THE EFFECT OF 3D PRINTING AND DESIGN ON STUDENT'S MOTIVATION, INTERESTS, MATHEMATICAL AND REAL-LIFE SKILLS: AN INFORMAL STEM EDUCATION

A Thesis

by

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ABSTRACT

My goal of this thesis was to develop two publication-ready research articles rather than a traditional thesis. Technology is changing the way students learn in amazing ways. Researchers found that student-centered, technology-integrated learning environments help to produce students who are better able to think critically, solve problems, collaborate with others, and engage deeply in the learning process. In addition, the emergence of technology-rich classrooms helps diverse learners understand conceptual ideas and apply those ideas and skills to real-life. When teachers know how to effectively use the unique features of technologies, they can address the varying cognitive strengths and needs of different students. Because understanding the impact of technology and finding the best ways to integrate technology into the classroom is critical, an investigation was conducted to determine whether the use of 3D printers and design software in a summer camp setting had a positive effect on student's motivation, interests, mathematical and real-life skills. There were statistically significant increase in students' motivation, interests, real-life skills, and some of the mathematical skills. In addition, positive effect sizes indicated practical importance of the study. Despite the complexities of the program and high cognitive load for students, 3D printing and design class allowed students gain motivation, interests, real-life skills, and some mathematical skills.

Although there has been growing interest in Science, Technology, Engineering and Mathematics (STEM) for students in the United States, previous research shows that there is a growing concern that the United States will not have sufficient numbers of skilled workers in STEM field. To determine if informal STEM educational setting can improve students' interest for learning STEM, the second article employed a quasi-experiment design to explore the effectiveness of a summer camp program on student's affect towards STEM. Although there were no statistically significant increases in any of the disciplines, students had more positive attitude toward science, engineering, and mathematics after the summer camp. If the intervention was longer where students had lower cognitive load, more practical importance is expected.

DEDICATION

To God,

The Almighty,

for His showers of blessings throughout my research work

to complete the research successfully.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

1.1 Statement of the Problem

Our world is constantly changing and it is important to embrace it and grow with the change. Technology is changing the way we interact and learn in amazing ways. Because technology is prevalent in our society, students will be using technology throughout their careers. Sanders (2009) found that there was "the rapidly emerging awareness in America that technology is not just a ubiquitous component of contemporary culture, but also one of the critical keys to global competitiveness" (p.25). Many careers require technical skills, and science, technology, engineering, and mathematics (STEM) jobs are expected to grow by 21.4% during the next five years (Torlakson, 2014). Research has shown that STEM education improved students' interests and learning in STEM (Becker & Park, 2011; National Science Board, 2010; Sanders, 2009). Thus, STEM education must be highlighted for students to stay competitive in the global economy of the 21st century.

As technology advances and is increasingly incorporated into classrooms, understanding the implications of using technology to achieve educational goals is important. The decrease in the cost of technology allows many schools to implement technology into the curriculum and makes it more accessible for a larger number of students (Hollenbeck & Fey, 2009). Therefore, understanding the impact of technology and finding the best ways to integrate technology into the classroom is critical.

Despite the importance and interest in STEM, the number of students enrolling in STEM majors is decreasing. This will result in a shortage of engineers and scientists in the United States workforce in future (National Science Board, 2010; Ross & Bayles, 2007; Torlakson, 2014). Business leaders do not have enough skilled workers to fill the increasing number of STEM careers. Even students who will work outside STEM fields will have to deal with complex issues, requiring strong science competence (Torlakson, 2014).

Moreover, many students lack STEM knowledge and the capabilities in STEM they will need to pursue careers or understand STEM-related issues in the workforce or in their roles as citizens (Olson & Labov, 2014). The efforts to improve STEM education have focused mostly on the formal education system resulting in increased learning standards and objectives for STEM subjects. Additionally, teachers have participated in various STEM professional developments (Torlakson, 2014). The U.S. Department of Education (2007) stated that one of the STEM education goals for K-12 education was to prepare student with STEM knowledge to succeed in the 21st century technological economy and to avoid the declining STEM pool of human resources. In addition, all students should have the opportunity to experience STEM learning that prepares them for STEM careers and post-secondary success. However, due to the limitations of formal learning settings, most STEM learning occurs out of school such as afterschool and summer programs during interactions with peers, parents, mentors, and role models (Olson & Labov, 2014).

1.2 Purpose of the Study

The primary purpose of the research that I conducted during my thesis study was to determine the effectiveness of technology-integrated classrooms in a summer camp, and how this summer camp intervention can enhance students' STEM knowledge and interest towards STEM education. Despite increasing interests towards STEM education, there has been little research conducted to determine the effects of the informal STEM education on student affect. This lack of research makes not only educators and parents, but also students themselves unaware of the benefits of informal STEM education. An examination of the effects of informal STEM education can guide educators in helping students gain STEM interests and resolve some of the current challenges in STEM formal education.

The purpose of the first article was to use quantitative research methods to determine the change in student affect through an informal STEM education setting. A quasi-experiment approach was employed to address the research questions of this study and to facilitate a greater understanding of the effects of informal STEM education. The findings may help to increase public awareness about the importance of informal

STEM education and allow STEM experiences and programs accessible to all students through informal STEM education.

The second article used a quantitative approach to determine the effectiveness of 3D printing and design on students' interests, motivation, mathematic skills, and real-life skills. A summer camp offered a 3D printing and design class and was used as an intervention. Determining whether or not the 3D printing and design positively affected student performance will help educators to appreciate the importance of technology-integrated lessons. If there were no strong effects, educators will be able to understand what they should keep in mind when they employ technology integration in classrooms.

1.3 Research Questions

The purpose of the research is to evaluate whether the use of 3D printing and design classes as implemented by a 2-week summer camp, had a positive influence on student's motivation, interests, mathematical and real-life skills in an informal STEM setting.

Specific questions that will be addressed through this research study will include:

1. Do informal STEM education settings change student affect towards STEM?
2. Did students who have used 3D printing and design software make meaningful gains in mathematics achievement?

3. Is 3D printing and designing effective in motivating students to learn?

1.4 Literature Review

1.4.1 Informal STEM Education

Science, technology, engineering, and mathematics (STEM) is everywhere in our life. Interest in STEM in the United States (U.S.) has increased (Denson, Stallworth, Hailey, & Householder, 2015). STEM education is becoming more popular for students and educators due to the low mathematics and science performance of U. S. students compared to international students in the past (Burke & Mattis, 2007). Although U.S. students' ability in mathematics and science has grown, the National Assessment of Education Progress (NAEP, 1990-2011) has shown that it is not enough. The world has changed that it requires citizens to have a higher level of STEM literacy to make decisions about complex issues (Krishnamurthi et al., 2014). In addition, most jobs require STEM skills. To thrive in a globally competitive world, access to adequate STEM educational experiences will be needed.

In the past efforts to help U.S students get engaged in STEM education took place in formal learning environments like schools; these were also the primary focus of the literature. However, formal education is not sufficient to get students exposed to STEM education (Burke & Mattis, 2007; Denson et al., 2015; Krishnamurthi et al., 2014). Thus, informal STEM learning environments, where students can be excited and motivated to learn, are necessary.

More than 80% of students' time during the academic year is spent outside of a classroom (Denson et al., 2015); thus, it is important to provide informal education for students to gain STEM knowledge. Informal learning settings are defined as "out of school time offerings such as after school programs, community resources such as science centers, libraries, and media" (Denson et al., 2015, p.1). Moreover, researchers have shown that social and economic factors play an important role in influencing academic success, and students need supports beyond the school walls (Krishnamurthi et al., 2014; National Research Council, 2011). Thus, an informal learning experience can provide strong STEM learning experiences.

In response to the high demand for STEM education, afterschool programs have started to include STEM with hands-on, inquiry-driven activities in their STEM programs. Through those before and after school informal learning programs, students are not only able to increase their academic performance but also social and emotional needs through informal STEM educational activities (Dorssen, Carlson, & Goodyear, 2006; Krishnamurthi et al., 2014). These informal STEM learning experiences are making an impact on participating students to get not only excited and engaged in these fields but also to develop STEM knowledge and skills.

Current research findings indicate that before school, after school and summer STEM programs have been successful in motivating and increasing students' interest in STEM fields. Each year, more and more students participate in informal STEM learning activities that offer innovative learning opportunities. Researchers (Krishnamurthi et al., 2014) have found that there were positive changes through informal learning environments in a variety of outcomes- “interest and engagement in science, greater knowledge of STEM careers, election of school science classes, and, sometimes, improved test scores in science and math” (p.4). Moreover, STEM education in general encompasses the processes of critical thinking, analysis, and collaboration. Students are able to integrate these process and concepts in real-world contexts of STEM that allows them to foster STEM skills (Bieber, 2005; Bell et al., 2009; Denson et al., 2015; Dorssen et al., 2006). Thus, informal STEM learning environments can lead to greater knowledge and interest in STEM fields and careers through authentic learning experiences.

Multiple STEM learning environments provide even more options for student learning and interest in STEM. Informal STEM education can create meaningful connections between curriculum taught in school and practical applications outside of school (Bell et al., 2009; Bieber, 2005; Denson et al., 2015; Dorssen et al., 2006; Torlakson, 2014). Therefore, formal and informal STEM education environments will provide students opportunities to develop STEM skills and knowledge both inside and outside of the classroom, and increase their readiness for university, careers, and life.

1.4.2 Technology in Education

Because technology is prevalent in our society, students will be using technology in their careers. The digital age workforce requires some degree of technical competency, and students can acquire these skills by using technology in education. Various technologies such as learning platforms, interactive videos, complex gaming, innovative technologies, and electronic presentation tools are incorporated into classrooms (Dror, 2008; Lacey, 2010). With emerging technologies, especially 3D printers, students are able to get more engaged in science and mathematics (Craig, 2000; Lacey, 2010; Segerman, 2012). Thus, the use of 3D printers is a great example of how educators can bring up-to-date hands-on learning to classrooms that ensure high-quality education for tomorrow's professionals.

Students enjoy learning using technology. Introducing students to mathematics through technology can get students excited because they are able to understand the subject, and it is an engaging way for them to get involved and to be active in the learning activities (Craig, 2000; Dix, 1999; Segerman, 2012). Because students have become engaged in technology-rich lessons, students used their cognitive ability to observe and reflect on the relationships among the representations provided by the dynamic software (Kilic, 2013). Students with technology were able to explore mathematical ideas, which allowed them to touch, verbalize, and build representations (Kilic, 2013; Knuth & Hartmann, 2005). In addition, student-centered lessons and technology-integrated lessons helped students to think critically, solve problems, and engage in the learning process (Lacey, 2010). Thus, technology-incorporated lessons can have a positive effect on overall student performance.

By providing a student with a visual image alongside a concept or skill, the likelihood of the student's ability to understand and remember increases. The nature of geometry requires visualization and critical thinking which may be limited in paper-pencil classrooms (Bakar et al., 2002; Hollenbeck, & Fey, 2009). New and powerful technology tools are available to support changing roles for schools (Bakar et al., 2002; Craig, 2000; Dede, 1996). In mathematics classrooms, technology tools such as *Graphing calculators, Geometer's Sketchpad, e-transformation*, and *Geogebra* have been widely used at the secondary level (Bakar et al., 2002; Hollenbeck & Fey, 2009). Despite various technologies being implemented in secondary schools, there is limited evidence of positive effects on student achievement. It is important to establish which technologies and under what conditions technology positively affects the teaching and learning of geometry.

As the visual image is a pedagogical tool for helping students understand, technology is another learning tool for enhancing recall and discovery, which can greatly affect a student's performance. A calculator or computer can be used as an initial step to check a conjecture before solving the problem by hand (Dror, 2008; Goldenberg, 2000; Healy & Hoyles, 2009). For example, when dividing 30 by 7, the answer on a calculator reads 4.28571428571429. This number is rounded, but a pattern is evident in this number. If the goal of this lesson was to find the pattern, then the student can do the problem by hand to understand the reasoning behind the pattern. Having the calculator's result in the beginning can help reduce error in the calculation, making the calculations less tedious and stressful for the student, and drawing their focus to the more important mathematics (Dror, 2008; Healy & Hoyles, 2009). However, if using technology is not carefully planned in relation to curriculum target goals or if teachers do not connect the use of technology with learning goals, then its use is not warranted (Dede, 1996; Dror, 2008). Therefore, if many students do not gain any of the potential learning benefits, much of the effort expended in introducing computers into mathematics classrooms will have been wasted.

The emergence of technology-rich mathematics classrooms helps diverse student populations to learn mathematical ideas. In addition, it helps students to reason mathematically, and apply their mathematical thinking to real-life (Ching, Basham, & Planfetti, 2005; Dede, 1996). "When teachers know how to effectively use the unique features of computer applications, they can address the varying cognitive strengths and needs of different students" (Suh, 2010, p. 440). Scaffolding a progression of meaningful experiences of cognitive technology tools not only encouraged students to make conjectures through interactive activities by trying what-if scenarios, but also promoted mathematical talk and critical thinking.

When technology is correctly used, it can enhance teaching and learning. Ching et al. (2005) found that "student-centered, technology-integrated learning environments help to produce students who are better able to think critically, solve problems, collaborate with others, and engage deeply in the learning process" (p. 226). In addition, the appropriate use of technology can enhance teaching and conceptual development, and enrich visualization (Kilic, 2013; Knuth & Hartmann, 2005). Therefore, it is important that technology-integrated lessons math the curriculum target.

As technology can be beneficial for students, it can also be helpful for educators. Technology changed the way educators assess learning and the design of their curriculum's content (Herrington & Kervin, 2007; Jones, 2000; Jones 2001). Using the National Library of Virtual Manipulatives could be a useful tool to teach the area of a triangle (Hollenbeck & Fey, 2009). Web applets are very handy when demonstrating lessons involving rotation, growth, or movement (Hollenbeck & Fey, 2009; Jones, 2001; Kilic, 2013). The combination of visuals and numerical calculation with analytic reasoning on the mathematical subject allowed students to develop a solid understanding (Hollenbeck & Fey, 2009; Karner & Bell, 2013; Sinclair, 2009). Students could improve their mathematical abilities through using technology, including having visual and spatial representations, and instant feedback for students.

Technology can also be used in classrooms to provide meaningful information for teachers. Student Response Systems (SRS) can be handed out to students for them to post answers anonymously to the teacher. This allows for teachers to see what areas of the content students are struggling with, thus improving test scores by clearing up any confusion (Jones, 2000; 2001; Karner & Bell, 2013). It provides instant feedback and allows students to share their thoughts with classmates, to build confidence and understanding (Herrington & Kervin, 2007; Hollenbeck & Fey, 2009; Sinclair, 2009). Therefore, teachers can adjust their teaching accordingly.

In conclusion, technology can increase student achievement levels and improve teachers' competency and utilization of technology when properly utilized. Technology not only enhanced students' communication and collaboration, but also improved quality of instructional activities (Herrington & Kervin, 2007; Karner & Bell, 2013; Sinclair, 2009; Suh, 2010). In the current study, the researcher will examine through a meta-analysis whether informal STEM activities improved students' organizational skills; enhanced students' motivation; and promoted students' learning

1.5 Method

Quantitative research method was used during this proposed research sequence. A quasi-experimental approach was utilized for both the first and the second article.

For the first article, the effectiveness of informal STEM education on students affect toward STEM fields was analyzed. The second article analyzed the effectiveness of 3D printing and design software on students' interests, motivation, mathematic skills, and real-life skills. Key statistical outcomes included descriptive statistics and derivation of effect sizes through paired sample *t*-tests for both articles.

1.6 Journal Selection

To identify proper journals to be targeted for publication multiple factors were considered. A review of articles cited for this proposal will identify journals previously reporting studies of similar research interests. Journals addressing the informal STEM education effects will also be identified. A description of the readership and desired content for each journal will be considered. Information regarding acceptance rate and recommended manuscript length were found in *Cabell's Directories*. In addition, Texas A&M University professor, Dr. Robert Capraro, has recommended adequate journals that fit proposed articles. Proposed articles were matched with identified journals to increase the likelihood of each article being accepted for publication (See Table 1).

Table 1. Proposed Articles and Journals

Proposed Articles	Proposed Journal #1	Proposed Journal #2
Informal STEM Education Impact on Student Affect towards STEM fields	*Journal of STEM Education* • Acceptance rate: 20% • Editor in chief: P.K. Raju • Publisher: Public Knowledge Project • Type of review: Blind Peer Review • Manuscript length: 16-20 pages	*School Science and Mathematics* • Acceptance rate: 20% • Editor in chief: Carla Johnson • Publisher: Wiley • Type of review: Blind Review • Manuscript length: 25 pages Max
Effectiveness of 3D Printing and Design Software on Students' Performance	*Journal of STEM Education* • Acceptance rate: 20% • Editor in chief: P.K. Raju • Publisher: Public Knowledge Project • Type of review: Blind Peer Review • Manuscript length: 16-20 pages	*Journal of Educational Technology & Society* • Acceptance rate: 20% • Editors in chief: Kinshuk, Demetrios, G. Sampson, Nian- Shing Chen • Publisher: International Forum of Educational Technology & Society • Type of review: Bind Peer Review • Manuscript length: 7000 words Max

CHAPTER II

SUMMER CAMP IMPACT ON STUDENT'S AFFECT TOWARD STEM

2.1 Background

Although there is a growing interest in Science, Technology, Engineering and Mathematics (STEM) in the U. S., there is a growing concern that the U.S. will not have sufficient numbers of skilled STEM workers. There are a growing number of jobs requiring STEM proficiency, and research has shown that students in the U.S. are not prepared for these jobs and responsibilities as capable citizens (Dorsen et al., 2006). In addition, students in the U.S. underperformed on assessments measuring their mathematical abilities, particularly with higher cognitive demands, which required the application of mathematical concepts to real-life (Denson et al., 2015; Dorsen et al., 2006; Krishnamurthi et al., 2014; NAEP, 1990-2011). Integrating hands-on experience and project-based learning should be encouraged in classrooms (Capraro, Capraro, & Morgan, 2013). However, formal educational settings are not enough to engage all students in STEM learning experiences.

STEM education in the classroom is not practical when students have high cognitive demands. Due to the lack of science and mathematics performance in United States, there has been an increase in the number of objectives that are needed to be learned thus creating a high cognitive load for students (U.S. Department of Education, 2007). There is not enough time inside classrooms to incorporate STEM hands-on activities. In addition, students do not have sufficient access to quality STEM learning opportunities and not enough students see these disciplines as the starting gate for their careers (U.S. Department of Education, 2015). Thus, providing information about the importance of informal STEM education and providing learning opportunities is one solution.

Informal STEM education offers a variety of STEM activities based on students' personal interests. Research has shown that students gain interest in STEM through informal learning environments such as museums, community-based organizations, summer camps, and libraries (Denson et al., 2015; Krishnamurthi et al., 2014). These informal STEM educational settings play an important role by providing students with experiences that are different from school such as competitions and connections with communities (Burke & Mattis, 2007; Hailey & Householder, 2015). Informal learning institutions not only provide authentic learning experiences for students, but also provide parents and family opportunities to participate in STEM experiences (Denson et al., 2015; Krishnamurthi et al., 2014). Therefore, informal STEM educational setting can provide students opportunities to experience STEM concepts in a way that may be limited in a traditional learning setting.

2.2 Literature Review

As interests toward science, technology, engineering, and mathematics grows in the U.S., many careers require STEM skills. However, many students do have not enough interest in STEM fields to have a sufficient number of skilled STEM workers in the U.S. (Burke & Mattis, 2007; Denson et al., 2015). Thus, the effort to increase students' interests and attitude toward STEM is needed.

Researchers have claimed that integrating STEM concepts in education is beneficial to the national economy (Burke & Mattis, 2007; Tseng et al., 2013). The effort to motivate students to become engaged in STEM education has mostly taken place in a formal learning setting like schools. However, formal education setting may be limited in providing personal interests for students in gaining positive attitude towards STEM disciplines (Burke & Mattis, 2007; Denson et al., 2015; Krishnamurthi et al., 2014; Schnittka et al., 2012). Thus, it is necessary for students to engage in activities in informal STEM learning environments to encourage them to be excited and motivated to learn.

Informal learning settings can be after school programs, museums, summer camps, science centers, libraries, media, etc. (Denson et al., 2015). Research has shown that these informal learning settings allow the application of STEM concepts to real lives where students can find STEM disciplines useful and gain interest towards STEM fields (Krishnamurthi et al., 2014; Tseng et al., 2013). In addition, Mohr-Schroeder

(2014) argued that personal interest and motivation were key components in inspiring students to continue their education in STEM. Therefore, informal learning experience should provide authentic STEM learning experiences.

Afterschool programs and summer camps have begun to include STEM activities with hands-on, project-based learning, and inquiry-driven activities in their STEM programs. Project-based learning focuses on "organizing self-learning in an empirical project" (Tseng et al., 2013, p. 88). Through project-based learning activities, students were not only able to increase their academic performance but also gain interest and increase positive learning attitudes towards STEM subjects (Dorssen, Carlson, & Goodyear, 2006; Krishnamurthi et al., 2014; Schnittka et al., 2012; Tseng et al., 2013). These informal STEM learning experiences with project-based learning activities have an impact on students' attitude toward STEM.

Moreover, research has shown that informal STEM education, especially summer camp programs, provided authentic STEM learning experiences for students to gain interest in STEM fields (Mohr-Schroeder et al., 2014; Tseng et al., 2013; Yilmaz et al., 2010). Summer Camp programs not only allow students to gain interest towards STEM careers, but also acquire STEM skills through hands-on activities and engagement in learning experiences (Tseng et al., 2013; Yilmaz et al., 2010). In addition, students are able to make decisions to attend the camp or classes based on their interests and motivation, which inspires students to continue their education in

STEM fields (Mohr-Schroeder et al., 2014). Thus, summer camps can positively affect students' attitudes toward continuing their education in STEM fields.

Summer camps not only allow students to gain interests toward STEM topics, it also allows them to develop deeper into STEM concepts that they may not have experienced in their formal learning settings (Mohr-Schroeder et al., 2014; Tseng et al., 2013). Through the hands-on activities and project-based learning activities at the summer camp, students were able to be engaged in the authentic STEM learning process (Yilmaz et al., 2010). In addition, students are able to communicate with peers about the activities which may or may not be limited in formal learning environments. The advantages of the informal learning settings which may be limited in the formal learning settings can allow students to be more interested and engaged in STEM fields that may lead them to choose a STEM career.

However, because afterschool programs and summer camps are voluntary, there is little chance for students who are not interested in STEM fields to participate in informal STEM activities (Torlakson, 2014). Despite this fact, participation may change a student's attitude toward STEM, and if this is the case, many students will be able to increase their attitudes and interest towards STEM. Ultimately, they will be able to choose a STEM career. Thus, increasing the access to informal STEM education is crucial, which can change student affect towards STEM fields.

This quantitative research investigated whether the STEM summer camp positively affected students' attitude towards STEM fields. In addition, it examined if the participation of the two-week residential STEM camp affected students' commitment in STEM.

2.3 Method

2.3.1 Participants

This research was conducted with 130 secondary school students at a 2-week residential summer STEM camp. However, only 95 students responded to all the pre and post- survey questions. The summer STEM camp program took place in the central part of Texas during the summer of 2015. Students registered for the camp online. The camp consisted of students who were entering grades 7 through 12. Students were from several different states as well as countries around the world such as Italy, Honduras, Guatemala, and Canada. Their ethnic backgrounds were Hispanics, White, Asian, Black, and Indian with the remainder providing no specific ethnicity. Before the camp started, informed consent was gathered from all of the students and their parents.

2.3.2 Instruments

A pre- post survey was administered to the participants in two unique summer camps through Qualtrics. Participants took a pre-survey before the camp started and took the post-survey after the camp was finished. The questions were adopted from

Student Attitude Towards STEM Survey developed by Mahoney (2010). The survey questions consisted of 96 Likert-scale type, which measured participants' attitudes and interests towards science, technology, engineering and mathematics (1= "most like them," 2="more like them," 3= "somewhat like them," and 4= "least like them").

The items "I am not interested in a career in science," "I am not interested in a career in technology," "I am not interested in a career in engineering," and "I am not interested in a career in mathematics" were used to determine if students have gained interest toward STEM topics. To determine if there was a change in students' attitude towards pursuing a STEM related major, the variables "I do not wish to continue my education in science," "I do not wish to continue my education in technology," "I do not wish to continue my education in engineering," and "I do not wish to continue my education in mathematics" were used. In addition, to determine if students had stronger commitments in science, technology, engineering and mathematics, the variables "Commitment: I will continue to enjoy science," "Commitment: I will continue to enjoy technology," "Commitment: I will continue to enjoy engineering," "Commitment: I will continue to enjoy mathematics" were evaluated. A software package, SPSS 23, was used for statistical analysis.

2.3.3 Intervention

During the two-week summer STEM camp, students participated in variety of activities for total of 90 hours of instruction. Students had an opportunity to become engaged in science, technology, engineering, and mathematics project-based learning activities focused on solar energy, cosmetic chemistry, 3D printing and design, app creation, bridge or trebuchet building, Russian, Greek, cryptography, and SAT prep courses. All students had to take either the bridge or trebuchet building activity, and students were able to choose from other activities.

2.3.4 Procedure

In order to determine if students' affect change, a quasi-experimental design was selected. All students were pre-post tested to measure their attitude and interest toward science, technology, engineering, and mathematics. To determine if there was a change in student affect, the researcher used SPSS 23 to run paired-sample *t*-tests comparing pre- and post-survey mean scores for all participants. Cohen's *d* effect sizes were also reported for the entire set of participants. Because multiple paired-samples *t*-tests were calculated, a Bonferroni correction was used. There were 4 paired-sample *t*-tests, so the Bonferroni correction was calculated by dividing .05 by 4 to get the new alpha value, .013. The participant responses on the pre and post-surveys were used to investigate the change in students' attitudes and interest towards STEM related fields.

2.4 Results

As the survey was originally designed, the researcher measured four factors: affect towards science, affect towards technology, affect towards engineering, and affect towards mathematics. To obtain four composite variables for pre- and post-tests, the mean of each factors was calculated.

2.4.1 Descriptive Analysis

To understand the center and the spread for each variable and to determine the change in students' attitude toward science, technology, engineering, and mathematics, descriptive statistics analysis was performed. The mean score for all of the participants on the posttest was higher except for the technology variable. The mean score on the science post survey variable (M=1.656, SD= .809) was lower than the mean score on the science pre survey variable (M=1.556, SD= .809) which indicated that participants had positive attitudes toward science. In addition, both mean scores on the engineering post survey (M=1.501, SD= .679) and mathematics post survey (M =1.689, SD = .746) were lower than on the engineering pre survey (M=1.587, SD= .699) and mathematics pre survey scores (M=1.799, SD= .769). However, the technology post survey score (M=1.636, SD= .713) was higher than the pre survey score (M=1.600, SD= .680), which indicated that students' attitudes changed in a negative direction. The greatest mean difference was between science pre and post survey scores. Moreover, standard deviations were relatively the same between all pre and post survey scores (See Table 2).

Table 2. Means, Standard Deviations, and Mean Differences of Pre and Post Survey Scores

Pre and Post tests	*N*	Mean	*SD*	Mean difference
Science Pre Survey	95	1.656	.809	Pre-
Science Post Survey	95	1.574	.741	Post: .102
Technology Pre Survey	95	1.600	.680	Pre-Post:
Technology Post Survey	95	1.636	.713	-.031
Engineering Pre Survey	95	1.587	.699	Pre-
Engineering Post Survey	95	1.501	.679	Post: .088
Mathematics Pre Survey	95	1.799	.769	Pre-
Mathematics Post Survey	95	1.689	.746	Post: .084

Note: * Significant at $p < 0.05$

2.4.2 *t*-tests

To determine whether there were any changes in students' attitudes toward science, technology, engineering, and mathematics, paired samples *t*-tests were performed. There were no statistically significant increases in student affect towards science, technology, engineering, and mathematics. Thus, Cohen's *d*, the effect size was calculated to determine if there was any practical importance The effect size were: science (*d*=.164), engineering (*d*=.115), and mathematics (*d*=.101) These showed positive effects on students' affect towards science, technology, engineering, and mathematics.

2.5 Discussion

Although there is a growing interest toward science, technology, engineering, and mathematics (STEM) fields, the number of students enrolling in STEM majors is decreasing in the United States of America (National Science Board, 2010; Ross & Bayles, 2007; Torlakson, 2014). Previous research emphasizes the importance of STEM education for students to gain interest in STEM fields. However, formal educational settings are not enough for all students to have the opportunity to experience authentic STEM learning experiences where students are able to participate in hands-on activities, project-based learning, and inquiry-based learning,. Through these authentic STEM learning experiences, students will be able to have positive attitudes toward science, technology, engineering, and mathematics (Mohr-Schroeder et al., 2014). Thus, an investigation of the summer camp impact on students' attitude was conducted to determine if the current study results were consistent with previous research.

The mean scores on post-survey responses for attitude towards science was lower than the pre-survey for attitude towards science, which indicates that students increased their attitude towards science. Moreover, mean scores on post-survey responses in engineering and mathematics were lower than both pre-survey responses, which also indicated that students had a positive change in attitudes toward engineering and mathematics. This indicates that one summer camp encouraged students to grow in their interest towards science, mathematics, and engineering. In addition, it was consistent with previous research that demonstrated that summer camp experiences had a positive impact on students' motivation and attitudes toward science, technology, engineering, and mathematics.

The mean score on the post-survey responses for technology, however, increased from the pre-survey questions for technology. This demonstrates that students did not have positive attitude towards technology after the summer camp. Although 67 students were able to take the 3D printing and design class, 63 students took other classes such as cosmetic chemistry, app design, Russian, Greek, cryptography, or solar energy instead of 3D printing and design, where they were exposed less to technology. Because the pre and post survey responses were collected from all the students who participated in the summer camp, it may have affected the mean difference in attitude toward the technology variable.

Through the paired samples *t*-tests results, the researcher was able to note that there were no statistically significant increases in student attitude towards science, technology, engineering, and mathematics. This may be due to the small sample size. Statistically significant differences can be found with small differences when the sample size is large enough. Although the differences between the pre- and post-survey scores were not statistically significant, it does not indicate that the results are unimportant or unvaluable. Thompson (2006) notes that having a statistically significant result "does not mean that the results are important or valuable" (p. 147).

Thus, to measure the magnitude of the differences between the pre- and post-surveys, effect sizes should be reported.

Because the paired samples *t*-tests result did not achieve statistical significance, effect sizes were reported to determine whether the results were practically significant or not. To determine if there was some practical significance in students' attitude toward science, technology, engineering, and mathematics, Cohen's *ds* were calculated. Attitude toward science showed the largest effect size (d= .164). The effect size for attitude toward mathematics was d= .101 and for attitude toward engineering was d= .115. These effect sizes are reasonable for a 2-week summer camp program. Students had to accomplish many tasks such as building a bridge or a trebuchet, engage in different instructional activities which required a high cognitive load. The 3D printing and design class especially required students to learn several different software programs, which were very complex for students to accomplish in 3-5 days. If the intervention was longer, higher practical importance would be expected.

Not only did students have to learn a new software program in 3D printing and design class, but also in app design and solar energy class. Moreover, some students had to learn about the computer itself before they were able to do calculations or construct the final product for each class. Students had to accomplish a variety of complex skills in eight days, which is a great amount of cognitive load for these secondary students. Despite the complexities of the program and high cognitive load for students, the students' attitude toward science, engineering, and mathematics did not decrease after the summer camp program. This is consistent with previous research that students gain interest toward STEM fields through summer camp programs (Mohr-Schroeder et al., 2014; Tseng et al., 2013; Yilmaz et al., 2010). Many STEM activities allowed students to use engineering, science, and mathematics, and this may have allowed students to have an opportunity to explore these disciplines through authentic learning processes through summer camp experiences.

Although there was a decrease in the difference in the mean between the pre- and post-survey for attitudes toward technology (post- pre= .031), it is not a large difference among those two surveys. The technology pre survey results were more favorable than other disciplines. Because not all students had the opportunity to engage in using technology, the students who did not take course related to technology might have indicated that they were less likely to make commitments toward technology. In addition, students started out with high interest and strong commitment in the technology field, so they may have not increased as much in attitudes toward technology. Even though students spent a lot of time learning about the technology, instead of using and being able to apply it, it did not significantly decrease their affect towards technology.

Ultimately, the result of this study revealed that the summer camp activities improved students' affect toward STEM fields which was shown in previous researches (Mohr-Schroeder et al., 2014; Tseng et al., 2013; Yilmaz et al., 2010). The change in students' mean score from pre to post indicates that students were able to enjoy learning science, mathematics, technology, and engineering and had stronger commitments that they will continue to enjoy and hopefully major in STEM fields through informal STEM activities.

Because they were not only able to apply these disciplines to real-life, but also choose the subjects that matched with their own interests, there was a higher possibility of gaining interests toward STEM topics. For example, they were able to create a lip-gloss by using and learning about chemistry and were able to build their own 3D objects through learning software programs and using technology. Therefore, the results presented show the effectiveness of the STEM summer camp program.

2.6 Conclusion

Despite the complexities of the classes and high cognitive load for students in a 2-week summer camp, students were able to improve their attitude in a positive way towards science, engineering, and mathematics. Through hands-on activities and project based learning, students showed stronger interests and commitment that they will hopefully continue to enjoy after the 2-week STEM summer camp. Students will hopefully be able to have stronger commitment to these disciplines, and the U.S.

will gain more STEM workers. Moreover, students will be prepared for the increasing STEM jobs and responsibilities as capable citizens.

CHAPTER III

3D PRINTING AND DESIGN IMPACT ON STUDENT PERFORMACNE

3.1 Background

Our world is constantly changing and it is important to embrace it and grow with change. Technology is changing how we interact and learn in amazing ways. Because technology is prevalent in our society, students will be using technology in their careers. Students' out-of-school lives are richer in information and communication technology than their in-school lives. "Many middle-grades mathematics classrooms already provide an impressive array of technological tools. In some schools, access to tools is the easy part" (Hollenbeck & Fey, 2009, p. 431). Thus, students do not have to use a scientific ruler to compute and calculate. They now have access to graphing calculators, Excel®, software programs and other more sophisticated technologies.

As technology advances and is increasingly incorporated into classrooms, understanding the implications of using technology to achieve educational goals is important. The decrease in the cost of technology allows many schools to implement technology into curriculum and makes it more accessible to more students (Hollenbeck & Fey, 2009). Therefore, understanding the impact of technology and finding the best ways to integrate technology into the classroom is critical.

Researchers have demonstrated that implementing technology properly enhances not only learning experiences, but also academic performance (Dix 1999; Lavin, Korte & Davis, 2010). All information cannot be presented using paper and pencil. For example, geometry requires visualization and critical thinking which are limited in paper and pencil classrooms. Healy and Hoyles (1999) stated that the appropriate use of technology could enhance mathematics teaching and conceptual development and enrich visualization.

In mathematics, software can be used as technological tools, such as *Graphing Calculators*, *Geometer's Sketchpad*, *e-transformation*, and *Geogebra*, in teaching and learning in the mathematics classrooms. Introducing concepts and teaching through technology can get students excited because they are able to understand the subject, and it is a fun way for them to get involved in the lessons (Jones, 2000; Hollenbeck &Fey, 2009). Thus, adding technology to classrooms can be an effective approach to teaching, which has been continuously enhancing students' knowledge.

Although there are many benefits of technology, there are many possible negative aspects as well. Mathematics educators have concerns or fears that students rely too much on technology and, thus, will not experience true learning (Dror, 2008). Calculators are often thought of as an easy route to mathematics and, because of them, students no longer know how to do simple multiplication or division due to their use. This is not always the case. A calculator can be used as an initial step in developing a conjecture before solving the problem. Having a calculator to use can help reduce errors in calculation, making the calculations less tedious and stressful for the student, and drawing his or her focus to more complex mathematics. Such an effective approach to teaching should not be taken away from the classroom when it is enhancing the knowledge of our students like never before.

3.2 Literature Review

Because technology is prevalent in our society, students will be using technology in their careers. The digital age workforce requires some degree of technical competency, and students can acquire these skills by using technology in education. Various technologies such as learning platforms, interactive videos, complex gaming, innovative technologies, and electronic presentation tools are incorporated into classrooms (Dror, 2008; Lacey, 2010). With emerging technologies, especially 3D printers, students are able to get more engaged in science and mathematics. The 3D printers show how educators can bring up-to-date hands-on learning to classrooms that ensure high-quality education for tomorrow's professionals (Craig, 2000; Lacey, 2010; Segerman, 2012).

Students enjoy learning using technology. Introducing students to mathematics through technology can get students excited because they are able to understand the subject, and it is a fun way for them get involved and to be active in the lesson (Craig, 2000; Dix, 1999; Segerman, 2012). Because students become engaged in the technology-rich lessons, students used their cognitive ability to observe and reflect on the relationships among the representations provided by the dynamic software. Students with technology were able to explore mathematical ideas, which allowed them to touch, verbalize, and build representations. In addition, student-centered lessons and technology-integrated lessons help students to think critically, solve problems, and engage in the learning process (Lacey, 2010).

By providing a student with a visual image alongside a concept or skill, the likelihood of the student's ability to understand and remember increases (Bakar, Ayub & Tarmizi, 2002; Hollenbeck & Fey, 2009). The nature of geometry requires visualization and critical thinking which may be limited in paper-pencil classrooms. New and powerful technology tools are available to support changing roles for schools (Bakar et al, 2002; Craig, 2000; Dede, 1996). In mathematics classrooms, technology tools such as *Graphing calculators, Geometer's Sketchpad, e-transformation*, and *Geogebra* have been widely used at the secondary level (Bakar et al., 2002; Hollenbeck & Fey, 2009). Despite various technologies being implemented in secondary schools, there is limited evidence of positive effects on student achievement. It is important to establish which technologies and under what conditions technology positively affects the teaching and learning of geometry.

As the visual image is a pedagogical tool for helping students understand, technology is another learning tool for enhancing recall and discovery, which can greatly affect a student’s performance (Dror, 2008; Goldenberg, 2000; Healy & Hoyles, 2009). A calculator or computer can be used as an initial step to identify a conjecture before hand-solving the problem. For example, when dividing 30 by 7, the answer on a calculator reads 4.28571428571429. This number is rounded, but a pattern is evident in this number. If the goal of this lesson is to find the pattern, then the student can do the problem by hand to understand the reasoning behind the pattern. Having the calculator’s result in the beginning can help reduce error in the calculation, making the calculations less tedious and stressful for the student, and drawing their focus to the more important mathematics. However, if using technology is not carefully planned in relation to curriculum target goals or if teachers do not connect the use of technology with learning goals, then its use is not warranted (Dede, 1996; Dror, 2008). Therefore, if many students do not gain any of the potential learning benefits, much of the effort expended in introducing computers into mathematics classrooms will have been wasted (Dror, 2008; Healy & Hoyles, 2009).

The emergence of technology-rich mathematics classrooms helps diverse student populations to learn mathematical ideas, reason mathematically, and apply their mathematical thinking to real-life (Ching, Basham, & Planfetti, 2005; Dede, 1996; Suh, 2010). “When teachers know how to effectively use the unique features of computer applications, they can address the varying cognitive strengths and needs of different students” (Suh, 2010, p. 440). Scaffolding a progression of meaningful experiences of cognitive technology tools not only encouraged students to make conjectures through interactive activities by trying what-if scenarios, but also promoted mathematical talk and critical thinking.

When technology is correctly used, it can enhance teaching and learning. Ching, Basham and Planfetti (2005, p. 226) found that "student-centered, technology-integrated learning environments help to produce students who are better able to think critically, solve problems, collaborate with others, and engage deeply in the learning process." In addition, the appropriate use of technology can enhance teaching and conceptual development, and enrich visualization (Kilic, 2013; Knuth & Hartmann, 2005)

As technology can be beneficial for students, it can also be helpful for educators. Technology changed the way educators assess learning and the design of their curriculum's content (Herrington & Kervin, 2007; Jones, 2000; 2001). Using the National Library of Virtual Manipulatives could be a useful tool to teach the area of a triangle. Web applets are very handy when demonstrating lessons involving rotation, growth, or movement. The combination of visuals and numerical calculation with analytic reasoning on the mathematical subject allowed students to develop a solid understanding (Hollenbeck & Fey, 2009; Karner & Bell, 2013; Sinclair, 2009). Students could improve their mathematic abilities through using technology, including having visual and spatial representations, and instant feedback to students (Kilic, 2013; Knuth & Hartmann, 2005; Segerman, 2012;).

Technology can also be used in classrooms to provide meaningful information for teachers. Student Response Systems (SRS) can be handed out to students for them to post answers anonymously to the teacher. This allows for teachers to see what areas of the content students are struggling with, thus improving test scores by clearing up any confusion (Jones, 2000; Jones 2001; Karner & Bell, 2013). It provides instant feedback, where teachers can adjust their teaching accordingly, and allows students to share their thoughts with classmates, to build confidence and understanding (Herrington & Kervin, 2007; Hollenbeck & Fey, 2009; Sinclair, 2009).

In conclusion, technology can increase student achievement levels and improve teachers' competency and utilization of technology when properly utilized. Technology not only enhanced students' communication and collaboration, but also improved quality of instructional activities. In the study, it improved students' organizational skills; enhanced students' motivation; and promoted students' learning (Herrington & Kervin, 2007; Karner & Bell, 2013; Sinclair, 2009; Suh, 2010).

3.3 Statement of Purpose

The purpose of the study was to evaluate whether the use of 3D printing and designing had a positive influence on student's motivation, interests, mathematic skills, and real-world skills.

3.4 Methodology

3.4.1 Participants

The research was conducted with secondary school students at a Summer STEM Camp which took place in the southern part of Texas during the summer of 2015. Students registered for the camp online before the camp started. The camp consisted of students who were entering grades 7 through 12. There were 67 students who took 3D printing and design class, but only 47 students were able to finish both pre- and post-survey. Among those students who took 3D printing and design class, 3 students were from Italy, and the rest of the students were from several different states such as Texas, Alaska, New York, and Tennessee. Their ethnic backgrounds consisted of Hispanics (26.8%), White (56.3%), Asian (8.5%), Black (1.4%), and Indian (2.8%) with the remainder giving no specific ethnicity (4.2%). Before the camp started, informed consent was gathered from all of the students and their parents.

3.4.2 Intervention

Participants spent each day engaged in a 3D printing and design class during the two-week Summer Camp. On the first day of the camp, students filled out a survey about their knowledge and confidence on mathematics and real-life skills. All of the students participated in designing and printing a 3D object. Students used SketchUp and XYZ ware software to design and print their own object. Students had their own laptop to work on for every class. The teacher used video clips and software tutorials to introduce about 3D designing and printing. Students not only received help from the teacher and classmates, but also learned by themselves by watching the software tutorials again. The teacher checked if students were working on it correctly and addressed any misconceptions to the class. During the last week of the Summer Camp, students who finished their designing presented what objects they designed, what the purpose was, why their object was unique ore special, and what they liked about their project. On the last day of the camp, students filled out the same survey they took on the first day, which was about their knowledge and confidence on mathematics and real-life skills.

3.4.3 Instruments

A pre- post survey was administered to the participants in two summer camps through Qualtrics. The survey questions consisted of Likert-scale, open-ended, and short response types. Participants took a pre-survey before the camp started and took the post-survey after the camp was done. There were some identical questions on pre- and post- surveys to measure the difference of their level in confidence and knowledge regarding the following topics: project management tasks, problem solving skills, SketchUp software, XYZ ware software, critical thinking skills, spatial visualization skills, visualization skills, creativity, 3D Printing, 3D design, collaboration skills, transformation skills, 2- and 3- dimensional vectors, proportions, angles and measurements, and technical skills. A software package, SPSS 23, was used for statistical analysis.

3.4.4 Procedure

All students were pre-post tested to measure their motivation, interests, mathematic skills, and real-world skills. To see if there was a positive influence on student performance on the identical questions, the researcher used SPSS 23 to run a paired-sample *t*-test comparing pre- and post-survey mean scores for all participants. Cohen's *d* effect sizes were reported for the entire set of participants. In addition, one-sample *t*-tests were performed for the remaining post-survey questions about students' overall performance. Independent-sample *t*-tests were run with regard to the students' motivation, real-world skills, and mathematics skills. Because multiple univariate tests were calculated, a Bonferroni correction was used. There were 22 paired-sample *t*-tests, so the Bonferroni correction was calculated by dividing .05 by 22 to get the new alpha value, .002.

3.5 Results

3.5.1 Descriptive Analysis

To determine if the intervention was helpful, descriptive analysis was used. The mean score for all of the participants on the posttest was higher than that for the same participants on the pretest except for confidence in proportions and angles/measurements. The mean differences between the pre- and post-survey results are shown in Table 1 ranging from -.085 to 2.128 and standard deviation differing from .960 to 1.698. The greatest mean difference was the knowledge in XYZ ware Software, and the smallest mean difference was the confidence in proportions.

3.5.2 *t*-tests

To answer the question if there was a relationship between 3D printing and design class and student performance, paired samples *t*-tests were used (See Table 3).

3.5.2.1 Knowledge

Students' pre- and post-survey scores revealed a statistically significant increase in students' knowledge of SketchUp software, XYZ software, spatial visualization, 3D printing, 3D design, transformation, 2- and 3- dimensional vectors, and technical skills ($p < .002$). However, knowledge of visualization, proportions, and angles/measurements were not statistically significant.

3.5.2.2 Confidence

Students' pre- and post-survey scores revealed a statistically significant increase in students' confidence using SketchUp Software, XYZ ware software, 3D printing, and 2- and 3- dimensional vectors ($p < .002$). However, confidence with spatial visualization, visualization, 3D design, transformation, proportions, angles/measurements, and technical skills was not statistically significant.

Table 3. Paired Samples *t*-tests

Pre and Posttest pairs	N	Mean Difference	SD Difference	p
Knowledge in SketchUp Software	47	1.830	1.698	< .001*
Knowledge in XYZ ware Software	47	2.128	1.610	< .001*
Knowledge in Spatial Visualization	47	.681	1.218	< .001*
Knowledge in Visualization Skills	47	.255	1.031	.096
Knowledge in 3D Printing	47	1.170	1.551	< .001*
Knowledge in 3D Design	47	1.085	1.558	< .001*
Knowledge in Transformation	47	.723	1.246	< .001*
Knowledge in 2- and 3- Dimensional Vectors	47	.809	1.362	< .001*
Knowledge in Proportions	47	.106	.961	.452
Knowledge in Angles/Measurements	47	.234	.960	.102
Knowledge in Technical Skills	47	.532	1.060	.001*
Confidence in SketchUp Software	47	1.255	1.519	<. 001*
Confidence in XYZ ware Software	47	1.787	1.654	<. 001*
Confidence in Spatial Visualization	47	.213	1.062	.176
Confidence in Visualization Skills	47	.170	1.110	.298
Confidence in 3D Printing	47	.915	1.586	<. 001*
Confidence in 3D Design	47	.660	1.464	.003
Confidence in Transformation	47	.362	1.358	.074
Confidence in 2- and 3- Dimensional Vectors	47	.617	1.208	. 001*
Confidence in Proportions	47	-.085	1.039	.577
Confidence in Angles/Measurements	47	-.064	1.051	.679
Confidence in Technical Skills	47	.489	1.101	.004

* Significant at $p < .002$

One sample *t*-test for students' post survey only scores revealed a statistical significant increase in all items (See Table 4). The student's mean score was 4.190 on how motivated they were to learn new materials during the program. After the intervention, students' mean scores were high for having interest in 3D printing ($\bar{X}$=4.320) and design ($\bar{X}$=4.280). Students also felt confident enough with 3D printing to teach it to someone else ($\bar{X}$= 3.980). Lastly, not only students were more motivated to learn ($\bar{X}$=4.130), but also accomplished real-life skills ($\bar{X}$=3.910).

Table 4. One-Sample *t*-tests on Post Survey Questions

Post Test Questions	Mean (SD)	Sig. (2-tailed)
During this 3D printing and design project, I was motivated to learn new materials.	4.191 (1.056)	< .001*
After finishing this 3D printing and design project, I have interests in 3D printing.	4.319 (0.980)	< .001*
After finishing this 3D printing and design project, I have interests in 3D design.	4.277 (0.994)	< .001*
After finishing this 3D printing and design project, I feel comfortable enough with the topic of 3D printing to teach it to someone else.	3.979 (1.170)	< .001*
After finishing this 3D printing and design project, I have more enthusiasm toward learning.	4.128 (0.924)	< .001*
After finishing this 3D printing and design project, I learned real-world skills.	3.915 (1.139)	< .001*

* Significant at $p<.002$

3.5.3 Effect Size

To determine the magnitude of the differences between pre and posttest, Cohen's *d* effect sizes were calculated for all the variables, and they ranged from -.082 to 1.322.

Many variables showed practical importance, which indicated using 3D printing and designing software had a positive effect on overall student's performance.

3.5.3.1 Knowledge

Eight variables had practically important Cohen's *d* coefficients, and the variables were knowledge in SketchUp, XYZ ware, spatial visualization, 3D printing, 3D design, transformation, 2- and 3- dimensional vectors, and technical skills. The greatest Cohen's *d* was 1.322 for knowledge in XYZ ware software. These variables showed a large span of practical significance.

3.5.3.2 Confidence

Seven variables had practically important Cohen's *d* coefficients, and the variables were confidence in using SketchUp, XYZ ware, 3D printing, 3D design, transformation, 2- and 3- dimensional vector, and technical skills. The greatest Cohen's *d* was .577 for confidence in XYZ ware. These variables had a range from -.082 to 1.080 with seven variables greater than .443.

3.6 Discussion

The incorporation of technology into curriculum can enhance students' learning experiences and overall performance; however, factors that increase or decrease the effectiveness of technology should be taken into consideration. Factors that can lessen the effectiveness of technology in classrooms can be background knowledge of students, teacher competency levels with the technology, and students' social class. However, previous research has taken these factors into account when assessing the effectiveness of technology, and has found that they were effective and can increase students' overall performance, despite these factors. This quasi-experimental study, however, may be revealing to explore this topic.

The 3D printing and design class allowed students to be interested in learning the material. Previous research states that teaching concepts through technology can motivate students to become excited because they are able to understand the subject, and it is a fun way for them to engage in STEM lessons (Jones, 2000; Hollenbeck & Fey, 2009). *t*-test results reveal statistically significant results for students' motivation and interests. The mean for all the variables on the post survey only questions was high (4.319), showing that the intervention allowed students to gain enthusiasm toward learning. Students were also motivated to learn and gained interest towards 3D printing and design. As previous research shows, emerging technologies engage student in the learning process. Thus, using appropriate technologies will allow students to gain enthusiasm toward learning.

As students were motivated to learn, students' mathematics skills increased. In the both pre- and post-surveys, students' mean score for overall mathematical skills has increased. Variables such as knowledge of spatial visualization, transformation, and 2- and 3- dimensional vectors not only were statistically significant, but also had large effect sizes ranging from .580 to .599. The variable, confidence in 2- and 3-dimensional vectors, was also statistically significant, and the effect size was .511. This tells one that students have acquired mathematical skills and greatly increased their mathematical ability through the intervention program, and researchers have demonstrated that implementing technology properly enhances not only learning experiences, but also the academic performance (Dix 1999; Lavin et al., 2010). Moreover, Students did not only gain mathematical knowledge, but also were confident in their mathematical skills.

Although some of the mathematical skills improved statistically significantly, knowledge of visualization (p = .096), and knowledge of proportions (p = .452), and knowledge of angles/measurements (p = .102), confidence in spatial visualization (p =. 176), and confidence in visualization (p =. 298), confidence in transformation (p = .074), confidence in proportions (p = .577), and confidence in angles/measurements (p = .679) were not statistically significant. However, students did not receive any lessons on mathematics during the intervention, and the increase in the mean scores for the mathematical skills shows that students were able to verbalize, touch, and build representations as shown in previous researches. If students even had mini lessons on mathematical concepts, the intervention would have been more effective for increasing students' knowledge and confidence in mathematical skills.

Moreover, this may be due to the complication of intervention. First, students had to learn about the computer itself and other new software programs such as Google SketchUp software and XYZ ware in three to five days. They also had to make individual objects in 2D on the software and connect it to 3D software. To be able to print this, they had to visualize what the 3D object would look like on a plate because this could not be seen on Google SketchUp. Moreover, they had to scale arbitrary objects. Students had to accomplish all of these skills in eight days, which is a great amount of cognitive load for these secondary students. Thus, if the cognitive load was reduced for the students, they may have acquired more mathematical skills. Even though students had great amount of cognitive load, the results do not diverge far away from being statistically significant.

While student's overall performance increased, real-life skills were highly increased after the camp. As students are living in a technology rich world and there are many available technologies in schools now, educators should use those technological tools for teaching (Dix 1999; Lavin et al., 2010). Both knowledge of and confidence in 3D printing, SketchUp software, and XYZ ware software and knowledge of technical skills statistically significantly increased and effect sizes ranged from .502 to 1.322. Although the change in knowledge of 3D design was statistically significant ($p < .001$), the change in confidence in 3D design was not ($p = .003$). However, the confidence in 3D design is very close to be being statistically significant and its effect size is .451. In addition, the change in confidence in technical skills (p = .004) was also not statistically significant, but close to being statistically significant with an effect size .444. This shows that if the intervention was longer, the effect size would be more than 1 standard deviation, which is a great change in students' performance. Therefore, the effectiveness of using 3D printing and design software on student performance demonstrated here matches previous research.

3.7 Conclusion

The intervention, 3D printing and designing program, had a positive influence on student's motivation, interests, mathematic skills, and real-life skills. However, the cognitive load for students were high. If the intervention was longer that reduces the cognitive load for students, it would have been even more successful. Thus, using technology to reach each of the students in 21^{st} century classrooms must be flexible in meeting the unique needs of learners.

Moreover, the decrease in the cost of technology allows many schools to implement technology into curriculum and makes it more accessible to a larger number of students. As technology advances and is increasingly incorporated into classrooms, it is important to understand the implications of using technology to achieve the educational goals of all students (Hollenbeck & Fey, 2009). Therefore, teacher training, considering student technology proficiency, and clearly defined objectives of every technology-integrated lesson is necessary for successful student performance.

CHAPTER IV

SUMMARY AND CONCLUSION

Although there is a growing interest in the U.S. in STEM teaching and learning, researchers predict that there will not be enough skilled STEM workers or sufficient workers to fill the growing STEM careers in the U.S. (Krishnamurthi et al., 2014). Research has shown that informal STEM education can affect students' attitudes towards science, technology, engineering, and mathematics (Dorssen, Carlson, & Goodyear, 2006; Krishnamurthi et al., 2014; Tseng et al., 2013). Because students' personal interest can be taken into consideration while participating in informal STEM learning environments, more students are able to gain interests toward STEM than traditional school learning settings. Thus, providing informal STEM education, such as afterschool programs and summer camps, should be provided for all students in order for them to have additional opportunities to be exposed to STEM educational experiences.

A study was conducted at a 2-week summer camp in southern part of Texas to investigate if summer camp programs can enhance students' attitude toward STEM fields. Students who participated in a 2-week STEM summer camp were able to increase their attitude toward science, engineering and mathematics. Although there were no statistically significant differences between pre- and post- survey scores, the effect sizes were fairly reasonable considering the high cognitive load for students and the complex tasks that students had to accomplish in eight days. The hands-on and project based learning activities during the summer camp allowed students to gain interest in STEM topics and have stronger commitments toward pursuing a STEM major. Because students were able to express stronger commitments in these disciplines, these can lead to a positive prediction that the U.S will have a greater number of qualified STEM workers.

As many careers require technical skills, it is important for secondary school students to learn about and use emerging technologies. Sanders (2009) found that technology is “one of the critical keys to global competitiveness” (p.25). Thus, it is important for educators to prepare middle and high-school teachers should so that they can incorporate technology into their mathematics, science, and engineering classes to achieve educational goals. The secon study was conducted to determine whether 3D printing and designing activities had a positive influence on student’s motivation, interests, mathematical skills, and real-life skills. Despite the high cognitive load for students and the complexity of the intervention, students were able to gain interest, mathematical and real-life skills through the informal STEM education activities at a summer camp. The results not only demonstrated statistical significance for some of the mathematical skills, technical skills, and motivation to learn, but these variables also had a large enough effect size to show practical importance. If the duration of the intervention was longer and the cognitive load for students was less, it would have probably predicted even more success. Thus, using technology to reach all students in 21st century classrooms and informal settings must be flexible in meeting the unique needs of diverse learners.

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APPENDIX A

PRE/POST SURVEY QUESTIONS

Please rate your knowledge and confidence regarding the following topics. 1 represents the lowest level, while 5 represents the highest.

	Knowledge					Confidence				
	1	2	3	4	5	1	2	3	4	5
SketchUp Software										
XYZ ware Software										
Spatial Visualization										
Visualization Skills										
3D Printing										
3D Design										
Transformation										
2- and 3- Dimensional Vectors										
Proportions										
Angles/Measurements										
Technical Skills										

APPENDIX B

ONLY POST SURVEY QUESTIONS

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
During this 3D printing and design project, I was motivated to learn new materials.					
After finishing this 3D printing and design project, I have interests in 3D printing.					
After finishing this 3D printing and design project, I have interests in 3D design.					
After finishing this 3D printing and design project, I feel comfortable enough with the topic of 3D printing to teach it to someone else.					
After finishing this 3D printing and design project, I have more enthusiasm toward learning.					
After finishing this 3D printing and design project, I learned real-world skills.					