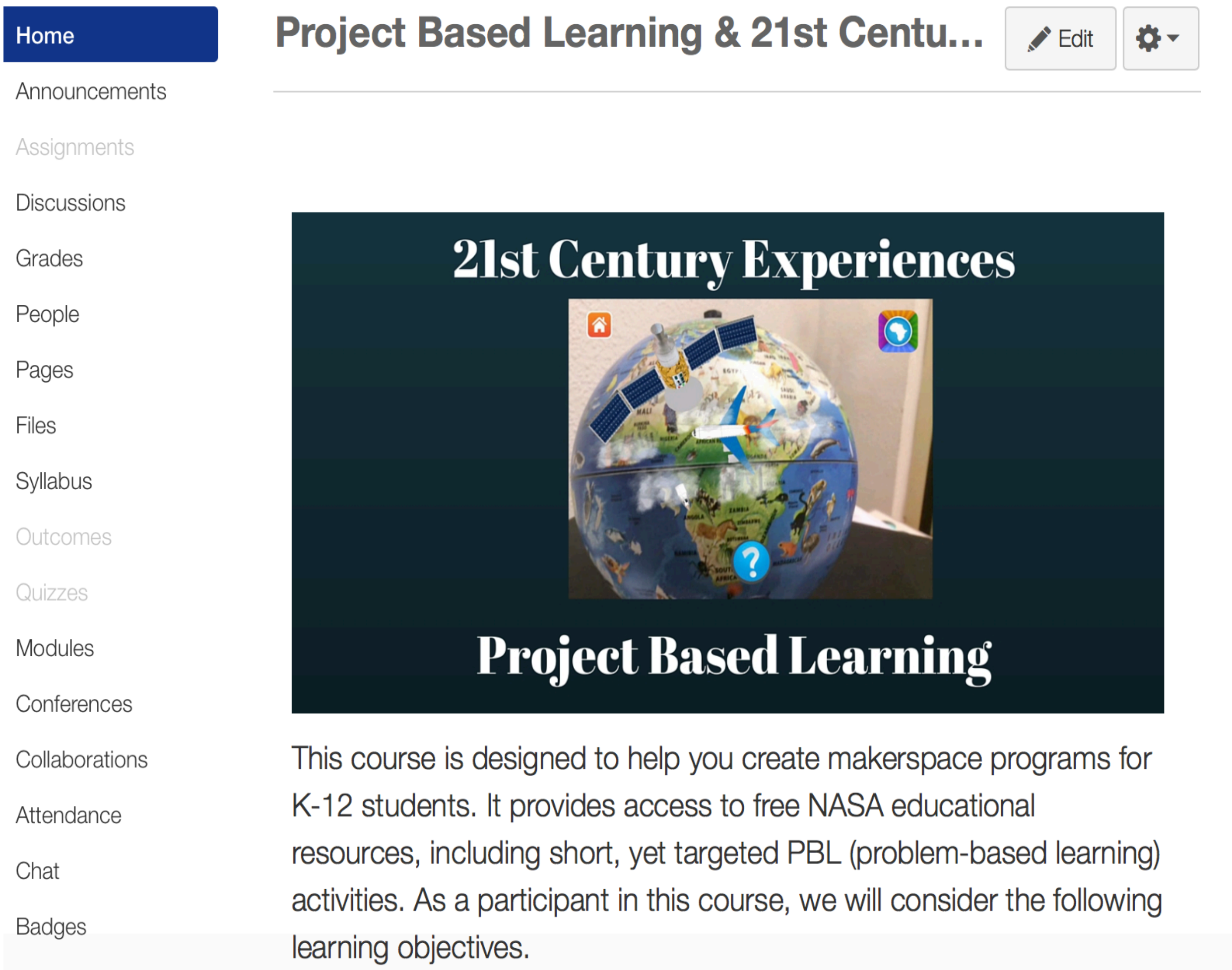

Figure 2. Online project-based canvas course.

Participants experienced hands-on approaches to tinkering and making at the public library's Makerspot. Training descriptions are listed and each training objective can also be located in the Appendix A. Training sessions were offered in the order listed.

- Building Makerspace experiences
    - An introduction to Makerspace K-12 environments
    - Types of Makerspace environments
    - Considerations for K-12 public school Makerspace experiences
    - Gaining community and academic buy-in
    - Integrating Makerspace in your curriculum
- Design thinking
    - What is design thinking?
    - What does a futuristic school look like?
    - Defining and designing your school's creative space
    - Sustainability considerations
    - Creating a design challenge
- Learning in 3D
    - Virtual representations in 3D environments (introduction to Tinkercad, Google Sketchup, Minecraft, fabrication printing programs)
    - Augmented reality
    - Virtual reality
    - Robotics
    - 3D learning technologies and cognitive science

    - 3D learning technology resources
    - Origami
- Project-based learning (PBL) and 21st century learning
    - Introduction to PBL
    - Connections to PBL and 21st century learning skill sets
    - Framing short PBL activities
    - Designing PBL for school Makerspace environments

Participants were introduced to the concept of Makerspace workstations to facilitate STEM career awareness through project-based learning activities. Challenge cards connecting content curriculum to Makerspace environments were introduced. The researcher collaborated with district curriculum and digital learning leaders to create a Makerspace project-based learning process, which was introduced to Makers' Guild participants. The Makerspace project-based learning process is illustrated in Figure 3. Curriculum leaders collaborated with the researcher to develop challenge cards to be placed in one of four stations that connected to curriculum content areas. The challenge cards included a research element to stress the importance of media literacy. Educators were provided challenge card examples in the online course and challenge cards were planned to be incorporated with students in the fall of 2016.

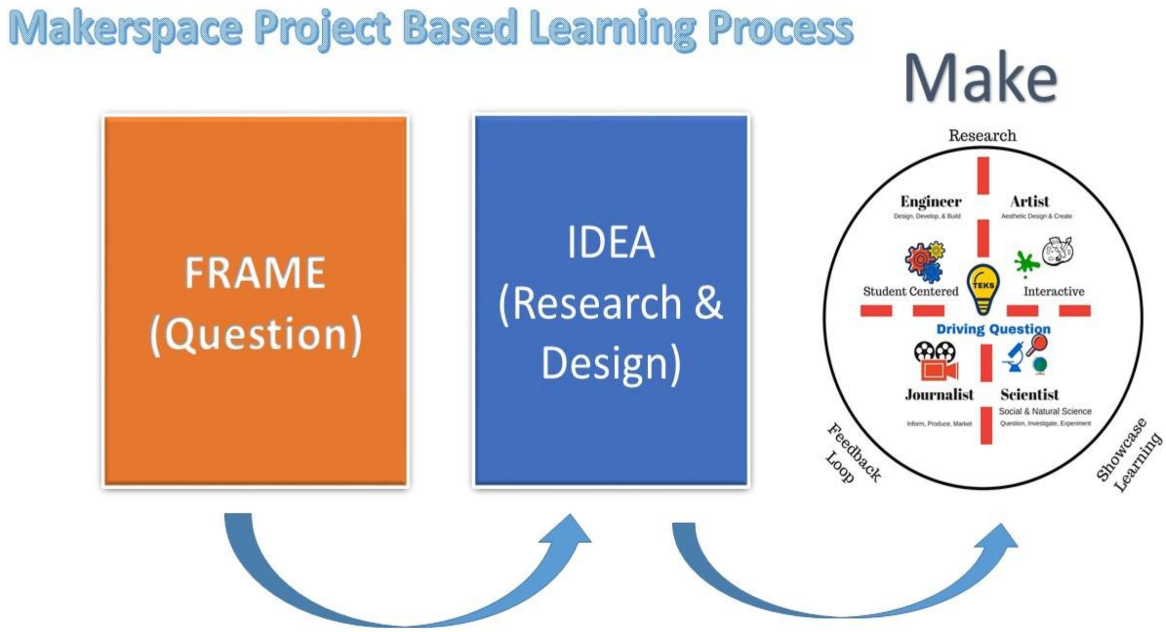

Figure 3. Makerspace project-based learning workstation process.

School personnel who participated in this research project designed a Makerspace environment to use with students and received green screen equipment, 3D printers, 2D printers, robotic kits, and Makerspace supplies in June 2016. This equipment will be used with students during the fall of 2016 to facilitate workstations that incorporate a variety of Makerspace approaches unique to each campus to include Genius Hour, Makerspace classroom activities, and mobile Makerspace environments. Genius hour is an hour in which students explore a topic for an entire year, research, and make an artifact to share with a wider community. Students reflect on goals and the problem solving process as part of their Genius Hour experience. Other approaches will tie Makerspace activities directly to curriculum via Challenge cards (Appendix B) using the Makerspace Project-based Learning Workstation

Process. As part of the training experience, participants were introduced to how to create challenge cards and connect Makerspace activities to curriculum content. The workstation model incorporating project-based learning employs a variety of visual art technology tools to include green screen technology, fabrication technology, and robotics. Schools participating in the study were awarded a green screen technology, fabrication technology, or robotics package in the summer of 2016.

Instrumentation

A review of literature identified appropriate instruments along with fiscal feasibility of instrumentation appropriate to the proposed study. Three instruments previously used in similar studies were selected to improve internal reliability and validity of the study.

The STEM Semantics Survey or SSS (Tyler-Wood, Knezek, & Christensen, 2010) was selected as it was successfully used to measure teacher and student attitudes toward STEM in the Middle Schoolers Save the World (MSOSW) program, which was funded by the National Science Foundation’s Innovative Technology Experiences for Students and Teachers (ITEST) Program. The STEM Semantics Survey is a result of previous modifications from Knezek and Christensen’s (1998) Teachers’ Attitudes Towards Information Technology questionnaire (TAT), which employed “Semantic differential adjective pairs derived from Osgood’s evaluation dimension” (Knezek et al., 2011, p. 94). Targeted statements producing five scales represents perceptions of science, math, engineering, technology, and STEM careers are provided to participants along with seven choices. Internal consistency reliability ratings for all scales are in the range of “very good to excellent,” according to DeVellis’ (1991) standards, ranging from .78 to .94 across five constructs for baseline data (Knezek et al., 2011).

An updated version of the TPSA, the Technology Proficiency Self-Assessment for 21st Century Learning (TPSA C-21), first developed by Ropp (1999) and recently improved to explore 21st century learning technologies by Christensen and Knezek (2015) was employed to measure the effect professional development had on teachers' attitudes and confidence levels towards technology integration. The Technology Proficiency Self-Assessment (TPSA) was incorporated to measure preservice programs technology skills and strategies by Christensen, Parker, & Knezek's (2005) during a four-year study of technology integration teacher preservice methods course. Gains pre to post were on confidence levels as measured by the TPSA were identified for email skills and teaching with technology (Chrisensen, Parker, & Knezek, 2005). As mentioned previously, the TPSA was employed by a large teacher population in Texas and Mexico in a previous study conducted by Morales et al. (2008) to investigate self-efficacy in regard to technology integration. The TPSA included a 20-item, Likert questionnaire with four subscales, in which participants self-assess their level of confidence in their competence in using technology. The researcher was given permission to employ Christensen and Knezek's (2015 a) updated version of the TPSA, TPSA 21st Century (TPSA C21), to utilize in this dissertation study. Christensen and Knezek's (2015 a) updated TPSA C21 Likert questionnaire on six factors: (a) E-Mail, (b) World Wide Web, (c) Integrated Applications, (d) Teaching with Technology, (e) Emerging Technologies for Student Learning, and (f) Emerging Technologies for Teacher Professional Development.

Finally, the Stages of Adoption of Technology instrument (Christensen, 1997) was used to investigate the level of teachers' attitudes toward teaching with technology over a period of time. The Stages of Adoption was adapted from Russell's (1995) research exploring how adults utilized new technologies and includes six stages: (a) awareness, (b) learning the process, (c) understanding the application of the process, (d) familiarity and confidence, (e) adaptation to other contexts, and (f) creative applications to new contexts. The Stages of Adoption instrument is a single-item survey, preventing internal consistency reliability measurement. However, it is a very efficient survey instrument and was previously shown to be useful in measuring the effectiveness of professional development, with "test-retest reliability estimates generally reported in the range of .91 to .96 for elementary and secondary populations" (Christensen, Parker, & Knezek, 2005, p. 189; Christensen & Knezek, 2002; Christensen & Knezek, 1999). For this reason, the instrument was employed to measure the effect professional development has on participating teachers' overall technology integration abilities. Participating districts are able to utilize this information to better understand general stages of technology adoption among participating educators.

Data Collection

Participants were administered a pre- and posttest to include the quantitative instruments mentioned above. Pretests were issued by paper at the public library in January of 2016 at the beginning of the first face-to-face meeting. Posttests were issued by paper at the last face-to-face training in May 2016. Follow-up phone calls and site visits were conducted if participants failed to respond. Surveys were originally planned to be distributed electronically, reducing cost, improving efficiency, and improving the overall security of data collection. However, the researcher encountered connectivity issues at the public library. As a result, pretests and posttest were delivered via paper copy. Responses were entered into a spreadsheet and imported into SPSS software. The last face-to-face professional development meeting allowed participants to reflect via short answer how this professional development experience might change their teaching practices. Reflections provided further knowledge as to how instructional activities affected teacher attitudes towards STEM and confidence levels toward integrating instructional technology.

Human Subject Protection

Surveys employed in this study contained demographic questions, questions regarding the use of technology, attitudes toward information technology, confidence levels toward information technology, and attitudes toward STEM. Surveys were distributed face-to- face and took approximately 10 minutes to complete. Information gathered and the evaluation of this data assisted in identifying relationships between levels of technology integration and content areas, as well as individual traits.

There were no foreseeable risks to completing surveys. Participants were adults and were free to withdraw consent and cease participation in the research study at any time, without penalty. If unforeseen circumstances had occurred, a participant's inclusion could have been terminated by the investigator. All responses to surveys were kept in a secure area. Only researchers had access to this data via a secure password.

Participants utilized their employee ID number as a primary key for data. All precautions were taken to ensure security of the responses. Participants were grouped and also identified by a campus number in the unlikely event of duplicate keys. A possibility does exist that data collected during the current research study could be used for additional research beyond the initial study. Such a study would only occur with approval from the University of North Texas

Institutional Review Board. The board will examine any request for further research and would require absolute control of security and confidentiality of data.

CHAPTER 4

PRESENTATION OF DATA

Introduction

This study examined how participation in a Makerspace professional development experience affects participants' technology integration abilities, their confidence levels toward the use of technology, and their attitudes toward STEM and technology integration over the course of the 2016 spring semester. The following research questions were analyzed.

Research Question 1

> To what extent do teachers who participate in STEM Makerspace professional development activities increase their self-appraisal of competence in technology integration abilities?

Research Question 2

> To what extent do teachers who participate in STEM Makerspace professional development activities increase in their confidence in integrating new information technology into pedagogical practice?

Research Question 3

> To what extent do teachers who participate in STEM Makerspace professional development activities become more positive in their attitudes toward STEM?

Description of Subjects

A total of 59 educators participated in the research study, with 59 completing the pretest and 52 completing the posttest surveys. Each participant identified with one of six schools using a campus ID number, which is represented in Table 1. One elementary and one middle school were selected by school leaders from each of three socioeconomic clusters—low, medium, or high socioeconomic status – so that for both middle school and elementary school level, there was representation from each of three socioeconomic levels. Leaders selected schools similar in population size and for convenience. Out of 59 subjects, 51 (86.4%) were identified as females and eight (13.6%) as males.

Table 1

Participating Campuses by Socioeconomic Cluster

Campus ID/ Income Level	Frequency	Percent	Valid Percent	Cumulative Percent
44: Middle Low Income	10	16.9	16.9	16.9
46: Middle High Income	12	20.3	20.3	37.3
47: Middle Middle Income	9	15.3	15.3	52.5
118: Elementary Middle Income	9	15.3	15.3	67.8
119: Elementary Low Income	10	16.9	16.9	84.7
121: Elementary High Income	9	15.3	15.3	100.0
Total	59	100.0	100.0	

Eleven participants identified themselves as campus leaders, defined as either a campus principal or academic coach, which is an instructional leader assigned to each campus. The remaining 48 participants identified themselves as classroom teachers, with five of the classroom teachers serving as librarians. Out of 59 participants, 19% of participants served in some type of leadership role (Table 2).

Table 2

Subject Occupation

	Frequency	Percent	Valid Percent	Cumulative Percent
Leaders	11	18.6	18.6	18.6
Teachers	48	81.4	81.4	100.0
Total	59	100.0	100.0	

Research Question 1

Research Question 1 asked, “To what extent do educators who participate in STEM Makerspace professional development activities increase in their self-appraisal of competence in technology integration?” The research hypothesis stated, “After participation in a semester-long series of professional development activities, teacher perceptions of their ability to integrate technology will increase as measured by Stages of Adoption of Technology.”

Educators were administered the Stages of Adoption questionnaire, which placed each in one of six stages, prior to receiving training in January 2016 and again at the conclusion of training in April 2016. Out of the 52 subjects who completed both the pre- and posttest Stages of Adoption of Technology survey, 12 moved up at least one category, 33 stayed the same, and six moved down at least one category. Twenty participants marked the highest category when completing the pre-test Stages of Adoption questionnaire, selecting the “Creative Applications to New Contexts” stage.

The mean scores, standard deviations, and number of all participants are reflected in Figures 4 and 5, with the January pretest administration mean of 5.25 and the posttest administration mean at 5.48. Hypothesis 1 was tested using a paired *t*-test comparing pretest to posttest Stages of Adoption questionnaire score. No significant differences ($p < .05$) were found. An analysis of variance (ANOVA) for gender found no statistically ($p < .05$) significant difference between male and female responses. Cohen's d for pre to post scores yielded a small effect with the change in Stages of Adoption pre to posttest results not found to be significant ($p < .05$). Results depicting an increase in the mean from pre to post for all respondents are reflected in Table 3 and Table 4.

A one-way analysis of variance (ANOVA) indicated no significant differences ($p<.05$) with regard to educators' stage of adoption based on campus socioeconomic status. As shown in Tables 5 and 6, a statistically significant ($p< .05$) increase in attitudes was noted for female teachers, with an effect size of .338 pre to post indicating a small to moderate effect (Cohen, 1988) and educationally meaningful according to commonly accepted guidelines (Bialo and Sivin-Kachala, 1996). The pre-post gain based on the one-tailed t-test reported in Table 6 was found to be statistically significant ($p<.05$). Therefore, the researcher concluded the gain was not due to chance. The overall trend indicates that female teachers improved pre to post. Tables 7 and 8 illustrate that leaders ($N = 11$) reported a higher level of competence in reported Stages of Adoption during the pretest administration, which was found to be statistically significant compared to teachers ($p < .05$). There were no significant differences with regard to occupation and level of adoption of technology for posttest administration.

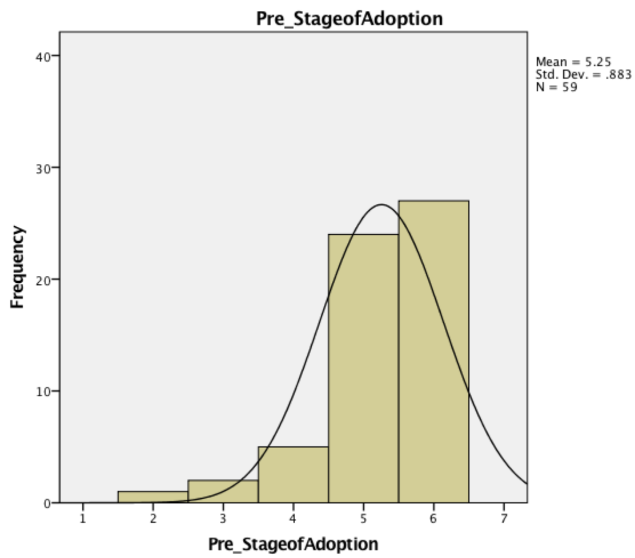

Figure 4. Stages of Adoption January pretest questionnaire results for Educators Participating in Makers' Guild Professional Development Activities.

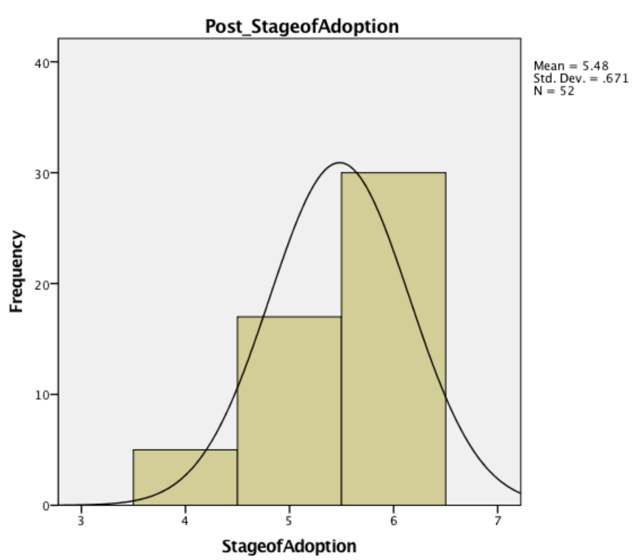

Figure 5. Stages of Adoption April posttest questionnaire results for Educators Participating in Makers' Guild Professional Development Activities.

Table 3

Descriptive Statistics for Pre-Post Stages of Adoption for All Respondents Participating in Makers' Guild Professional Development Activities

	N	Mean	Std. Deviation
Pre_StageofAdoption	52	5.37	.715
StageofAdoption	52	5.48	.671

Table 4

Paired t-*Test Results for Pre-Post Stages of Adoption for all Respondents Participating in Makers' Guild Professional Development Activities*

	Mean	Standard Deviation	Standard Error of the Mean	*t*	df	Sig. (1-tailed)
Stage of Adoption to Post Stage of Adoption	.115	.732	.101	-1.137	51	.1305

Table 5

Stages of Adoption for Female Teachers Participating in Makers' Guild Professional Development Activities, Pre-Post.

	N	Mean	Standard Deviation
Pre Stages of Adoption	33	5.15	.712
Post Stages of Adoption	33	5.39	.704

Table 6

Paired t-*Test Results for Pre-Post Stages of Adoption for Female Teachers Participating in Makers' Guild Professional Development Activities*

	N	Mean	Standard Deviation	T	df	1-Tailed Sig.	Effect Size
Pre-Post Stages of Adoption - Female Teachers	33	.242	.751	1.854	32	.036	.338

Table 7

Descriptive Statistics for Stages of Adoption for Three Groups of Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Pretest Stage of Adoption	Leaders	11	5.82	.405
	Teachers	48	5.13	.914
	Total	59	5.25	.883
Post Stage of Adoption	Leaders	11	5.64	.674
	Teachers	41	5.44	.673
	Total	52	5.48	.671

Table 8

Paired t-*Test Results for Pre-Post Stages of Adoption for Educators Participating in Makers' Guild Professional Development Activities, All Occupations Combined*

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Pretest Stage of Adoption	Between Groups	4.300	1	4.300	5.995	.017
	Within Groups	40.886	57	.717		
	Total	45.186	58			
Post Stage of Adoption	Between Groups	.338	1	.338	.746	.392
	Within Groups	22.643	50	.453		
	Total	22.981	51			

Research Question 2

Research Question 2 asked, “To what extent do educators who participate in STEM Makerspace professional development activities increase in their confidence in integrating new information technology into pedagogical practice?” The research hypothesis stated, “After participation in a semester-long series of professional development activities, teacher confidence levels in their ability to integrate technology will increase as measured by the Technology Proficiency Self-Assessment for 21st Century Learning.”

The researcher employed a version of the Technology Proficiency Self-Assessment for 21st Century Learning that measures six factors: (F1) Email, (F2) World Wide Web, (F3) Integrated Applications, (F4) Teaching with Technology, (F5) Emerging Technologies for Student Learning, and (F6) Emerging Technologies for Teacher Professional Development. However, the fourth factor, Teaching with Technology, produced a low reliability estimate because the version administered included only two of the five items normally used for Factor 4. Internal consistency reliabilities for the six scales ranged from .954 to .592, considered “very good to poor” according to guidelines provided by DeVellis (1991) with .592 representing factor four. Hypothesis 2 was tested using a paired sample *t*-test. Table 9 depicts the Technology Proficiency Self-Assessment for 21st Century Learning January pretest and April posttest means, number of responses, and standard deviations. Results indicate a positive group mean increase in all factors investigated, suggesting positive improvement in regard to educators’ confidence levels. The likelihood of all six measures exhibiting positive changes from pre to post simply by chance would be $p = .0156$ using GraphPad Prism version 6.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com.

Table 9

Descriptive Statistics for TPSA C-21 Pre-Post Scores for All Respondents Participating in Makers' Guild Professional Development Activities

		Mean	*N*	Standard Deviation	Standard Error of the Mean
Pair 1	TPSA Email Pretest	4.8231	52	.25867	.03587
	TPSA Email Posttest	4.9000	52	.22229	.03083
Pair 2	TPSA WWW Pretest	4.6731	52	.38812	.05382
	TPSA WWW Posttest	4.7404	52	.27954	.03876
Pair 3	TPSA Integrated App Pretest	4.4260	52	.65301	.09056
	TPSA Integrated App Posttest	4.5346	52	.66003	.09153
Pair 4	TPSA Teaching with Technology Pretest	4.3558	52	.68124	.09447
	TPSA Teaching with Technology Posttest	4.5000	52	.71401	.09901
Pair 5	TPSA Student Learning Pretest	4.1275	51	.98789	.13833
	TPSA Student Learning Posttest	4.4492	51	.64076	.08972
Pair 6	TPSA Teacher PD Pretest	4.6830	51	.44379	.06214
	TPSA Teacher PD Posttest	4.7895	51	.36052	.05048

Table 10 illustrates TPSA C-21's paired sample *t*-test results for all respondents. No significant ($p < .05$) individual scale pre to post gains were identified for four out of the six factors: (F2) World Wide Web, (F3) Integrated Applications, (F4) Teaching with Technology, and (F6) Emerging Technologies for Teacher Professional Development. However Factor 1, Email Skills, Factor 5, Emerging Technologies for Student Learning, and Factor 6, Teacher Professional Development, were found to have exhibited statistically ($p < .05$) significant gains. Educators were more confident in their technology proficiencies in the areas of Email Skills and using

Emerging Technologies for Student Learning at the end of Makers' Guild Professional Development Activities than at the beginning.

Table 10

Paired Sample Pre-Post t-*Test Results for TPSA C-21 Scales for All Respondents Participating in Makers' Guild Professional Development Activities*

		N	Correlation	*df*	Sig. (1-tailed)	Effect Size
Pair 1	TPSA Email Pretest & TPSA Email Posttest	52	.286	51	.030	.317
Pair 2	TPSA WWW Pretest & TPSA WWW Posttest	52	.373	51	.106	.199
Pair 3	TPSA Integrated App Pretest & TPSA Integrated App Posttest	52	.541	51	.109	.165
Pair 4	TPSA Teaching with Tech Pretest & TPSA Teaching with Tech Posttest	52	.433	51	.084	.205
Pair 5	TPSA Student Learning Pretest & TPSA Student Learning Posttest	51	.473	50	.0065	.385
Pair 6	TPSA Teacher PD Pretest & TPSA Teacher PD Posttest	51	.359	50	.0525	.262

Tables 11 and 12 contain findings regarding whether educators differed before professional development took place with respect to confidence in technology proficiencies based on occupation. Analysis of variance confirmed significant ($p < .05$) differences based on teacher or leader occupation for three of six TPSA C-21 scales at the time of the pretest survey administration: (F3) Integrated Applications, (F5) Emerging Technologies for Student Learning, and (F6) Emerging Technologies for Teacher Professional Development. The self-appraisal by educational leaders was higher than for teachers for all three scales. Leaders were more confident entering training than teachers in the technology proficiencies of integrated applications, emerging technologies for student learning, and emerging technologies for teacher professional development at the begining of the Makers' Guild professional development program.

Tables 13 and 14 contains ANOVA findings for the occupations of teachers versus leaders regarding TPSA C-21 scales at the time of the post test. There were no significant ($p < .05$) differences with regard to occupation for posttest administration on any of the six scales. Based on the group mean averages in Table 11 – 14, it appears that the self-appraisals of teachers and leaders with respect to their confidence in technology proficiencies became more closely aligned by the end of the professional development activities.

Table 11

TPSA C-21 Pretest Descriptives For Two Educator Occupations Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
TPSA Email	Leaders	11	4.8909	.18684
	Teachers	48	4.7760	.35250
	Total	59	4.7975	.32976
TPSA WWW	Leaders	11	4.7455	.23817
	Teachers	48	4.5792	.54459
	Total	59	4.6102	.50436
TPSA Integrated App	Leaders	11	4.8182	.20889
	Teachers	48	4.2615	.76271
	Total	59	4.3653	.72577
TPSA Teaching with Tech	Leaders	11	4.6364	.59544
	Teachers	48	4.2083	.83687
	Total	59	4.2881	.81051
TPSA Student Learning	Leaders	11	4.6136	.60066
	Teachers	48	3.9115	1.10305
	Total	59	4.0424	1.06031
TPSA Teacher PD	Leaders	11	4.9545	.10778
	Teachers	48	4.5764	.56906
	Total	59	4.6469	.53524

Table 12

ANOVA by Occupation for TPSA C-21 Pretest Results for Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.	Effect Size
TPSA Email	Between Groups	.118	1	.118	1.087	.301	.200
	Within Groups	6.189	57	.109			
	Total	6.307	58				
TPSA WWW	Between Groups	.247	1	.247	.972	.328	.194
	Within Groups	14.506	57	.254			
	Total	14.754	58				
TPSA Integrated App	Between Groups	2.774	1	2.774	5.692	.020	.446
	Within Groups	27.778	57	.487			
	Total	30.551	58				
TPSA Teaching with Tech	Between Groups	1.640	1	1.640	2.563	.115	.283
	Within Groups	36.462	57	.640			
	Total	38.102	58				
TPSA Student Learning	Between Groups	4.412	1	4.412	4.137	.047	.632
	Within Groups	60.794	57	1.067			
	Total	65.207	58				
TPSA Teacher PD	Between Groups	1.280	1	1.280	4.756	.033	.419
	Within Groups	15.336	57	.269			
	Total	16.616	58				

Table 13

TPSA C-21 Posttest Descriptives For TwolEducator Occupations Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
TPSA Email Posttest	Leaders	11	4.9091	.30151
	Teachers	41	4.8976	.20061
	Total	52	4.9000	.22229
TPSA WWW Posttest	Leaders	11	4.7273	.34955
	Teachers	41	4.7439	.26272
	Total	52	4.7404	.27954
TPSA Integrated App Posttest	Leaders	11	4.8000	.33466
	Teachers	41	4.4634	.70914
	Total	52	4.5346	.66003
TPSA Teaching with Tech Posttest	Leaders	11	4.6818	.64315
	Teachers	41	4.4512	.73148
	Total	52	4.5000	.71401
TPSA Student Learning Posttest	Leaders	11	4.5682	.53140
	Teachers	40	4.4165	.66999
	Total	51	4.4492	.64076
TPSA Teacher PD Posttest	Leaders	11	4.8333	.29814
	Teachers	40	4.7775	.37836
	Total	51	4.7895	.36052

Table 14

ANOVA by Occupation for TPSA C-21 Posttest Results For Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.	Effect Size
TPSA Email Posttest	Between Groups	.001	1	.001	.023	.880	.044
	Within Groups	2.519	50	.050			
	Total	2.520	51				
TPSA WWW Posttest	Between Groups	.002	1	.002	.030	.863	-.054
	Within Groups	3.983	50	.080			
	Total	3.985	51				
TPSA Integrated App Posttest	Between Groups	.983	1	.983	2.314	.135	.606
	Within Groups	21.235	50	.425			
	Total	22.218	51				
TPSA Teaching with Tech Posttest	Between Groups	.461	1	.461	.903	.347	.334
	Within Groups	25.539	50	.511			
	Total	26.000	51				
TPSA Student Learning Posttest	Between Groups	.198	1	.198	.478	.492	.250
	Within Groups	20.330	49	.415			
	Total	20.529	50				
TPSA Teacher PD Posttest	Between Groups	.027	1	.027	.204	.654	.081
	Within Groups	6.472	49	.132			
	Total	6.499	50				

Results indicating socioeconomic impact on educator confidence levels are represented in Tables 15, 16, 17, and 18. A one-way ANOVA was conducted to investigate whether confidence levels in technology proficiency differed by campus socioeconomic level. Analyses were conducted for both the pretest and posttest times of survey administration. Pretest results regarding socioeconomic status yielded no statistically ($p < .05$) significant differences for any of the six TPSA C-21 scales. Posttest results were found to be statistically significant ($p < .05$) for two of the six TPSA C-21 factors, F2 World Wide Web and F5 Emerging Technologies for Student Learning. All participants' confidence levels in World Wide Web and Emerging Technologies for Student Learning did increase at the end of training.

Table 15

Descriptive Statistics for TPSA C-21 Pretest Scores by Socioeconomic Level of School for Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
TPSA F1 Email Pretest	Low Income	20	4.9275	.12083
	Middle Income	16	4.5688	.49054
	High Income	23	4.8435	.23321
	Total	59	4.7975	.32976
TPSA F2 WWW Pretest	Low Income	20	4.8200	.26675
	Middle Income	16	4.3500	.71740
	High Income	23	4.6087	.41111
	Total	59	4.6102	.50436
TPSA F3 Integrated App Pretest	Low Income	20	4.6000	.54290
	Middle Income	16	3.8844	.88576
	High Income	23	4.4957	.60263
	Total	59	4.3653	.72577
TPSA F4 Teaching with Tech Pretest	Low Income	20	4.6250	.53496
	Middle Income	16	3.6563	.96123
	High Income	23	4.4348	.66237
	Total	59	4.2881	.81051

Table 15 (*continued*).

		N	Mean	Standard Deviation
TPSA F5 Student Learning Pretest	Low Income	20	4.5563	.80854
	Middle Income	16	3.3906	1.01023
	High Income	23	4.0489	1.07446
	Total	59	4.0424	1.06031
TPSA F6 Teacher PD Pretest	Low Income	20	4.8000	.39589
	Middle Income	16	4.3229	.69247
	High Income	23	4.7391	.43177
	Total	59	4.6469	.53524

Table 16

ANOVA by Socioeconomic Level of Educator's School for TPSA C-21 Pretest Scores Among Participants in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig. (2 tailed)
TPSA F1 Email Pretest	Between Groups	1.224	2	.612	6.741	.002
	Within Groups	5.083	56	.091		
	Total	6.307	58			
TPSA F2 WWW Pretest	Between Groups	1.964	2	.982	4.299	.018
	Within Groups	12.790	56	.228		
	Total	14.754	58			
TPSA F3 Integrated App Pretest	Between Groups	5.193	2	2.597	5.734	.005
	Within Groups	25.358	56	.453		
	Total	30.551	58			
TPSA F4 Teaching with Tech Pretest	Between Groups	9.153	2	4.576	8.853	.000
	Within Groups	28.949	56	.517		
	Total	38.102	58			
TPSA F5 Student Learning Pretest	Between Groups	12.079	2	6.039	6.366	.003
	Within Groups	53.128	56	.949		
	Total	65.207	58			
TPSA F6 Teacher PD Pretest	Between Groups	2.344	2	1.172	4.598	.014
	Within Groups	14.272	56	.255		
	Total	16.616	58			

Table 17

Descriptive Statistics for TPSA C-21 Posttest Scores by Socioeconomic Level of School for Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
TPSA F1 Email Posttest	Low Income	18	4.9556	.18856
	Middle Income	13	4.8308	.24285
	High Income	21	4.8952	.23340
	Total	52	4.9000	.22229
TPSA F2 WWW Posttest	Low Income	18	4.8556	.25489
	Middle Income	13	4.6000	.31623
	High Income	21	4.7286	.24319
	Total	52	4.7404	.27954
TPSA F3 Integrated App Posttest	Low Income	18	4.7222	.42917
	Middle Income	13	4.2769	.79389
	High Income	21	4.5333	.70805
	Total	52	4.5346	.66003
TPSA F4 Teaching with Tech Posttest	Low Income	18	4.6944	.57238
	Middle Income	13	4.2692	.88070
	High Income	21	4.4762	.69779
	Total	52	4.5000	.71401

Table 17 (*continued*).

		N	Mean	Standard Deviation
TPSA F5 Student Learning Posttest	Low Income	17	4.7437	.36650
	Middle Income	13	4.1758	.73907
	High Income	21	4.3801	.68113
	Total	51	4.4492	.64076
TPSA F6 Teacher PD Posttest	Low Income	17	4.9510	.12862
	Middle Income	13	4.6538	.47367
	High Income	21	4.7429	.37508
	Total	51	4.7895	.36052

Table 18

ANOVA by Socioeconomic Level of School for TPSA C-21 Posttest Scale Scores Among Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig. (2 tailed)
TPSA F1 Email Posttest	Between Groups	.118	2	.059	1.207	.308
	Within Groups	2.402	49	.049		
	Total	2.520	51			
TPSA F2 WWW Posttest	Between Groups	.498	2	.249	3.498	.038
	Within Groups	3.487	49	.071		
	Total	3.985	51			
TPSA F3 Integrated App Posttest	Between Groups	1.497	2	.748	1.770	.181
	Within Groups	20.721	49	.423		
	Total	22.218	51			
TPSA F4 Teaching with Tech Posttest	Between Groups	1.385	2	.692	1.378	.262
	Within Groups	24.615	49	.502		
	Total	26.000	51			
TPSA F5 Student Learning Posttest	Between Groups	2.546	2	1.273	3.398	.042
	Within Groups	17.983	48	.375		
	Total	20.529	50			
TPSA F6 Teacher PD Posttest	Between Groups	.728	2	.364	3.029	.058
	Within Groups	5.771	48	.120		
	Total	6.499	50			

TPSA C-21 Analyses by Gender

Tables 19, 20, 21, and 22 contain findings based on examining whether or not degree of confidence in technology proficiency varied based on the gender of the Makerspace PD participant. Examination of gains in TPSA C-21 teacher confidence levels with both genders combined produced significant findings pre to post, with significant (p<.05) gains in F1 Email Skills, F5, Emerging Technologies for Student Learning, and F6 Teacher PD. An effect size of .387 was calculated for Email,.481 for Student Learning, and.393 for Teacher PD pre to post. Effect sizes of these magnitudes approach a moderate effect in magnitude (Cohen, 1988) and are educationally meaningful (ES > .3) according to commonly accepted guidelines (Bialo and Sivin-

Kachala 1996). Additional analyses investigating teachers indicated that female teachers experienced significant ($p < .05$) improvements in confidence levels in F1 Email, F2 WWW, F5 Student Learning and F6 Teacher PD. Pre-post effect size magnitudes for females were greater than for the group of teachers overall: F1 Email ES for females = .425 vs. .387 for teachers overall; F2 WWW ES for females = .338 vs. .256 for teachers overall; F5 Student Learning ES for females = .512 vs. .481 for teachers overall; and F6 Teacher PD ES for females = .406 vs. .393 for teachers overall. This trend provides evidence for the broader observation/conclusion to be presented by the researcher in chapter 5, that female teachers' confidence levels especially increased pre to post, during the Makerspace PD activities.

Table 19

Descriptive Statistics for TPSA C-21 Scales Pre-Post for Teacher Respondents Participating in Makers' Guild Professional Development Activities.

		Mean	*N*	*Std. Deviation*
F1 TPSA Email	*TPSAFactor1*	4.8049	41	.27382
	TPSAFactor1PostT	4.8976	41	.20061
F2 TPSA WWW	*TPSAFactor2*	4.6537	41	.41958
	TPSAFactor2PostT	4.7439	41	.26272
F3 TPSA Integrated Apps	*TPSAFactor3*	4.3207	41	.69219
	TPSAFactor3PostT	4.4634	41	.70914
F4 TPSA Teaching with Tech	*TPSAFactor4*	4.2805	41	.68964
	TPSAFactor4PostT	4.4512	41	.73148
F5 TPSA Student Learning	*TPSAFactor5*	3.9938	40	1.03618
	TPSAFactor5PostT	4.4165	40	.66999
F6 TPSA Teacher PD	*TPSAFactor6*	4.6083	40	.47223
	TPSAFactor6PostT	4.7775	40	.37836

Table 20

Paired Samples Pre-Post t-*Test Results for TPSA C-21 Scales for Teachers Participating in Makers' Guild Professional Development Activities*

		Mean	*Standard Deviation*	*t*	*df*	Sig. (1-tailed)	Effect Size
Pair 1	TPSA Email Pretest & TPSA Email Posttest	.09268	.27963	2.122	40	.020	.387
Pair 2	TPSA WWW Pretest & TPSA WWW Posttest	.09024	.38846	1.488	40	.0725	.256
Pair 3	TPSA Integrated App Pretest & TPSA Integrated App Posttest	.14268	.67838	1.347	40	.093	.203
Pair 4	TPSA Teaching with Tech Pretest & TPSA Teaching with Tech Posttest	.17073	.77144	1.417	40	.082	.240
Pair 5	TPSA Student Learning Pretest & TPSA Student Learning Posttest	.42277	.93520	2.859	39	.0035	.481
Pair 6	TPSA Teacher PD & TPSA Teacher PD Posttest	.16917	.47552	2.250	39	.015	.393

Table 21

Paired Samples t-*Test Descriptive Statistics for TPSA C-21 Scales for Female Teacher Respondents in Makers' Guild Professional Development Activities.*

		Mean	N	Std. Deviation
Pair 1	*TPSA Email1Pretest*	*4.7636*	*33*	*.28920*
	TPSA Email Posttest	*4.8727*	*33*	*.21690*
Pair 2	*TPSA WWW Pretest*	*4.5939*	*33*	*.43728*
	TPSA WWW Posttest	*4.7182*	*33*	*.27552*
Pair 3	*TPSA Integrated App Pretest*	*4.2045*	*33*	*.71767*
	TPSA Integrated App Posttest	*4.3939*	*33*	*.76073*
Pair 4	*TPSA Teaching With Tech Pretest*	*4.1818*	*33*	*.72692*
	TPSA Teaching with Tech Posttest	*4.3636*	*33*	*.78335*
Pair 5	*TPSA Student Learning Pretest*	*3.8633*	*32*	*1.06841*
	TPSA Student Learning Posttest	*4.3292*	*32*	*.71545*
Pair 6	*TPSA Teacher PD Pretest*	*4.5417*	*32*	*.49910*
	TPSA Teacher PD Posttest	*4.7271*	*32*	*.40767*

Table 22

Paired Samples t-*Test Results for TPSA C-21 Scales for Female Teacher Respondents in Makers' Guild Professional Development Activities.*

		Mean	*Standard Deviation*	*t*	*df*	Sig. (1-tailed)	Effect Size
Pair 1	TPSA Email Pretest TPSA Email Posttest	.10909	.30859	-2.031	32	.0255	.425
Pair 2	TPSA WWW Pretest TPSA WWW Posttest	.12424	.41910	-1.703	32	.049	.338
Pair 3	TPSA Integrated App Pretest TPSA Integrated App Posttest	.18939	.73779	-1.475	32	.075	.256
Pair 4	TPSA Teaching with Tech Pretest TPSA Teaching with Tech Posttest	.18182	.85530	-1.221	32	.115	.240
Pair 5	TPSA Student Learning Pretest TPSA Student Learning Posttest	.46596	.99644	-2.645	31	.0065	.512
Pair 6	TPSA Teacher PD Pretest TPSA Teacher PD Posttest	.18542	.52370	-2.003	31	.027	.406

Research Question 3

Research Question 3 asked, “To what extent do educators who participate in STEM Makerspace professional development activities become more positive in their attitudes toward STEM?” The research hypothesis for Research Question 3 explored was, “After participation in a semester-long series of professional development activities, teacher attitudes toward STEM will increase based on results identified through the STEM Semantics Survey instrument.” Participants were administered the STEM Semantics Survey prior to training in January 2016 and at the conclusion of training in April 2016. For the 52 participants who completed both the pretest and posttest STEM Semantics Survey questionnaire, all reported an increase on each of the five scales.

Internal consistency reliabilities for the six scales ranged from .939 to .788, considered “excellent to good” according to guidelines provided by DeVellis (1991). Pre-post mean values were calculated for each STEM Semantics Survey scale. Table 23 indicates an increase in the mean for each scale explored, which included dispositions towards science, engineering, technology, mathematics, and STEM careers. Results of the analyses for the STEM Semantics Survey are depicted in Tables 23 and 24.

Table 23

Paired Samples Pre-Post Descriptive Statistics for STEM Semantics Survey for All Respondents Participating in Makers' Guild Professional Development Activities

		Mean	*N*	Standard Deviation
Science	Pretest	6.3731	52	.90231
	Posttest	6.6231	52	.62579
Engineering	Pretest	5.8269	52	1.07304
	Posttest	6.0923	52	1.02934
Tech	Pretest	6.1500	52	1.02737
	Posttest	6.5538	52	.83887
Math	Pretest	4.9923	52	1.75609
	Posttest	5.8269	52	1.25622
STEM Career	Pretest	5.8692	52	1.35351
	Posttest	6.2769	52	1.01915

The researcher conducted a paired samples *t*-test comparing pretest and posttest survey administration scale scores. Of the five areas accessed, there were positive and statistically significant ($p < .05$) increases in STEM perceptions for Science, Math, Technology, and STEM as a Career. Surprisingly, participants reported the strongest positive increase in perceptions towards Math, with a *p* value at .001, as illustrated in Table 24. Effect sizes indicating the magnitude of the gain in each area assessed were (from smallest to largest): .252 for perceptions toward Engineering, .322 for perceptions toward Science, .339 for perceptions toward STEM as a Career, 430 for perceptions toward Technology and .545 for perceptions toward Math. Pre to post gains range from a small effect (.2 standard deviations) (Cohen, 1988) to a moderate effect (.5 standard deviations) (Cohen, 1988). The four STEM disposition measures that exhibited statistically significant (p < .05) gains all are in the range that would be considered educationally meaningful according to commonly accepted guidelines (Bialo and Sivin-Kachala 1996), and all lie within the zone of desired effects as outlined by Hattie (2009). These analyses confirmed that Makerspace Guild educators did become more positive in their perceptions of math, science, technology, and STEM as a career between the start and the end of professional development.

Several ANOVAs were performed to investigate whether differences existed by gender, occupation, and socioeconomic level of educators' schools for the five STEM Semantics Survey scales. Tables 25, 26, 27, and 28 indicate no statistical significant ($p < .05$) findings with regard to the educator's schools' three levels of socioeconomic status for either pretest or posttest administration for all respondents. Tables 29, 30, 31 and 32 indicate that no statistical significant findings emerged with regard to gender for either pretest or posttest administration for all respondents. With regard to occupation, no statistical significant differences on STEM dispositions were found for the group of respondents overall, as illustrated in Tables 33, 34, 35, and 36 for all respondents. Further analysis indicated that female teachers became statistically significantly (p < .05) more positive in perceptions of Science, Math, Engineering, and Technology, as indicated in Tables 37 and 38. Effect size calculations indicated a small to moderate pre-post effect of d = .372 among female teachers in perceptions toward STEM as a Career, with a moderate effect (Cohen, 1988) in science, mathematics, and technology STEM disposition measures. For the female teachers participating in Makerspace PD activities, all effect sizes except for STEM as a Career fall within the zone of desired effects as outlined by Hattie (2009). Female teachers became more positive in their perceptions of Science, Math, Engineering, and Technology between the beginning to the end of Makerspace professional development activities.

With regard to differences occurring among schools in areas with low, medium or high socioeconomic status, results of ANOVAs indicated a statistical significant (p < .05) finding that teachers working in low income schools improved in their perceptions of Math and Technology, as depicted on Tables 39 and 40. Effect sizes further support these findings, with low income area teacher perceptions of Science yielding a pre-post effect size of .297, indicating a small effect, and all other scales producing a moderate effect (Cohen, 1988) and within the zone of desired effects as outlined by Hattie (2009).

Table 24

Paired Samples -Test Results for STEM Semantics Survey Scales for All Respondents Participating in Makers' Guild Professional Development Activities

		Mean	Standard Deviation	*T*	*df*	Sig. (1-tailed)	Effect Size
Science	Pretest-Posttest	.25000	.78403	-2.299	51	.013	.322
Math	Pretest-Posttest	.83462	1.68998	-3.561	51	.0005	.545
Engineering	Pretest-Posttest	.26538	1.12840	-1.696	51	.048	.252
Tech	Pretest-Posttest	.40385	1.12476	-2.589	51	.0065	.430
STEM Career	Prettest-Posttest	.40769	1.43457	-2.049	51	.023	.339

Table 25

Descriptive Statistics for STEM Semantics Survey Pretest Scores for Educators Participating in Makers' Guild Professional Development Activities, by Three Levels of Socioconomic Status of the Educators' Schools

		N	Mean	Standard Deviation
Science Pretest	Low Income	20	6.1800	1.23612
	Middle Income	16	6.0375	1.00457
	High Income	23	6.5739	.74175
	Total	59	6.2949	1.01190
Math Pretest	Low Income	20	5.2400	1.54047
	Middle Income	16	4.6375	1.57855
	High Income	23	4.9478	2.00474
	Total	59	4.9627	1.73264
Engineering Pretest	Low Income	20	5.7800	1.11620
	Middle Income	16	5.5125	1.20437
	High Income	23	5.9826	1.01965
	Total	59	5.7864	1.10164
Technology Pretest	Low Income	20	6.1200	1.08074
	Middle Income	16	5.8125	1.05696
	High Income	23	6.4000	.91054
	Total	59	6.1458	1.02104
STEM Career Pretest	Low Income	20	5.7700	1.53729
	Middle Income	16	5.6875	1.23282
	High Income	23	5.9739	1.41332

	Total	59	5.8271	1.39282

Table 26

ANOVA Pretest Results for STEM Semantic Measures for Socioeconomic Level of School for Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Science Pretest	Between Groups	3.115	2	1.557	1.550	.221
	Within Groups	56.274	56	1.005		
	Total	59.388	58			
Math Pretest	Between Groups	3.235	2	1.618	.530	.591
	Within Groups	170.883	56	3.051		
	Total	174.118	58			
Engineering Pretest	Between Groups	2.087	2	1.043	.855	.431
	Within Groups	68.303	56	1.220		
	Total	70.389	58			
Technology Pretest	Between Groups	3.277	2	1.638	1.604	.210
	Within Groups	57.190	56	1.021		
	Total	60.466	58			
STEM Career Pretest	Between Groups	.873	2	.436	.219	.804
	Within Groups	111.644	56	1.994		
	Total	112.517	58			

Table 27

Descriptive Statistics for STEM Semantics Survey Posttest Scale Scores by Socioeconomic Level of School, for Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Science Posttest	1	18	6.6333	.66598
	2	13	6.3846	.77658
	3	21	6.7619	.44997
	Total	52	6.6231	.62579
Math Posttest	1	18	5.9444	.90178
	2	13	5.6615	1.44311
	3	21	5.8286	1.43288
	Total	52	5.8269	1.25622
Engineering Posttest	1	18	6.2556	.93508
	2	13	5.8462	1.13770
	3	21	6.1048	1.05758
	Total	52	6.0923	1.02934
Technology Posttest	1	18	6.7333	.77914
	2	13	6.2462	1.11102
	3	21	6.5905	.66776
	Total	52	6.5538	.83887
STEM Career Posttest	1	18	6.5556	.61951
	2	13	5.9077	1.44825
	3	21	6.2667	.95149
	Total	52	6.2769	1.01915

Table 28

ANOVA by Socioeconomic Level of School Results for Posttest Scores on STEM Semantic Survey Measures for Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Science Posttest	Between Groups	1.146	2	.573	1.491	.235
	Within Groups	18.826	49	.384		
	Total	19.972	51			
Math Posttest	Between Groups	.604	2	.302	.185	.831
	Within Groups	79.878	49	1.630		
	Total	80.482	51			
Engineering Posttest	Between Groups	1.271	2	.635	.590	.558
	Within Groups	52.766	49	1.077		
	Total	54.037	51			
Tech Posttest	Between Groups	1.839	2	.919	1.323	.276
	Within Groups	34.050	49	.695		
	Total	35.889	51			
STEM Career Posttest	Between Groups	3.172	2	1.586	1.560	.220
	Within Groups	49.800	49	1.016		
	Total	52.972	51			

Table 29

Descriptive Statistics by Gender for STEM Semantics Pretest Survey Scales for Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Science Pretest	Female	51	6.2706	1.03524
	Male	8	6.4500	.89283
	Total	59	6.2949	1.01190
Math Pretest	Female	51	4.8627	1.79799
	Male	8	5.6000	1.11612
	Total	59	4.9627	1.73264
Engineering Pretest	Female	51	5.7216	1.11073
	Male	8	6.2000	1.00854
	Total	59	5.7864	1.10164
Tech Pretest	Female	51	6.1490	1.02125
	Male	8	6.1250	1.08989
	Total	59	6.1458	1.02104
STEM Career Pretest	Female	51	5.7216	1.45771
	Male	8	6.5000	.54511
	Total	59	5.8271	1.39282

Table 30

ANOVA by Gender for Pretest STEM Semantic Survey Measures for Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Science Pretest	Between Groups	.223	1	.223	.214	.645
	Within Groups	59.166	57	1.038		
	Total	59.388	58			
Math Pretest	Between Groups	3.759	1	3.759	1.258	.267
	Within Groups	170.359	57	2.989		
	Total	174.118	58			
Engineering Pretest	Between Groups	1.583	1	1.583	1.311	.257
	Within Groups	68.806	57	1.207		
	Total	70.389	58			
Technology Pretest	Between Groups	.004	1	.004	.004	.951
	Within Groups	60.462	57	1.061		
	Total	60.466	58			
STEM Career Pretest	Between Groups	4.190	1	4.190	2.205	.143
	Within Groups	108.326	57	1.900		
	Total	112.517	58			

Table 31

Descriptive Statistics by Gender for STEM Semantics Posttest Survey Measures for Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Science Posttest	Female	44	6.6364	.57591
	Male	8	6.5500	.89921
	Total	52	6.6231	.62579
Math Posttest	Female	44	5.7455	1.32831
	Male	8	6.2750	.62278
	Total	52	5.8269	1.25622
Engineering Posttest	Female	44	6.1273	1.02444
	Male	8	5.9000	1.10583
	Total	52	6.0923	1.02934
Tech Posttest	Female	44	6.5227	.85423
	Male	8	6.7250	.77782
	Total	52	6.5538	.83887
STEM Career Posttest	Female	44	6.2591	1.08656
	Male	8	6.3750	.54968
	Total	52	6.2769	1.01915

Table 32

ANOVA by Gender for STEM Semantics Posttest Measures for Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*Df*	Mean Square	*F*	Sig.
Science Posttest	Between Groups	.050	1	.050	.127	.723
	Within Groups	19.922	50	.398		
	Total	19.972	51			
Math Posttest	Between Groups	1.898	1	1.898	1.208	.277
	Within Groups	78.584	50	1.572		
	Total	80.482	51			
Engineering Postttest	Between Groups	.350	1	.350	.326	.571
	Within Groups	53.687	50	1.074		
	Total	54.037	51			
Tech Posttest	Between Groups	.277	1	.277	.389	.536
	Within Groups	35.612	50	.712		
	Total	35.889	51			
STEM Career Posttest	Between Groups	.091	1	.091	.086	.771
	Within Groups	52.881	50	1.058		
	Total	52.972	51			

Table 33

ANOVA Descriptive Statistics for STEM Semantics Pretest Survey for Three Groups of Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Science Pretest	Leader	11	6.2727	1.18075
	Teacher	48	6.3000	.98326
	Total	59	6.2949	1.01190
Math Pretest	Leader	11	4.8182	2.10229
	Teacher	48	4.9958	1.66081
	Total	59	4.9627	1.73264
Engineering Pretest	Leader	11	6.2000	.97980
	Teacher	48	5.6917	1.11543
	Total	59	5.7864	1.10164
Tech Pretest	Leader	11	6.4000	.99197
	Teacher	48	6.0875	1.02887
	Total	59	6.1458	1.02104
STEM Career Pretest	Leader	11	5.8182	1.27892
	Teacher	48	5.8292	1.43036
	Total	59	5.8271	1.39282

Table 34

ANOVA Results for STEM Semantics Pretest Survey for Two Groups of Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Science Pretest	Between Groups	.007	1	.007	.006	.937
	Within Groups	59.382	57	1.042		
	Total	59.388	58			
Math Pretest	Between Groups	.282	1	.282	.093	.762
	Within Groups	173.836	57	3.050		
	Total	174.118	58			
Engineering Pretest	Between Groups	2.312	1	2.312	1.936	.169
	Within Groups	68.077	57	1.194		
	Total	70.389	58			
Tech Pretest	Between Groups	.874	1	.874	.836	.364
	Within Groups	59.593	57	1.045		
	Total	60.466	58			
STEM Career Pretest	Between Groups	.001	1	.001	.001	.981
	Within Groups	112.516	57	1.974		
	Total	112.517	58			

Table 35

Descriptive Statistics for STEM Semantics Posttest Survey for Two Groups of Educators Participating in Makers' Guild Professional Development Activities

		N	Mean	Standard Deviation
Science Posttest	Leader	11	6.5273	.65892
	Teacher	41	6.6488	.62254
	Total	52	6.6231	.62579
Math Posttest	Leader	11	5.9455	1.34786
	Teacher	41	5.7951	1.24618
	Total	52	5.8269	1.25622
Engineering Posttest	Leader	11	6.1091	1.19453
	Teacher	41	6.0878	.99704
	Total	52	6.0923	1.02934
Technology Posttest	Leader	11	6.4182	.96521
	Teacher	41	6.5902	.81111
	Total	52	6.5538	.83887
STEM Career Posttest	Leader	11	6.3636	1.02691
	Teacher	41	6.2537	1.02861
	Total	52	6.2769	1.01915

Table 36

ANOVA Results for STEM Semantics Posttest Survey for Two Groups of Educators Participating in Makers' Guild Professional Development Activities

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Science Posttest	Between Groups	.128	1	.128	.323	.573
	Within Groups	19.844	50	.397		
	Total	19.972	51			
Math Posttest	Between Groups	.196	1	.196	.122	.728
	Within Groups	80.286	50	1.606		
	Total	80.482	51			
Engineering Posttest	Between Groups	.004	1	.004	.004	.952
	Within Groups	54.033	50	1.081		
	Total	54.037	51			
Tech Posttest	Between Groups	.257	1	.257	.360	.551
	Within Groups	35.632	50	.713		
	Total	35.889	51			
STEM Career Posttest	Between Groups	.105	1	.105	.099	.754
	Within Groups	52.867	50	1.057		
	Total	52.972	51			

Table 37

Paired Samples t-*Test Pre-Post Descriptive Statistics for STEM Semantic Measures, Female Teacher Participants in Makers' Guild Professional Development Activities*

		Mean	*N*	Standard Deviation
Science	Pretest	6.3879	33	.82604
	Posttest	6.6727	33	.55186
Engineer-ing	Prettest	4.9030	33	1.77491
	Posttest	5.6788	33	1.33598
Tech	Pretest	5.6121	33	1.08736
	Posttest	6.1333	33	.98192
Math	Pretest	6.0727	33	1.04261
	Posttest	6.5576	33	.82728
STEM Career	Pretest	5.7333	33	1.49136
	Posttest	6.2242	33	1.11888

Table 38

Paired Samples t-*Test Pre-Post Result for STEM Semantic Measures, Female Teacher Participants in Makers' Guild Professional Development Activities*

		Mean	Standard Deviation	*T*	*df*	Sig. (1-tailed)	Effect Size
Science	Pretest – Posttest	.28485	.75338	-2.172	32	.0185	.406
Math	Pretest – Posttest	.77576	1.36634	-3.262	32	.0015	.492
Enginee ring	Pretest – Posttest	.52121	1.12909	-2.652	32	.006	.501
Tech	Pretest – Posttest	.48485	.96440	-2.888	32	.0035	.514
STEM Career	Pretest – Posttest	.49091	1.59224	-1.771	32	.043	.372

Table 39

Paired Samples Pre-Post Descriptive Statistics for STEM Semantic Measures for Teachers from Low Income Area Schools Participating in Makers' Guild Professional Development Activities

		Mean	*N*	Standard Deviation
Science	Pretest	6.5867	15	.70292
	Posttest	6.7867	15	.54231
Engineer-ing	Pretest	5.2400	15	1.71081
	Posttest	6.1333	15	.82693
Tech	Pretest	5.8400	15	1.04799
	Posttest	6.3867	15	.79090
Math	Pretest	6.0533	15	1.16488
	Posttest	6.9600	15	.15492
STEM Career	Pretest	6.1600	15	1.41664
	Posttest	6.6667	15	.49377

Table 40

Paired Samples t-*Test Pre-Post Results for STEM Semantic Measures for Teachers from Low Income Area Schools Participating in Makers' Guild Professional Development Activities*

		Mean	Standard Deviation	*t*	*df*	Sig. (1-tailed)	Effect Size
Science	Pretest-Posttest	.20000	.59040	-1.312	14	.1055	.297
Math	Pretest-Posttest	.89333	1.36039	-2.543	14	.0115	.662
Enginee ring	Pretest-Posttest	.54667	1.21059	-1.749	14	.051	.587
Tech	Pretest-Posttest	.90667	1.14360	-3.071	14	.004	-.478
STEM Career	Pretest-Protest	.50667	1.47526	-1.330	14	.1025	-.477

Summary

This study examined the effect of professional development on educators' perceptions of ability and confidence levels toward STEM and technology integration in a Makerspace environment. The following hypotheses were tested.

> H1: After participation in a semester-long series of professional development activities, teacher perceptions toward their ability to integrate technology will increase as measured by the Stages of Adoption of Technology.

H2: After participation in a semester-long series of professional development activities, teacher confidence levels in their ability to integrate technology will increase as measured by the Technology Proficiency Self-Assessment for 21st Century Learning.

H3: After participation in a semester-long series of professional development activities, teacher attitudes toward STEM will increase based on results identified through the STEM Semantics Survey instrument.

A total of $N = 59$ subjects participated in the study from three elementary and three middle schools in a large school district. Schools were similar in size but served different student populations, with one elementary and middle school serving low income students, one elementary and middle school serving middle-income students, and one elementary and middle school serving high-income students. The study included 51 (86.4%) female and eight (13.6%) male participants. Eleven participants identified themselves as campus administrators and 48 identified themselves as teachers. As a whole, the group of all educators experienced an increase in attitudes toward instructional technology during the professional development experience, with overall means increasing when comparing pre- to posttest administration.

Leaders reported a statistically significant ($p < .05$) higher Stage of Adoption than teachers at pretest time, mean = 5.82. Leaders reported a decrease in Stage of Adoption, mean = 5.64 at the time of post-test administration. Teachers reported an increase in competence in technology integration, pretest mean = 5.13 and posttest mean = 5.44. An increase in self-reported competence in technology integration was noted for female teachers, with an effect size of .338 pre to post, indicating an educationally meaningful effect according to commonly accepted guidelines (Bialo & Sivin-Kachala 1996) and pre to post gains of ($p < .036$) statistically significant. . The Makers' Guild program appears to have improved the alignment of self-reported competencies in technology integration between leaders and teachers over the course of the professional development activities. Evidence also emerged that an increase in competence in technology integration may have occurred for female teachers in particular, but this cannot be concluded at the $p < .05$ level based on the findings of this study.

Participants as a group did increase in confidence in their technology proficiency levels in the areas of World Wide Web and Emerging Technologies for Student Learning, over the course of the Makers' Guild professional development program. Statistically significant ($p < .05$) increases in confidence levels toward emerging technologies for student learning and world wide web skills emerged.

Leaders reported a statistically significant ($p < .05$) higher confidence level in integrated applications, emerging technologies for student learning, and emerging technologies for teacher professional development compared to teachers during pretest activities. Socioeconomic posttest analysis of variance indicated statically significant ($p < .05$) confidence levels toward World Wide Web and emerging technologies for student learning.

Low socioeconomic campuses reported a higher confidence levels in both World Wide Web and emerging technologies for student learning technology proficiencies compared to campuses serving middle and high-income students. ANOVAs examining gender did not produce statically significant findings. Further analysis found educationally significant findings ($p<.05$) to support an increase in confidences levels toward Email, Emerging Technologies for Student Learning, and Teacher Professional Development for female teachers and teachers employed from low income schools. It was found female teachers employed at low income schools improved confidence levels toward technology integration increased at the end of training.

Educators overall did report a statically significant ($p < .05$) increase in attitudes toward math, science, technology, and STEM careers. Attitudes toward math indicated the largest increase followed by technology, science, and STEM careers. ANOVAs investigating gender, occupation, and socioeconomic pre- and posttest did not produce statically significant findings. Teachers serving low income campuses increased perceptions toward math and technology ($p < .05$) with the finding being of sufficient magnitude to be educationally meaningful as defined by Bialo & Sivin-Kachola (1996).

Female teachers did improve their attitudes toward Science, Math, Engineering, and Technology over the course of the training. Female teachers working at a low income campus improved perceptions toward Math and Technology over the course of the training, further supporting the trend that the Makers' Guild program improved female teachers' confidence levels toward technology and attitudes toward technology and STEM over the course of professional development activities.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

Liddicoat (2008) highlights the importance of "strengthening K-12 STEM education, with an emphasis on skills and training programs for teachers, to aid in stimulating economic competiveness and growth" (p. 14). This study adds to the limited research exploring STEM professional development in a Makerspace environment. Results indicate that educators participating in the Makers' Guild professional development program did increase in self-reported level of competence in technology integration, confidence in technology proficiencies for integrating technology, and STEM dispositions toward math, technology, science, and STEM as a career. In addition, this study provides insight toward how leadership and teachers participating together in professional development may increase teachers' confidence toward the level of technology adoption or attitudes toward integrating technology after learning in a Makerspace environment.

Ashbrook (2013) highlights the importance of planning activities for learners to work on a problem or challenge, which promotes STEM inquiry. One way to connect early interest in and the pursuit of STEM careers includes project-based learning activities connected that are applicable to the real world (Christensen & Knezek, 2015 b; Christensen & Knezek, 2017). Activities presented to Makers' Guild participants incorporating project-based learning challenge cards through four STEAM career workstations may cause an increase in attitudes toward math, science, technology, and STEM careers.

Discussion of Findings

This study examined the effect of professional development on elementary and middle school educators' perceptions and confidence levels toward STEM and technology integration. The following research questions were investigated by the study.

Research Question 1: To what extent do educators who participate in STEM Makerspace professional development activities increase in their self-appraisal of competence in technology integration abilities?

Research examining participants' self-reported level of competence in technology integration by female teachers following Makerspace professional development did provide statistically significant findings. All participants did report an increase in attitude toward technology integration. Participants indicated a high level of adoption prior to professional development, leaving little room for growth. This is evident, as leaders reported a statistically significant high level of adoption (p < .05) on pretest survey questionnaires as compared to teachers entering training. This finding could have improved the alignment of self-reported competencies in technology integration between leaders and teachers over the course of the professional development activities. Makerspace environments emphasize "learning and sharing with an emphasis on participatory culture of community building" (Barniskis, 2014, p. 7). It was observed that the cohort Makers' Guild fostered a sense of community. Teachers seemed to be more excited and inclined to try new technologies because leaders participated in the professional development program, providing value to the school cohort group, which consisted of 1 leader, 8 content teachers, and a Makerspace facilitator from each campus. The school cohort groups were observed to be an asset as educators' represented a variety of content backgrounds and conversations on connecting Makerspace activities to content areas naturally developed. Educators did report an increase in attitudes toward technology integration. Activities were presented by the Makerspace community, modeling an active Makerspace community to participants. It was observed that community connections and extended partnerships provided through the public library's Makerspace community strengthened relationships between participating schools and community stakeholders.

Librarians were able to connect with content teachers and teachers began to consider how they could work together to offer creative opportunities for students in a campus Makerspace program. Groups worked together during Makerspace activities to solve problems. Hands-on activities and active learning experiences were a new form of professional development to many of the educators' participating in the program. Activities introduced to participants during the Learning in 3D workshop incorporated applications for augmented reality, virtual reality, robotics, origami, audio technology, textiles, and 2D and 3D graphic design. Leaders found it difficult to create and make an artifact, with their mean score for self-reported competencies in technology integration slightly decreasing after the Makers' Guild training. It was observed that many leaders participating in trainings had little to no experience using 3D technologies, 2D technologies, augmented reality, online learning management systems and robotics and some leaders never accessed content placed in the learning management system, preferring email communications. Self-reported competence toward technology did increase following this experience.

Research Question 2: To what extent do educators who participate in STEM Makerspace professional development activities increase in their confidence in integrating new information technology into pedagogical practice

It has been observed that teachers' confidence in one's competence in technology integration as measured by the TPSA is an important contributor to success in the classroom (Chrisentsen & Knezek, 2014). Research produced a statistically significant increase in educators' confidence levels in integrating new information technology into pedagogical practice during Makers' Guild professional development activities. Activities were designed to engage participants in an established Makerspace environment. During the first training, educators were slow to participate in Makerspace activities and many began the training session observing workstations and the Makerspace community. When challenged with the freedom to make any artifact, most teachers did not know how to respond as they seemed to want structure. Most participants had never seen a 3D printer or built a robot, but the Makerspace community was proactive at encouraging participants to try new technologies and experiment with new creative approaches. The social aspect of the community encouraged educators to make an artifact and educators seemed to be at ease and comfortable trying new emerging technologies.

After the first training, resources, communication, and further reading on how Makerspace activities could connect with curriculum were communicated by the researcher and Makers' Guild through emails and Canvas announcements. It was through this platform, that participants began to consider project-based learning activities. Challenge cards with curriculum examples were provided to participants. An example is provided in Appendix B. It was observed that content teachers and leaders were very interested in connecting Makerspace activities to curriculum content. The Learning in 3D workshop modeled how this concept could be connected to curriculum with all activities centering around math, science, and vocabulary. Participants were exposed to new applications framed around a curriculum standard. It was observed that online support along with challenge card activities encouraged teachers to try new emerging applications for creation and curation, many of which are located on the World Wide Web. Teachers seemed to enjoy professional development, as learning experiences were active in nature, with participants making artifacts and sharing with a wider community, particularly for female teachers and teachers serving low income students. This finding suggests that further research is needed to explore how the Makerspace environment might contribute to increasing female teacher confidence levels and teachers serving low income student populations.

It was observed that the Makerspace environment lends a safe and natural technology playground for learners to experience creative approaches to new technologies without a fear of failure. Moving professional development to an established Makerspace community provides a natural setting for educators to explore new technologies that may not be readily available. Since educators took on the role of a student, it is only natural that their confidence level toward integrating Emerging Technologies for Student Experiences would increase. It was surprising to the researcher to see an increase in confidence levels toward email by both female teachers and teachers serving low income students. Communication was delivered by email and also posted in the Canvas learning management system. It was observed that teachers preferred the use of email for communication in part because teachers are so busy and logging into another website to find information might be seen as another “to do” task. Teachers are used to checking email throughout the day and this communication method seemed to work better as teachers routinely access email. The Canvas learning management system is also a new initiative for the participating schools and many had yet to attend training on the use of the Canvas environment. The participating district was also awarded a large blended learning grant during the Spring of 2016, which encouraged the use of the Canvas environment.

It was observed that the design of activities introduced to educators during the Learning in 3D workshop encouraged teachers’ confidence levels toward using technology. Educators rotated to different workstations to learn about new approaches using augmented reality, origami, virtual reality, 3D printing, and robotics. Several educators serving low income students seemed to be very excited at the level of engagement these technologies could possibly lend to their students.

Many of the augmented reality and 3D modeling applications introduced to teachers were web based. It was observed that teachers serving low-income populations were excited to try challenge cards with students to improve academic vocabulary. Many of the applications and examples used during training incorporated web based applications in which participants would create an artifact to meet a mathematical or scientific challenge. Many of the challenges emphasized vocabulary activities, and all of the participating schools identified vocabulary as a continuous improvement goal. In addition, it was observed that the online project-based learning Canvas course was well received by participants serving low income student populations. This might explain why educators’ serving low income students reported a higher confidence level integrating World Wide Web on posttest results from low income campuses.

Also, an increase in confidence levels toward the World Wide Web could be due to the blended learning grant initiatives. The community exchange offered in the online professional development course was an entirely new experience for all participants in the program.

Research Question 3: To what extent do educators who participate in STEM Makerspace professional development activities become more positive in their attitudes toward STEM? Christensen & Knezek (2017) stress the importance of STEM proficiency and interest in STEM in elementary and middle school, as skills and interest have been shown to have a large impact students' academic performance and interest in entering a STEM career pathway. Teacher quality in regard to knowledge of the subject matter is "now understood as the greater predictor of academic success" and most teachers have little to no STEM training experiences (Liddicoat, 2008, p. 14). Research did produce a statistically significant finding toward increasing educators' attitudes toward STEM. Many participants in the Makers' Guild had little to no STEM training experience and lacked insight on how STEM could be integrated into content areas prior to training. The Makerspace community offered educators the opportunity to see how integrated STEM activities could engage students in a variety of content areas. Activities introduced to educators included a strong math and science connection. For example, educators were introduced to scientific augmented reality interactive word walls, which could be used to improve scientific vocabulary. Scaling methods incorporating 3D design and fabrication printing provided strong connections to math content areas. Measurement conversion activities and story writing introduced through robotics connected both English language arts and mathematics content areas.

Educators were interested in the four workstation STEAM concept in which participants design a project-based learning activity and make an artifact serving one of fourcareer roles: scientist, engineer, artist, and journalist. The project-based learning Makerspace process influenced teacher perceptions toward STEM careers. All participants found value in connecting student Makerspace activities to curriculum content. Further investigation is needed to explore the four workstation concept along with the impact the Makerspace environment may have on educators' perceptions toward STEM, especially female teachers employed at low income schools.

Conversations began to emerge on how such activities could extend classroom content through a creative space for students. Teachers and leaders began to recognize that Makerspace activities could be approached as an extension to curriculum content. Purposeful design could provide a level of engagement for students to consider curriculum content in a Makerspace environment. Student can become a STEM career professional, serving the role of a scientist, engineer, artist, or journalist. Site visits later emphasized this level of excitement as campuses began to design their Makerspace environment to facilitate STEM career workstations incorporating fabrication printing, robotics, and green screen technologies. Activities incorporated many visualization activities surrounding topics in math and science. Further research exploring visualization technologies, purposeful design, and Makerspace design is needed.

The online project-based learning course offered many STEM connections and resources to participants. Participants were encouraged to share applications and resources using this space were scheduled to be continued. Two elementary schools have chosen to begin a robotics club, two middle schools are building a fabrication printing shop, and green screen technology will be used to create student video projects in one elementary and one middle school as a result of the NASA Makers' Guild grant. One campus has implemented a Makerspace Lab in which the four workstation concept is completely designed by content teachers, not the campus librarian. The campus has invited the local artists and businesses to serve as guest speakers and mentors to students as part of the STEAM workstation concept.

Limitations

All participants had yet to experience professional development in a Makerspace environment. The sample of participants represented individuals from north Texas, which may limit generalizability to other locations. Participants may already have been exposed to topics surrounding professional development. In addition, it is important to recognize the issue of self-selection, which is a common limitation identified in education studies. Participants might naturally be interested in learning more about Makerspace and instructional technology environments.

Recommendations for Further Study

Based on the results of this study, several recommendations are given for further studies. Did the Makerspace environment influence the increase in attitudes toward technology? Because the number of participants in this study is small, there is a need to conduct the same study with a larger number of administrators and teachers. Any future study could investigate the impact of assigned content area and years of experience on educators' attitudes and confidence levels toward integrating technology and STEM. This study should be repeated to a larger population to further explore statistically significant findings in regard to leaders' self-appraisal of technology adoption. Perhaps, leaders' entered the Makers' Guild professional development program lacking a growth mindset. Future studies could provide further insight as to why leaders' perceive a higher level of technology adoption compared to teachers entering the Makers' Guild program. This finding seems to have encouraged teachers to improve their attitudes toward technology at the end of training. Although female teacher attitudes did increase at the end of training, the difference was statistically significant. Further research is needed to explore how the Makers' Guild program influences attitudes toward integrating technology, particularly targeting female teachers. Further research is needed to explore how leaders might influence female teachers' attitudes toward technology. In addition, it is not known if the Makerspace environment had an effect on participants' attitudes toward integrating technology. Further research is needed to explore how the Makerspace environment might influence participants' attitudes toward technology integration.

Did the Makerspace professional development program activities influence female teacher perceptions toward integrating technology? The Makers' Guild teachers did report a statistically significant ($P<.05$) increase in confidence levels toward integrating technology, with an emphasis on Emerging Technologies for Student Learning, the World Wide Web, and Teacher PD. Findings further support the need for additional research exploring the impact of the Makers' Guild professional development activities on female teachers and teachers serving low income populations. Further research could explore the impact of activities incorporating augmented reality, origami, virtual reality, 3D printing, and robotics on low income students. The researcher plans to repeat this exercise during the Spring of 2017 with a new group of educators. It would be interesting to study the effect of Makerspace professional development activities on students' attitudes towards STEM. The researcher plans to investigate student attitudes during the 2016-2017 academic school year.

Overall the Makers' Guild professional development experience appears to have been a success. Educators' confidence levels regarding technology and attitudes towards technology and STEM, especially for female teachers and teachers serving low income populations did report a statistically significant ($p < .05$) increase. Future research is needed as this study was limited to a treatment group study. A future comparison study could further explore the impact of the Makerspace environment. In addition, future studies are needed to investigate female teacher confidence levels toward technology and attitudes toward STEM and technology in a Makerspace professional development program. Activities incorporated the arts and visualization technologies, with participants creating artifacts using augmented reality, 3D modeling, and origami. Perhaps these activities influenced the increase in teacher confidence levels toward technology and perceptions toward STEM. Future research is needed to explore the art component's impact using the project-based learning process on both students' and educators' perceptions towards math and science in future studies.

Research exploring the relationship between elementary and middle school student STEM interest and STEM careers continues to increase (Christensen & Knezek, 2017). Teacher preparation programs that provide participants with hands-on STEM project-based learning activities and connect teachers to extended Makerspace communities could improve teachers' self-appraisal of competence of technology integration, confidence levels toward integrating technology, and increase attitudes toward STEM. Liddicoat (2008) stresses the importance of empowering teachers to be collaborative through strong STEM teacher professional development programs, as “highly effective teacher workforce competent in STEM is critical to the STEM talent pool” (p. 19). It was observed that the Makers’ Guild professional development program did empower teachers to collaborate within the Makerspace community and begin integrating STEM into core content areas. Additional studies are needed to further investigate findings and impact on academic achievement.

APPENDIX A

MAKER’S GUILD LEARNING OBJECTIVES

Building Makerspace Experiences

- Experience learning in a Makerspace environment.
- Learn about different approaches towards designing Makerspace environments.
- Connect with public library Makerspace programs.

Design Thinking

- Understand the design thinking process.
- Identify future ready initiatives.
- Define and design a school innovation space.
- Create a design challenge.

Learning in 3D

- Explore a variety of 3D learning technologies within a Makerspace environment to include 3D printing, augmented reality iOS application, and virtual reality.
- Develop an understanding as to how to apply curriculum core connections (science, mathematics, social studies, and English language arts) integrating a 3D technology.
- Consider what types of 3D technologies your campus Makerspace might want to pursue.

Project-Based Learning

- Design Makerspace environment using free resources that incorporates a Project-Based Learning workshop model.
- Use a STEAM (science, technology, engineering, art, and math) approach to map discovery learning experiences to core content needs.

- Consider how to transform classrooms and schools for 21st century learners through design.
- Identify futuristic learning approaches and skills sets needed for a future digital citizen.
- Understand how to begin to implement 3D printing software programs, computational thinking activities, green screen, and other STEAM programs.
- Connect with other professionals to share best practices for achieving community buy-in.
- Identify funding opportunities and gain insights about how to connect your organization’s Makerspace to community partners

APPENDIX B

CHALLENGE CARD EXAMPLES

Think Like an Engineer

Design and Engineer Your Own Water Cycle Model

Research how the sun interacts with the water cycle process. (TEKS 5.4A, 5.8 B)

Challenge: Design and make a realistic ecosystem using moss, lichen and small plants to engineer a water cycle model or terrarium. Investigate to see if it can sustain life. How much sun will it need?

Think Like an Artist

Water Cycle Art Challenge

Research: Research how the water processes of precipitation, evaporation, and condensation How do they connect to weather? (TEKS 2.8C).

Challenge: Create a work of art that illustrates the water cycle process and how it connects to weather.

Think Like a Journalist

Hydroelectric Power Investigative Report

Research information about urbanization and water quality. How does urbanization affect the water cycle? How can water be utilized as an alternative water source? (TEKS 5.7 C)

Challenge: Create a public service announcement or blog on the effects of urbanization on water resources and the uses of hydroelectric power.

Think Like a Scientist

Natural Scientist Investigates Water in Earth's Hydrosphere

Research the meaning of hydrosphere and why it is important for the scientist to study the condition of the surface waters. How do scientists measure the condition of surface waters? (TEKS 5.4A)

Challenge: Make a prediction regarding your local hydrosphere today. Measure and record your local water temperature and water clarity. Explain if your prediction was accurate. Did you understand your data?

Mapping a Watershed History

Research maps and/or area photographs of Birdville ISD and the surrounding areas. Identify different physical features, landforms and water features to include defining the boundaries of local watershed. What changes have occurred? How have people adapted over time? (Social Studies TEKS 5.6.A, B)

Challenge: Make a timeline video or display depicting physical features to include watershed changes over time. Show how people have adapted over time.

APPENDIX C

RESEARCH SCHOOL APPLICATION, ACCEPTANCE LETTER, IRB

Effect of Makerspace Professional Development Activities on Middle School Educator Perceptions of Integrating Technologies with STEM (Science, Technology, Engineering, Mathematics)

Research Study [redacted] ISD Application
[redacted] University of North Texas Proposal of Dissertation
For Ph.D. in Learning Technologies and Cognitive Systems

Project Description

Makerspaces deliver an active learning environment, providing opportunities to assist organizations in efforts to improve teacher attitudes and confidence levels towards STEM and instructional technology. The purpose of this study is to explore the effect of professional development on teachers' attitudes and confidence levels towards STEM and technology integration. This study will investigate a professional development provided to teachers within north Texas over the course of a semester. The research design will employ a constructionism approach using instructional methods that utilize 2D and 3D technologies during STEM instructional activities within a creative space.

Background and Rationale

The President's Council of Advisors on Science and Technology (2010) identifies the importance of equipping both teachers and students with strong STEM career skill sets to assist in preparing a future workforce participating in a highly competitive global economy. Marsick (1998) describes challenges facing traditional education systems and provides a sound argument as to how technological shifts along with a globalization has produced a new economic era, the "Knowledge Era" (p. 121). As a response to the Knowledge Era, schools will need to fundamentally shift approaches from a "paradigmatic knowledge environment in which knowledge is characterized as abstract or analytic to a situated cognition environment in which knowledge is understood as a narrative that is specific, personal, and contextualized"(Marsick, 1998, p. 126). Recent research highlights critical areas needed to improve STEM education efforts to include stronger partnerships between school districts, state, federal, and industry that center on improving training and retraining of K-12 teachers to fill current skill sets and knowledge gaps existing in STEM education (Batts & Lesko, 2011).

According to the Congressional Research Service Report to Congress (Kuenzi, 2008), there is still a confirmed concern regarding STEM preparation programs serving students, teachers, and practitioners. Professional development programs fail to include a focus on science knowledge, pedagogical experiences, and produce teachers who often have limited confidence regarding STEM skill sets (Murphy & Mancini-Samuelson, 2012). Few teachers engage in professional development activities to improve scientific teaching after receiving degrees (Cotabish, Dailey, Hughes, & Robinson, 2011). How do we improve middle school student perceptions towards STEM and STEM career pathways? Limited research exists examining STEM knowledge base, STEM skill sets, and experiences necessary for teachers to implement STEM integrated instruction.

Research Questions and Hypothesis

The following research questions will be addressed through the proposed study.

1. Does participation in STEM makerspace professional development activities affect educators' self-appraisal of competence in technology integration abilities?

According to literature review, research is needed investigating a constructionism framework comparing different knowledge levels to learning motivation in regards to learning technologies. Knezek and Christensen (2002) suggest that teachers advance in regards to technology integration as attitudes improve.

H1: After participation in a semester-long series of professional development activities, teacher perceptions toward their ability to integrate technology will increase as measured by the Stages of Adoption of Technology.

2. Does participation in STEM makerspace professional development activities affect educators' confidence in integrating new information technology into pedagogical practice?

Teacher confidence is the primary factor of effective use of technology by students to assist in learning (Knezek & Christensen, 2002). The ability to successfully integrate technology creatively occurs in part due to the teacher's willingness to "play with technologies and an openness to building new experiences for students to have fun in which learning is viewed as play" (Mirshra & Koehler, 2009, p. 18). Makerspaces provide a playground in which teachers explore new learning technologies at their own pace. Playgrounds provide the opportunity for professional development to be fun, increasing attitudes and building confidence towards integrating technology.

> H2: After participation in a semester-long series of professional development activities, teacher confidence levels in their ability to integrate technology will increase as measured by Technology Proficiency Self-Assessment for 21st Century Learning.

3. Does participation in STEM makerspace professional development activities affect educator attitudes towards STEM?

Enhancing the quality of K-12 STEM professional development is strongly linked to the quality of STEM education experiences, which promote an increase in STEM career interest (Nadelson, Seifert, Moll, and Coats, 2012). Makerspaces introduce an exploratory playgrounds in which teachers can acquire access to STEM professional development that is self-directed, providing the opportunity to introduce STEM concepts that may increase STEM perceptions and confidence levels. This dissertation study will provide insight on the relationship of professional development on teacher confidence levels and attitudes towards STEM, with the expectation that confidence levels and attitudes will increase as a result of professional development.

> H3: After participation in a semester-long series of professional development activities, teacher attitudes toward STEM will increase based on results identified through the STEM Semantics Survey instrument.

Methods

The researcher proposes to conduct a quantitative study to investigate and measure the relationship of professional development to teacher's attitudes and confidence levels towards technology integration and attitudes towards STEM. Participants participate in professional development activities over the course of a semester, with the following semester having the expectation that teachers will transfer learning to their classrooms. Teachers will be introduced in a series of 4-6 professional development trainings in science, technology, engineering, the arts, and mathematical activities integrating 2D and 3D technologies delivered in a face to face trainings and at least one online training. Course activities will integrate programing, drafting programs, digital art, digital media, social media, and creation tools with a library makerspace program targeting elementary and middle school core content areas. Activities will be developed with a professional development team consisting of a librarian and STEM consultant working with museums and community public libraries. Activities will explore hands on constructionist approaches to themes geared to reading programs employed by all core content areas.

Instrumentation

A review of literature identified appropriate instruments along with fiscal feasibility of instrumentation appropriate for the proposed correlational study. Four instruments previously used in similar studies were selected to improve internal reliability and validity. The STEM Semantics Survey (Tyler-Wood, Knezek, & Christensen, 2010), was selected as it was successfully used to measure teachers and students attitudes towards STEM in MSOSW (Middle Schoolers Save the World) program, which is part of the National Science Foundation's (NSF) Innovative Technology Experiences for Students and Teachers. Targeted statements exploring 5 scales to include science, math, engineering, technology, and STEM careers are provided to participants along with seven choices. Internal consistency reliability ratings for all scales are in the range of "very good to excellent" according to DeVellis (1991) standards,

ranging from .78 to .94 across 5 constructs for baseline data (Knezek et al., 2011).
An improved version of the TPSA, Technology Proficiency Self-Assessment for 21st Century Learning (TPSA), first developed by Ropp (1999) and recently improved to explore 21st century learning technologies (Christensen, -n.d.) will be employed to measure the effect professional development will have on teachers' attitudes and confidence levels towards technology integration. The researcher has gained permission to employ Christensen's (n.d.) updated version of the TPSA to utilize in this dissertation study. Finally, the Stages of Adoption of Technology (Christensen & Knezek, 1999) instrument developed for Christensen's (1997, 2002) previous research will be employed to investigate the level of teachers' attitudes towards teaching with technology over a period of time. The Stages of Adoption was adapted from Russell's (1995) research exploring how adults utilized new technologies over a period of time and categorizes into six stages: awareness, learning the process, understanding the application of the process, familiarity and confidence, adaptation to other contexts, creative applications to new contexts. The Stages of Adoption is a single item survey, preventing internal consistency reliability measurement. However, it is a very efficient survey instrument and was previously shown to be effective at measuring the effectiveness of professional development. For this reason, the instrument will be employed to measure the effect professional development has on participating teachers' attitudes towards technology integration. Participating districts can utilize this information to better understand general stages of technology adoption with participating campuses.

Data Collection

Participants will be administered a pre and posttest to include the quantitative instruments mentioned above. Participants entering the semester program will be administered a pretest in the Fall of 2015 through email prior to the first professional development meeting. Follow up phone calls will be conducted if participants fail to respond. Surveys will be distributed electronically, reducing cost, improving efficiency, and improving the overall security of data collection. Pretests will be delivered electronically at the first face to face training to participants and posttest administration will be delivered at the conclusion of the last training, which will be a face to face event. All scales will be posted as a single unit to the University of North Texas's Department of Learning Technologies. Access to instruments will be password protected to ensure that only sample participants have access to surveys. Responses will be exported a spreadsheet and analyzed using SPSS software. The last face to face professional development will ask participants to reflect via short answer how their experience with professional development might change their teaching practices as an exit activity. The overall experience will encourage teacher reflection and will provide further knowledge as to how instructional activities affected teacher attitudes towards STEM and confidence level towards integrating instructional technology. A collaborative makerspace event showcasing final teacher reflections would be incorporated during the spring of 2015. At this time short follow up interviews will be conducted along with final makerspace artifact productions, which would be shared with a wider audience.

Human Subject Protection

No foreseeable risks to completing online surveys exist. Participants are adults and are free to withdraw consent and cease participation in the research study at any time, without penalty. Unforeseen circumstances may occur and a participant's participation may be terminated by the investigator. All responses to surveys will be kept on a secure server at the University of North Texas and backed up on an external drive. Only researchers and assistants will have access to data using a secure password. Participants will utilize their school id as a primary key for data and will not be shared. All precautions will be taken to ensure security of responses. A possibility does exist that information from surveys could be used for additional research beyond the initial study. Such a study would only occur upon approval from the University of North Texas Institutional Review Board. The board will examine any request for further research and would require absolute control of security and confidentiality of data. The researcher would like to follow up to conduct additional research investigating student perceptions towards STEM and STEM careers as a result of the makerspace approaches that teachers will integrate into the classroom. The researcher will file another research study application and IRB exploring student and parent perceptions in the event that his study is approved.

[redacted] **INDEPENDENT SCHOOL DISTRICT**

[redacted]

October 19, 2015

To Whom It May Concern:

I am writing to inform you that [redacted] has submitted a request to perform a research project in [redacted] Independent School District entitled, "Effect of Makerspace Professional Development Activities on Middle School Educator Perceptions of Integrating Technologies with STEM." Her request was reviewed by a district committee and approved as described in the attached proposal.

While the district is in support of the plan to implement this research project, any changes to the plan or additional research projects would need to be reviewed prior to start of that work. In addition, one other requirement is that copies of the finished product are provided to the district upon completion of the project.

Please feel free to contact me if you have questions or need additional information.

Sincerely:

[redacted]

Earn a Makerspace For Your School!

Spring 2016 Maker's Guild Design Program

Interested campus teams will learn together during 3 after school professional learning (PL) sessions, 1 online professional learning (PL) session, and a site visit to collaboratively design a makerspace program during the Spring of 2016. Course descriptions are located on the following page.

UNT

Research and Economic Development
THE OFFICE OF RESEARCH INTEGRITY AND COMPLIANCE

November 24, 2015

Supervising Investigator: Dr. Gerald Knezek
Student Investigator: Jennifer Miller
Department of Learning Technologies
University of North Texas

Re: Human Subjects Application No. 15405

Dear Dr. Knezek:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), the UNT Institutional Review Board has reviewed your proposed project titled "Effect of Makerspace Professional Development Activities on Middle School Educator Perceptions of Integrating Technologies with STEM." The risks inherent in this research are minimal, and the potential benefits to the subject outweigh those risks. The submitted protocol is hereby approved for the use of human subjects in this study. **Federal Policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, November 24, 2015 to November 23, 2016.**

Enclosed is the consent document with stamped IRB approval. Please copy and **use this form only** for your study subjects.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. The IRB must also review this project prior to any modifications. **If continuing review is not granted before November 23, 2016, IRB approval of this research expires on that date.**

Please contact Shelia Bourns, Research Compliance Analyst at extension 4643 if you wish to make changes or need additional information.

Sincerely,

Chad R. Trulson, Ph.D.
Professor
Department of Criminal Justice
Chair, Institutional Review Board

CT/sb

UNIVERSITY OF NORTH TEXAS®
1155 Union Circle #310979 Denton, Texas 76203-5017
940.369.4643 940.369.7486 fax www.research.unt.edu

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Effect of Makerspace Professional Development Activities on Middle School Educator Perceptions of Integrating Technologies with STEM

Supervising Investigator: Dr. Gerald Knezek, University of North Texas (UNT) Department of Learning Technologies

Student Investigator: Jennifer Miller, University of North Texas (UNT) Department of Learning Technologies

Purpose of the Study: You are being asked to participate in a research study which involves an investigation of a makerspace professional development semester program. The purpose of this study is to explore the effect of professional development on teachers' attitudes and confidence levels towards STEM and technology integration.

Study Procedures: You are being asked to participate in a pre and posttest that will take about an hour of your time. Participants entering the semester program will be administered a pretest in the fall of 2015 through email prior to the first professional development meeting. Follow up phone calls will be conducted if participants fail to respond. Surveys will be distributed electronically. Pretests will be delivered electronically at the first face to face training to participants and posttest administration will be delivered at the conclusion of the last training. The last face to face professional development will ask participants to reflect via short answer how their experience with professional development might change their teaching practices as an exit activity.

Foreseeable Risks: Your participation in the online survey involves risks to confidentiality similar to a person's everyday use of the Internet.

Benefits to the Subjects or Others: We expect the project to benefit you by introducing you to new teaching strategies to employ within a makerspace environment and to possibly provide insight on your confidence levels and attitudes towards technology and STEM. We hope to learn more about makerspace environments during this study.

Compensation for Participants: Campuses will receive technology to place in a school makerspace as a result of this study. Campus teams will select equipment that could include a 3D printer, 2D printer, green screen, robots, and circuit kits.

APPROVED BY THE UNT IRB
FROM 11/24/15 TO 11/23/16

Office of Research Integrity & Compliance
University of North Texas
Last Updated: July 11, 2011

Procedures for Maintaining Confidentiality of Research Records: The confidentiality of your individual information will be maintained in any publications or presentations regarding this study.

Questions about the Study: If you have any questions about the study, you may contact Jennifer Miller at jennifermiller254@gmail.com, or Dr. Gerald Knezek at gerald.knezek@unt.edu.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-4643 with any questions regarding the rights of research subjects.

Research Participants' Rights: Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- Jennifer Miller has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

APPROVED BY THE UNT IRB
FROM 11/24/15 TO 11/23/16

____
Printed Name of Participant

____________________________ __________
Signature of Participant Date

For the Student Investigator: I certify that I have reviewed the contents of this form with the subject signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

____________________________ __________
Signature of Investigator Date

Office of Research Integrity & Compliance
University of North Texas
Last Updated: July 11, 2011

REFERENCES

Ashbrook, P. (2013). The STEM of inquiry. *Science and Children, 51*(2), 30-31.

Alesandrini, K., & Larson, L. (2002). Teachers bridge to constructivism. *The Clearing House*, *75*(3), 118–121.

Barniskis, S. C. (2014). Makerspaces and Teaching Artists. *Teaching Artist Journal*, *12*(1), 6-14.

Bahr, D. L., Shaha, S. H., Farnsworth, B. J. L., Valerie, K., & Benson, L. F. (2004). Preparing tomorrow's teachers to use technology: Attitudinal impacts of technology-supported field experience on pre-service teacher candidates. *Journal of Instructional Psychology*, *31*(2), 88-98.

Barr, R. (2010). Transfer of learning between 2D and 3D sources during infancy: Informing theory and practice. *Developmental Review*, *30*(2), 128-154.

Batts, D., & Lesko, C. (2011, July). *JETS TEAMS competitions builds future leaders in STEM fields*. Poster session presented at the meeting of the American Society for Quality STEM (Science, Technology, Engineering, and Mathematics) Agenda in Education, the Workplace, and Society Conference, Menomonie, WI. Poster session paper retrieved from http://asq.org/edu/2011/06/best-practices/jets-teams-competition-builds-future-leaders-in-stem-fields.html

Baxter, J., Ruzicka, A., Beghetto, R., & Livelybrooks, D. (2014). Professional development strategically connecting mathematics and science: The impact on teachers' confidence and practice. *School Science and Mathematics*, *114*(3), 103–113.

Bequette, J. W., & Brennan, C. (2008). Advancing media arts education in visual arts classrooms: Addressing policy ambiguities and gaps in art teacher preparation. *Studies in Art Education*, *49*(4), 328-342.

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning Through STEM-Rich Tinkering: Findings From a Jointly Negotiated Research Project Taken Up in Practice. *Science Education*, *99*(1), 98-120.

Bialo, E. R., & Sivin-Kachala, J. (1996). The effectivenss of technology in schools: A summary of recent research. *School Library Media Quarterly*, 25(1) 51-57.

Black, J., & Browning, K. (2011). Creativity in digital art education teaching practices. *Art Education*, *64*(5), 19–34.

Bouvier, S., & Connors, K. (2011). *Increasing student interest in science, technology, engineering, and math (STEM): Massachusetts STEM Pipeline Fund programs using promising practices. Report prepared for the Massachusetts Department of Higher Education.* Retrieved from http://www.mass.edu/stem/documents/ Student%20Interest%20Summary%20Report.pdf.

Bouwma-Gearhart, J. (2012). Research university STEM faculty members' motivation to engage in teaching professional development: Building the choir through an appeal to extrinsic motivation and ego. *Journal of Science Education and Technology*, *21*(5), 558-570.

Brown, T. A. (2015). Teacher's guide to using the Next Generation Science Standards with gifted and advanced learners. *Science and Children*, *52*(8), 74.

Candy, L. (2007). Constraints and Creativity in the Digital Arts. *Leonardo, 40*(4), 366-367.

Christensen, R. (1997). *Effect of technology integration education on the attitudes of teachers and their students*. Unpublished doctoral dissertation, University of North Texas, Denton, TX. Retrieved March 17, 2016, from http://digital.library.unt.edu/explore/collections/UNTETD/.

Christensen, R. (2002). Effects of technology integration education on the attitudes of teachers and students. *Journal of Research on technology in Education*, *34*(4), 411-433.

Christensen, R., Parker, D., & Knezek, G. (2005). Advances in preservice educator competence and confidence in technology integration: Comparative findings from two Pt3 projects. *Integrated technologies, innovative learning: Insights from the PT3 program. Eugene, OR: ISTE*.

Christensen, R., & Knezek, G. (1999). Stages of adoption for technology in education. *Computers in New Zealand Schools*, *11*(3), 25-29.

Christensen, R., & Knezek, G. (2015, July). The technology proficiency self-assessment 1uestionnaire (TPSA-C21): evolution of a self-efficacy measure for technology integration. In T. Brinda, N. Reynolds, R. Romeike, & A. Schwill (Eds.), *Proceedings of the KEYCIT 2014: Key competencies in informatics and ICT Conference* (p. 311). Potsdam, Germany: University of Potsdam.

Christensen, R. & Knezek, G. (2015). Active learning approaches to integrating technology into middle school science classrooms: Reconceptualizing a middle school science curriculum based on 21st century skills. In X.Ge, D. Ifenthaler, & J.M. Spector (Eds.). Full Steam Ahead: Emerging Technologies for STEAM. New York: Springer Academic.

Christensen, R. & Knezek, G. (2017). Validating the technology proficiency self Aasessment for 21st century learning (TPSA C21) instrument. *Journal of Digital Learning in Teacher Education.* DOI:10.1080/21532974.2016.1242391

Christensen, R., & Knezek, G. (2014). The technology proficiency self-assessment questionnaire (TPSA): Evolution of a self-efficacy measure for technology integration. In T. Brinda, N. Reynolds & R. Romeike (Eds.) *Proceedings of KEYCIT 2014 – Key Competencies in Informatics and ICT*, 2014, pp. 190-196.

Cohen, J. (1988*). Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cotabish, A., Dailey, D., Hughes, G. D., & Robinson, A. (2011). The effects of a STEM professional development intervention on elementary teachers' science process skills. *Research in the Schools*, *18*(2), 16–25.

Das, A. K. (2014). Fundamentals of virtual learning environments (VLE) and its components. *Indian Journal of Library and Information Science*, *8*(1), 41.

Daugherty, J. L., & Custer, R. L. (2012). Secondary level engineering professional development: Content, pedagogy, and challenges. *International Journal of Technology and Design Education*, *22*(1), 51–64.

DeVellis, R. F. (1991). Guidelines in scale development. *Scale development: Theory and applications* (p. 5191). Newbury Park, CA: Sage.

English, L. D. (2016). STEM education K-12: perspectives on integration.*International Journal of STEM Education*, *3*(1), 1.

Feldman, A., & Pirog, K. (2011). Authentic science research in elementary school after-school science clubs. *Journal of Science Education and Technology*, *20*(5), 494–507.

Flowers, L. O., Raynor, J. E., & White, E. N. (2012). Evaluation in online STEM courses. *International Journal of Business and Social Scienc*e, *3*(18), 16-20.

Fourie, I. and Meyer, A. (2015) 'What to make of makerspaces', *Library Hi Tech*, 33(4), pp. 519–525.

Gilakjani, A. P., Lai-Mei, L., & Ismail, H. N. (2013). Teachers' use of technology and constructivism. *International Journal of Modern Education and Computer Science*, *5*(4), 49.

Hattie, J. A. C. (2009). *Visible learning: A synthesis of 800+ meta-analyses on achievement.* Abingdon: Routledge.

Hira, A., Joslyn, C. H., & Hynes, M. M. (2014). Classroom Makerspaces: Identifying the opportunities and challenges. *In Proceedings of the 2014 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). New York, NY: Institute of Electrical and Electronics Engineers (IEEE).

Henson, R. K., Bennett, D. T., Sienty, S. F., & Chambers, S. M. (2000). *The relationship between means-end task analysis and context-specific and global self-efficacy in emergency certification teachers: exploring a new model of teacher efficacy.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Hooper, S., & Rieber, L. P. (1995). Teaching with technology. In A. C. Ornstein (Ed.), *Teaching: Theory into practice* (pp. 154-170). Needham Heights, MA: Allyn and Bacon.

Horowitz, S. S., & Schultz, P. H. (2014). Printing space: Using 3D printing of digital terrain models in geosciences education and research. *Journal of Geoscience Education*, *62*(1), 138–145.

Hoy, W.K., & Woolfolk, A.E. (1990) Socialization of student teachers. *American Educational Research Journal,* 27, 279-300.

Huziak-Clark, T., Sondergeld, T., van Staaden, M., Knaggs, C. and Bullerjahn, A. (2015). Assessing the impact of a research-based STEM program on STEM majors' attitudes and beliefs. *School Science and Mathematics*, *115*(5), 226–236.

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*(2), 284-301.

Kafai, Y. B., & Resnick, M. (Eds.). (1996). *Constructionism in practice: Designing, thinking, and learning in a digital world*. London, UK: Routledge, 1-2.

Karagiorgi, Y., & Symeou, L. (2005). Translating constructivism into instructional design: Potential and limitations. *Journal of Educational Technology & Society*, *8*(1), 17-27.

Keengwe, J., Georgina, D., & Wachira, P. (2010). Faculty training strategies to enhance pedagogy-technology integration. *International Journal of Information and Communication Technology Education (IJICTE)*, *6*(3), 1-10.

Knezek, G., & Christensen, R. (1998). Internal consistency reliability for the Teachers Attitudes Toward Information Technology (TAT) questionnaire. In S. McNeil, J. D. Price, S. Boger-Mehall, B. Robin, & J. Willis, (Eds.), *Proceedings of the Society of Information Technology & Teacher Education (SITE)'s 9th international conference* (Vol. 2, pp. 831-832). Charlottesville, VA: Association for the Advancement of Computing in Education.

Knezek, G., Christensen, R., & Tyler-Wood, T. (2011). Contrasting perceptions of STEM content and careers. *Contemporary Issues in Technology and Teacher Education*, *11*(1), 92–117.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)?. *Journal of Education*, *193*(3).

Koh, K., & Abbas, J. (2015). Competencies for information professionals in learning labs and Makerspaces. *Journal of Education for Library and Information Science*, *56*(2), 114.

Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action. Washington, DC: Congressional Research Service, Library of Congress.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The philosophy of educational Makerspaces: Part 1 of making an educational Makerspace. *Teacher Librarian*, *41*(5), 8.

Li, Z. Z., Cheng, Y. B., & Liu, C. C. (2013). A constructionism framework for designing game-like learning systems: Its effect on different learners. *British Journal of Educational Technology*, *44*(2), 208-224.

Liddicoat, S. (2008). NASA enriched collaborative STEM K-12 teacher professional development institutes within the California State University system. In *2008 IEEE Frontiers in Education Conference (FIE)* (pp. 14–19). New York, NY: Institute of Electrical and Electronics Engineers (IEEE).

Lubinski, D., & Benbow, C. P. (2006). Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise (Special section: Doing psychological science), *Perspectives in Psychological Science*, *1*(4), 316–345.

Maddux, C. D. (2006). PT3 and the Deans' Grants: Some Important Differences. *Computers in the Schools*, *23*(3-4), 151-155.

Marsick, V. J. (1998). Transformative learning from experience in the knowledge era. *Daedalus*, *127*(4), 119–136.

Matherson, L. H., Wilson, E. K., & Wright, V. H. (2014). Need TPACK? Embrace sustained professional development. *Delta Kappa Gamma Bulletin*, *81*(1), 45-52.

Mishra, P., & Koehler, M. (2006). Technological Pedagogical Content Knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017-1054.

Moakler, M. W., & Kim, M. M. (2014). College major choice in STEM: Revisiting confidence and demographic factors. *The Career Development Quarterly*, *62*(2), 128-142.

Moore, W., & Esselman, M. (1992). *Teacher efficacy, power, school climate and achievement. A desegregating district's experience.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Morales, C., Knezek, G., & Christensen, R. (2008). Self-efficacy ratings of technology proficiency among teachers in Mexico and Texas. *Computers in the Schools*, *25*(1-2), 126–144.

Murphy, C., Neil, P., & Beggs, J. (2007). Primary science teacher confidence revisited: Ten years on. *Educational Research*, *49*(4), 415-430.

Murphy, T. P., & Mancini-Samuelson, G. (2012). Graduating STEM competent and confident teachers: The creation of a STEM certificate for elementary education majors. *Journal of College Science Teaching*, *42*(2), 18–24.

Nadelson, L. S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers. *The Journal of Educational Research*, *106*(2), 157-168.

Nadelson, L. S., Seifert, A., Moll, A. J., & Coats, B. (2012). iSTEM summer institute: An integrated approach to teacher professional development in STEM. *Journal of STEM Education*, *13*(2), 69–84.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the compute*r. New York: Basic Books.

Papert, S., & Harel, I. (1991). Situating Constructionism (Preface), in I. Harel & S. Papert (Eds.), *Constructionism: Research reports and essays, 1985-1990* (pp. 1-11). Norwood, NJ: Ablex.

Park, J., Kim, D.-E., & Sohn, M. (2011). 3D simulation technology as an effective instructional tool for enhancing spatial visualization skills in apparel design. I*nternational Journal of Technology and Design Education*, *21*(4), 505–517.

Polly, D., Mims, C., Shepherd, C. E., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and Teacher Education*, *26*(4), 863-870.

Prain, V., & Waldrip, B. (2006). An exploratory study of teachers' and students' use of multi-modal representations of concepts in primary science. *International Journal of Science Education*, *28*(15), 1843–1866.

President's Council of Advisors on Science and Technology. (2010, September). Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for

America's future (pp. A-6, A-7). [Executive Report]. Retrieved from https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Pryor, B. W., Pryor, C. R., & Kang, R. (2016). Teachers' thoughts on integrating STEM into social studies instruction: Beliefs, attitudes, and behavioral decisions. *The Journal of Social Studies Research*, *40*(2), 123-136.

Purpur, E., Radniecki, T., Colegrove, P. T., & Klenke, C. (2016). Refocusing mobile Makerspace outreach efforts internally as professional development. *Library Hi Tech*, *34*(1), 130-142.

Ropp, M. M. (1999). Exploring individual characteristics associated with learning to use computers in preservice teacher preparation. *Journal of Research on Computing in Education*, *31*(4), 402–424.

Russell, A. L. (1995). Stages in learning new technology: Naive adult email users. *Computers & Education*, *25*(4), 173-178.

Salvo, M. J. (1998). Constructionism in Practice: Designing, Thinking, and Learning in a Digital World. *Technical Communication Quarterly*, 7(4), 467.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three Makerspaces. *Harvard Educational Review*, *84*(4), 505-531.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Skaza, H., Crippen, K. J., & Carroll, K. R. (2013). Teachers' barriers to introducing system dynamics in K-12 STEM curriculum. *System Dynamics Review*, *29*(3), 157-169.

Smay, D., & Walker, C. (2015). Makerspaces: A creative approach to education. *Teacher Librarian*, *42*(4), 39.

Smith, S. (2014). Through the teacher's eyes : Unpacking the TPACK of digital fabrication integration in middle school language arts. *Journal of Research on Technology Education*, *46*(2), 207–227.

Stager, G. S. (2013). Papert's prison fab lab: Implications for the maker movement and education design. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 487-490). New York, NY: ACM.

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), 28‑34.

Sun, P. C., Finger, G., & Liu, Z. L. (2014). Mapping the evolution of eLearning from 1977–2005 to inform understandings of eLearning historical trends. *Education Sciences*, *4*(1), 155‑171.

Tangdhanakanond, K., Pitiyanuwat, S., & Archwamety, T. (2006). A development of portfolio for learning assessment of students taught by full-scale constructionism approach at Darunsikklialai School. *Research in the Schools*, *13*(2), 24-36.

Teo, T. W., & Ke, K. J. (2014). Challenges in STEM Teaching: Implication for Preservice and Inservice Teacher Education Program. *Theory Into Practice*,*53*(1), 18-24.

Texas Education Agency (2015). School Report Card. Retrieved July 2016, from https://rptsvr1.tea.texas.gov/perfreport/src/2015/campus.srch.html.

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education*, *18*(2), 345‑368.

Varney, M. W., Janoudi, A., Aslam, D. M., & Graham, D. (2012). Building young engineers: TASEM for third graders in Woodcreek Magnet Elementary School. *IEEE transactions on education*, *55*(1), 78.

Voogt, J., Knezek, G., Cox, M., Knezek, D., & ten Brummelhuis, A. (2013). Under which conditions does ICT have a positive effect on teaching and learning? A call to action. *Journal of Computer Assisted Learning*, *29*(1), 4–14.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J‑PEER)*, *1*(2), 2.