HOW PARTICIPATION IN THE ARTS IMPACTS LEARNING COMPREHENSION FOR HIGH SCHOOL STUDENTS DURING STEM COURSEWORK AT TWO HIGH SCHOOLS IN SOUTHWEST FLORIDA: A CASE STUDY

by

Tiffany Lynn Jennings

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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2019

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APPROVED BY:

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ABSTRACT

The purpose of this case study was to understand how participation in the arts impacts Science, Technology, Engineering, and Mathematics (STEM) coursework for students at two Southwest Florida High Schools. Within the context of the study, the term "arts' was used to collectively refer to all visual and performing arts courses, including painting, drawing, graphic arts, two-dimensional and three-dimensional, music, and theatre. Studies show that in order to be innovative, students need to have the experiences that the arts can foster in the right side of the brain, the side associated with creativity (Eisner, 2002). I chose a case study approach for this qualitative study, in which the participants had the opportunity to share their individual experiences in, and insight with, the arts and STEM coursework. The first theory guiding this study was associated with Elliot Eisner, who believed that the arts encourage exploration and play a key part in the development of the imagination and cognition (Eisner, 2002). The second theory that guided this study was Howard Gardner's theory on multiple intelligences (1995), which states when students are able to approach their coursework from different perspectives, learning comprehension can be displayed in varying ways (Gardner, 1995). Lastly, Maslow's (1943) theory of human motivation deals with how individuals prioritize their needs, including their need for self-respect and self-actualization (Maslow, 1943). Both sites for this case study offer arts and STEM coursework. Through open-ended interviews and observations with the participants, I collected and analyzed data. Based on the feedback provided by participants, the case study provided insight into how students use learning strategies, skills, and creative problem solving, resulting from their participation in the arts and in their STEM coursework.

Keywords: creativity, high school students, STEAM, STEM.

Dedication/Acknowledgments

I am grateful to God for placing the desire to earn a doctoral degree on my heart. Additionally, my heart is thankful for the guidance and blessings He bestowed upon me throughout this journey. The support, patience and encouragement from my husband Michael and daughters, Sierra and Kaitlyn, while working on my dissertation, were nothing but unconditional love. They all helped out with day-to-day responsibilities from which I had to withdraw from on many occasions. My parents, Tim and Robin Howard always made me want to push forward, while they beamed with parental pride throughout my studies. I would like to acknowledge my colleagues and friends who provided me impromptu advice and insight into the doctoral journey; Dr. Owen Bradley, Dr. Jackie Henson-Dacey, Dr. Chris Brown, and Dr. George Kenney. Their words of encouragement and experiences were at times silently repeated in my mind throughout the process. My students and coworkers inspired me throughout this journey and always helped me maintain a positive outlook. Lastly, I would like to thank my committee members, Dr. Kenneth Tierce and Dr. Ronald DiPillo for their guidance and support throughout the dissertation process.

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List of Abbreviations

Every Student Succeeds Act (ESSA)

International Baccalaureate (IB)

Multiple Intelligence (MI)

National Coalition for Core Arts Standards (NCCAS)

No Child Left Behind Act (NCLB)

Problem Based Learning (PBL)

Science, Technology, Engineering, Arts, Mathematics (STEAM)

Science, Technology, Engineering, Mathematics (STEM)

Visual Performing Arts (VPA)

CHAPTER ONE: INTRODUCTION

Overview

The first chapter of this study illuminates my intent to understand how students and teachers perceive that participation in the arts impacts science, technology, engineering, and mathematics coursework. As STEM fields grow globally, there is an increased emphasis on STEM education (Masson, Klop, & Osseweijer, 2016). The founder and CEO of STEAM education, Georgette Yakman, theorizes education should be based on a multi-disciplined approach where science, technology, engineering, art, and mathematics work together to educate students (Yakman, 2016). Art educator Elliot Eisner theorized when the arts are fully integrated into a student's education, this integregration demonstrates educational practices at their best (Eisner, 2002). The activities taught and practiced in the arts create an environment that lends itself to problem solving, trial and error, and a tolerance of ambuiguity while developing a variety of solutions (Eisner, 2002). Despite the thoeries of Elliot Eisner and the increased emphasis on student achievement, the United States is behind other nations in STEM fields. Arts integration into the STEM subjects creating the STEAM model in education can help student achievement (Yakman, 2016). This chapter includes background information about attitudes and beliefs about education, my situation to self, problem statement, purpose statement, significance of the study, research questions, and key definitions. A summary concludes Chapter One.

Background

Throughout history cultures around the world have placed value on education. Benjamin Franklin (1706-1790) believed that the middle-class youth should receive a vernacular and utilitarian education (Gutek, 2011). In the periods following the American and French Revolutions, education became a priority for both countries as the priority of nationalism grew in

importance (Gutek, 2011). In recent years, a college in Nigeria conducted a research study showing the positive attitudes about education as computer technology grew in use; teachers reported student ideas became more sophisticated with computer technology usage (Abass, 2012). Additionally, parents in South Korea have placed high distinction on their child's education; 75 % of the children in South Korea receive a private education (Shin & Kim, 2014). Parents teach their children that in order to gain employment, to make a living, and achieve their dreams, they need to get an education.

Philosopher and progressive educator, John Dewey believed that when a child is educated, it is for the whole human organism (Gutek, 2011). The arts are a vital part of any curriculum. Elliot Eisner (2002), a leading art educator, wrote a document about 10 lessons that the arts can teach children. Eisner (2002) suggested the arts help children learn complex problem-solving skills. Additionally, Albert Einstein blended his musical talent with his thinking and credited his scientific insights to musical thinking (Root-Bernstein, 2015). All children, regardless of age, ability, or even their amount of interest in arts classes, can benefit from experiences in the arts ("Arts Education Partnership," 2012). The arts help students to develop the ability to think in new ways (Schlegel, 2014).

Too often the decision-makers in education place more emphasis on what students learn in core subjects (Yakman, 2016). Furthermore, student enrollment and funds in STEM courses has increased over the past two decades (Pittinsky & Diamante, 2015), while the arts are considered secondary to the academic curriculum rather than one of the essential core curricula. According to Elliot Eisner (1994), in order for students to know something, they must experience it; the arts allow students to experience what they are learning. To prepare future generations for

the challenges of the world, all areas of education, including the development of creative thinking, must be included as part of one's education (Gustina & Sweet, 2014).

Historical Context

The arts offer students an experience that they cannot receive from other sources, and provide students with the ability to discover the range and diversity of what they are able to feel (Eisner, 2002). While education and curriculla continually evolve, the areas of greatest priority have been associated with reading and mathematics (Freedman, 2011). Since the No Child Left Behind Act was implemented in 2002, elementary and secondary school administrators have given special priority to the reading and math curriculum while neglecting the arts (Freedman, 2011). Since of the enactment of the NCLB act, high school graduation rates and college student enrollments have increased and are at their highest as of 2016 (Freedman, 2011). However, it is important to note NCLB was reassessed and reviewed in 2007, renamed Every Student Succeeds Act, and signed into law by President Obama in 2015 (Every Student Succeeds Act (ESSA) U.S. Department of Education, 2016). In 2010 the Obama administration recognized areas of improvement in NCLB. Some of the areas ESSA focused on were high academic standards for all students, the need to expand quality pre-schools, and yearly evaluations statewide (Every Student Succeeds Act (ESSA) U.S. Department of Education, 2016). The arts have always been a difficult subject to evaluate and are not viewed as a high priority in one's education ("A Snapshot of State Policies for Arts Education," 2014). According to the National Endowment for the Arts, standards-based models and rubrics of varying levels already exist for assessing how students perform in the arts (Iyengar, 2017). Additionally, because the arts impact other core subjects, such as mathematics and science, no objective evaluation process exists because the

arts are subjective to an evaluator's own insight rather than a concrete right or wrong answer to a mathematics problem (Iyengar, 2017).

Social Context

Professor Georgette Yakman at the Virginia Polytechnic Institute and State University is the founder and has been the CEO of STEAM education since 2006. She believes that schools should convert the traditional modes of learning into interdisciplinary learning centers (Yakman, 2016). She has proposed the STEAM education theory in which students learn science, technology, engineering, art, and mathematics through a multi-disciplined approach where education is based on project-based learning (Yakman, 2016). Since STEAM education is only a theory proposed by Yakman (2016), there is a gap in the academic research on how the arts have influenced Science, Technology, Engineering, and Mathematics (STEM) education.

Pedagogically, the arts help students develop high level thinking skills, express ideas, foster imagination, and engage in advance problem-based learning, all of which are required in STEM fields (Bequette & Bequette, 2012). Research has been conducted on the arts when combined with other disciplines; however, the combination of arts with STEM is lacking in research. It is possible to consummate, by integrating the arts into STEM education, STEM coursework can be positively influenced and learning comprehension can be deeper (Maeda, 2012). Arts educators have advocated for the arts for decades (ArtScan, 2014). While arts classes have been considered a luxury at some schools, arts classes are also thought to be a brain-break for students in many k-12 schools (Pittinsky & Diamante, 2015). The arts are viewed as the fun, elective classes that give regular teachers a break during the day (Pittinsky & Diamante, 2015).

According to Elliot Eisner (2002), the arts have historically been placed on the periphery of a child's education rather than being a primary subject like mathematics or science (Eisner,

2002). While many arts educators realize the imperative role that creativity plays in other subject areas, they still need to fight for the arts programs (Eisner, 2002). Since there has been an increased emphasis in the last decade on the importance of STEM courses, many arts educators would like to see the arts infused into STEM. The desire to remain a top competitor and innovator in the global market, and to have high achieving students is a priority for government officials and educators (Stevenson, 2014). For the United States to compete globally in STEM fields, businesses and the nonprofit community have banded together to improve Science, Technology, Engineering, and Mathematics (STEM) education (Stevenson, 2014). It is the responsibility of the decision-makers in education, to provide students with a quality education, using all means necessary at the highest level to ensure they can compete in the future (ArtScan, 2014). The increase towards more STEM-type of programs has grown out of the desire to be a global leader in STEM fields (Jang, 2015). For over a decade, STEM programs have been implemented at every age level (Pittinsky & Diamante, 2015). In President Obama's 2013 State of the Union Address, he called for the training of 100,000 teachers in the STEM subject areas, giving credence to the importance of this initiative (Stevenson, 2014). Part of President Obama's initiative stated schools that developed partnerships with colleges and businesses in which science, technology, engineering and mathematical skills were made a priority, would be rewarded for developing the classes and partnerships that ultimately fill STEM jobs (Stevenson, 2014). However, an important component that has been overlooked in the growth and success of STEM education and fields is the influence the arts have when combined with the STEM component (Saraniero, 2014). Yet the National Science Foundation has funded workshops centered on STEM and STEAM themes and the National Endowment for the Arts have hosted events called Artscience initiatives, evidence that government agencies are acknowledging the

relationships (Maeda, 2012). Technologies are advancing at increasing speed, and education is the counterbalance as changes impact society (Berkowicz & Myers, 2017). For students to achieve at their highest levels, innovation must go hand in hand with STEM readiness (Simonton, 2012). Experiences in the arts can potentially develop sensory qualities that carry over into other domains (Eisner, 1994). The arts provide students with opportunities that can adapt into STEM subjects, and careers (Maeda, 2012). For example, students who participate in the arts use trial and error techniques when problem-solving (Schlegel et al., 2014). Additionally, arts students learn how to quickly translate observations, a useful skill in STEM coursework (Schlegel et al., 2014). Students need to see and touch what they are learning (Jackson, 2003).

Theoretical Context

According to Daugherty (2013), Nobel laureates in the sciences are 25 times more likely than the average scientist to sing, dance, or act. Additionally, they are also 17 times more likely to be an artist, 12 times more likely to be a poet, eight times more likely to do other crafts like woodworking, and four times more likely to be a musician (Daugherty, 2013). Based on the statistics provide by Daugherty (2013) the arts, creativity, or creative problem solving can propel students and professionals in STEM. The importance of STEM education and how STEM will affect the U.S. in the future has been documented and researched in the past two decades (Masson, Klop, & Osseweijer, 2016). STEM education allows the U.S. to compete with other countries around the world that have had a focus on science and technology education (Jang, 2015). By implementing a creative component to STEM, students learn to use the creative right-side of their brain simultaneously with the logical or left the side of the brain. Creative people notice stimuli or come up with solutions that may be irrelevant or not pertinent to individuals who lack creativity, which enable them to develop original thoughts and ideas (Simonton, 2012).

Situation to Self

This study is close to my heart. I am an artist and arts educator who believes that STEM education and careers in STEM fields can help the U.S. compete and be a leader globally if the arts are included in STEM coursework, creating a STEAM model. My research topic has been decades in the making. The arts provided an avenue for me to discover my own gifts and talents, develop my imagination, and seek visual means to learn new content. I was a child who enjoyed making things with my hands, and based on the multiple intelligences theory of Gardner (1995) I am a visual and spatial learner. I could sit and draw a picture, build a fort out of blankets and boxes, and create things from found objects, for hours on end. Even at an early age, my attention span would allow me to work on tasks for long periods of time. Based on the research of Eisner (2002) the arts help develop the imagination, which was true for me as a child and still applies to my life now. In school and at home, being creative was a top priority. In high school, I would rush through my classwork, and then beg the teachers for a pass to the art room.

In the art room, my art teacher would give assignments that were typical for the stage of development, and appropriate for the specific learning objective, building on learning and previous experiences in class. Once the assignment was given, my mind would spiral with ideas and creative solutions for the projects. I always wanted to go above and beyond the teacher's expectations, and ultimately challenge myself. Self-actualization, the final level for an individual's needs based from the theories of Maslow (1943) ties into my self-esteem since the arts gave me confidence, a purpose, and a direction for this dissertation. The use of my skills and imagination spilled over into my science, social studies, and English classes. My teachers noticed that I had an aptitude for visual expression. Traditional modes of instruction bored me. When a lesson was delivered simply through means of taking notes, listening to lectures, then having to

memorize those notes, I floundered. However, when my science, social studies, or English teacher gave an assignment that required creative problem solving or some type of visual output for the assessment, I flourished. Even back in high school, I realized the importance of arts education in my own learning comprehension in other subjects. Ultimately, the arts helped me to achieve and be a thinker while in high school. Without the arts as a form of communication, or an outlet, and self-expression, I would have struggled through high school.

At one point during high school, I expressed the desire to go into the arts as a career. Everyone discouraged me. I was told there were no jobs or money to be made in the arts. As a senior in high school, I was encouraged to go into communications. It sounded interesting and seemed like something I might be good at. After one semester in college, the notion of becoming an art major tugged at my heart. I knew I was nowhere near being at the skill level of the Renaissance master Michelangelo Buonaratti, nor was I the creative genius of twentieth-century artist Pablo Picasso, but I loved art. This is where my faith in Jesus Christ stepped in. If God had put this desire in my heart, there had to be a purpose. So, I switched majors, from speech communications to art education. Even while in the art education program, my college advisor at Temple University in Philadelphia, Pennsylvania, explained how difficult it would be to obtain a teaching position in the arts. Although the jump in majors seemed crazy to others, my faith never wavered, “For I know the plans I have for you," declares the LORD, "plans to prosper you and not to harm you, plans to give you hope and a future,” (Jeremiah 29:11, English Standard Version).

God delivered on his plan for my life rather quickly. Once I finished my undergraduate work in 1996, I received my first teaching offer. My teaching certificate had not even been delivered at the time of the interview. That first teaching position required I move 3000 miles to

teach art and photography in San Bernardino County, California, and I had the privilege of serving disadvantaged minority students for five years. My relationships with the students were a blessing. When I was the high school student in the art room, my experience was centered on my own growth. As the art teacher, my role was that of a mentor, counselor, and cheerleader for art students. In 2001, God provided a new door of opportunity for my husband, our two young daughters, and myself. A new high school was being built in southwest Florida. This high school was focused on academics: it was a school-within-a-school concept, similar to middle school teacher teams, in which a group of teachers shares the same students, each team having a teacher for each subject. This high school offered academies in communications and arts, law and legal studies, hospitality, and business. We moved our family back to the east coast to take part in this opportunity with mixed emotions but trusting God the entire way.

Since the opening of the academy high school, I have been a part of, and have witnessed tremendous strides in student achievement in the arts. As the art program has grown in numbers and accolades, so have other programs. Most recently, the STEM program has shown steady growth and success. Additionally, in recent years, many colleagues, especially in the science department, have pointed out how well the art students do with creative problem solving and projects in their classes. Because of my own personal experiences in the arts and other core high school subjects, I believe the arts can teach and foster problem-solving skills that enhance student learning and achievement. With the increase toward more STEM focused curricula, I believe the arts are essential to developing well-centered and educated students, especially in the STEM field.

As an art educator and artist, naturally I see the importance of the arts within a balanced curriculum. I have also been very blessed to teach some incredibly talented and creative students.

However, the one thing I have always enjoyed most about teaching is witnessing students learning. During my first year of doctoral studies, a few STEM colleagues approached me about students we shared. The engineering teacher commented about how creative one young man was in his class when problem-solving. He was amazed at how our student came up with ideas for engineering projects. A science teacher approached me about a few students who sometimes struggled with the content in science class; however, when given the opportunity to show comprehension of content through visual means the students would perform much better on assessments. From my own perspective, I have always known how the arts have helped me in other subjects, yet some colleagues were amazed at how the arts affected their content. These discussions prompted me to have students who simultaneously take art and STEM courses tell their own stories. A qualitative case study seemed perfect to give students a platform to share their thoughts, feelings, and ideas on how the arts and STEM could possibly work together.

Although I may have a personal bias in this research, I am aware that I must keep my personal feelings and beliefs separate from my research. The philosophical assumptions I will be using to develop the qualitative research in this study are ontological and methodological. Ontological assumptions look more at the reality of all different viewpoints or perspectives of each participant. Since ontological assumptions in research look at humans in a social context in order to determine if something exists, I am seeking to determine if the arts help high school students learn and perform better in STEM coursework. A methodological approach will allow the research to emerge, be inductive, and allow the research to form while I am collecting and analyzing data (Creswell, 2013).

My own assumption is the arts do help students learn and perform better in STEM coursework. The research paradigms that have guided my thoughts and ideas surrounding this

research are associated with Maslow's (1943) hierarchy of needs, Eisner's (2002) theories on the arts and creativity, and Gardner's multiple intelligences. My positive experiences as a high school art student have helped formed my opinions and beliefs regarding arts integration with STEM coursework. Eisner (2002) stated learning in and amidst the arts grows aspects of the mind. The arts make great contributions to the development of a student's thinking skills, expression, and communication, which allow them to reference and interact when experiencing other aspects of the world (Eisner, 2002). Realizing I could synthesize skills I learned through the arts into other disciplines gave me confidence. Maslow (1943) theorizes once all other basic needs are meet for individuals, self-actualization in which one's full potential is realized, occurs. The last research paradigm that helped frame the approach to my research centers on Gardner's (1995) theory of multiple intelligence. Gardner (1995) theorized that intelligences come in a variety of forms. Early on in my schooling, I remember feeling as if I was never smart enough. As I matured as a student, I realized I was stronger in certain ways of learning rather than traditional modes of learning. I am more of a spatial and visual learner. God designed me this way, someone who could achieve anything I wished, through my own ways of learning. While STEM did not exist as an acronym in education during the 1980's, my art experiences and skills helped me with creative thinking and cognition with my core subjects. Therefore, my assumptions and a basic set of beliefs for this case study are deeply rooted in my own educational experience, (Creswell, 2013). My goal in this case study is to have current high school students tell their own experiences and interpretations of how the arts have influenced their STEM coursework and comprehension. The participants were informed of my personal values regarding the arts, and why I am conducting this case study. Additionally, the case study method is the most relevant form of research to conduct because it requires in-depth descriptions

of a social phenomenon (Yin, 2014). With an axiological assumption, I must acknowledge that biases are present and that my values will shape the narrative, (Creswell, 2013).

Problem Statement

The problem of this study is the impact of participation in the arts on learning comprehension for high school students during STEM coursework at two high schools in southwest Florida. While research exists among science, technology, engineering, and mathematical education, very little has been done to see how the arts impact student comprehension in those subjects. The United States is lagging behind other countries in STEM related fields (Breiner, Johnson, Harkness, & Koehler, 2012). For example, a cross-national test, the Program for International Student Assessment (PISA) that measures key skills in various subjects including math and science in developing countries (Desilver, 2017), revealed that of 71 countries, the U.S. ranked 19th in science and 30th in math (Desilver, 2017). STEM jobs grew three times faster than non-STEM jobs between 2001 and 2011 and are projected to grow 17-18% before 2020 (Pittinsky & Diamante, 2015). When students are in elementary school, STEM is viewed as fun, but there is a drop off in interest as the STEM content gets more difficult in high school and college (Pittinsky & Diamante, 2015). Recent data have shown that 40% of college freshmen who enter college majoring in math, science, or engineering, switch their major to a non-STEM field or drop out of college altogether (Pittinsky & Diamante, 2015). The lack of participation in the much-needed STEM fields and the U.S. ranking in science and math will impact schools and the future of the country (Masson, Klop, & Osseweijer, 2016). A cause of the lack of interest and success in STEM areas centers on creativity, innovation, and problem-solving (Pittinsky & Diamante, 2015). A case study which investigates student

participation in the arts, while enrolled in STEM courses, could provide an explanation of how the arts influence the students' learning comprehension during STEM coursework.

With the recent increase in STEM education, arts educators see a potential problem where the arts receive less support in education (Daugherty, 2013). Daugherty et al. (2013) stated: "Art advocates have tried to make the case that the arts are important because they improve students' performance in academic subjects" (p. 11). There is no generic, one-size-fits-all approach that applies to creativity (Simonton, 2012). Students miss out on a key component—such as creative problem solving and varying perspectives when solving problems—of their education when the arts are reduced or cut (Eisner, 2002), Too often the arts are one of the programs cut in the school's budget as a result of achievement crisis situations (Yokana, 2014). Many educators would like to see a movement toward a STEM curriculum combined with an arts curriculum, creating a teacher team of science, technology, engineering, arts, and mathematics teachers working together when planning lessons, units, and developing the curriculum (Wynn & Harris, 2013). Artistic processes and scientific methods have been considered opposites in the school curriculum. However, both the arts and sciences have a process and product aspect because they allow creative and critical thinking to be combined (Saraniero, 2014). In the U.S., all the goals for the nation to prosper center on a world-class STEM workforce (Maeda, 2012), indicating there is a place for arts and design education in the STEM conversation. Over the past decade there has been a movement to change STEM to STEAM by adding artistic skills and processes (Riley, 2013). Creativity, explored through the arts when implemented into a STEM curriculum, can improve student skill and problem-solving (Saraniero, 2014). One research study at Dartmouth College, conducted in 2014, looked at neural and behavior changes of arts students and non-arts students while drawing and painting (Schlegel

et al., 2014). The researchers conducted and studied results from four one-hour-long magnetic resonance imaging (MRI) and Torrance Tests of Creative Thinking (TTCT) over a three-month period, using 45 participants (Schlegel et al., 2014). The researchers discovered that the arts students became more creative through the restructuring of prefrontal white matter (Schlegel et al., 2014). Increasing the use of evidence-based teaching in STEM and infusing the arts into the STEM curriculum can influence the cognition of STEM content for students enrolled in those courses.

The United States is falling behind in STEM related assessments and fields (Pittinsky & Diamante, 2015). With the urgency to prepare students in STEM, there has been increased funding at the federal level. The federal STEM budget in 2011 invested $3.7 billion into education (Breiner, Johnson, Harkness, & Koehler, 2012). The Race to the Top competition which includes STEM as the only viable priority, allocated $4.3 billion to education (Breiner, Johnson, Harkness, & Koehler, 2012). The central ideas of combining the arts and STEM focuses on the roles of creativity and innovation to better educate students (Daugherty, 2013). Students need to possess a 21st-century skill set, referred to as the 4C's, that includes creativity, collaboration, critical thinking, and communication (Miller, 2014). STEAM essentially is the fusion of the arts with science, technology, engineering, and mathematics, enabling students to achieve in all these areas (Saraniero, 2014). Principal to America's story of progress has been inventiveness and creativity (Maeda, 2012). Because there is very little research on the STEAM model, an in-depth case study where students are involved with the arts and STEM coursework at the high school level simultaneously is needed. The students' perception of their experiences could provide educators with insight to whether a phenomenon exists among the arts and STEM coursework. The STEAM education model involves combining the sciences to help students

comprehend the laws of the world, engineering and technology to allow individuals to change the world, the arts to enrich the world, and mathematics to provide the configurations needed (Yakman, 2016). Few studies have provided in-depth understanding of the arts on STEM coursework learning comprehension of high school students.

Purpose Statement

The purpose of this qualitative case study was to understand the impact of participation in the arts on STEM coursework learning comprehension for high school students at two high schools in southwest Florida. This case study focused on how students apply the skills learned through the arts and how the students apply what they acquired through their arts courses to their STEM coursework and comprehension. This case study was framed by Maslow's hierarchy of needs (1943) in which Maslow describes the individual's need for self-actualization, Gardner's theory on multiple intelligences (1995) wherein Gardner theorizes there intelligences comes in a variety of forms, and Eisner's theories (2002) on the impact of the arts on other areas of the curriculum.

Significance of the Study

According to Schlegel (2014) students who work in the arts learn to be creative, increase their motor skills, and possess a high level of perception. Whether in the visual or performing arts, artists process new material or content, causing their brains to make connections among new ideas (Schlegel et al., 2014). With the recent increase in STEM education, Daugherty (2013) states the collaboration of the arts with STEM, creating STEAM, ultimatley educates students better.

The findings of this case study could assist educators at the state and local levels when planning curriculum and instructional goals for their STEM programs. Likewise, once educators

see the influence of the arts, they can implement the arts into STEM programs, solidifying STEAM in high schools and colleges. Equally, the results of this study will ultimately create students who are better prepared for their future, propelling the U.S. in STEM related fields globally. According to Wynn (2013) in order to meet the demands of the race to the top initiative, and in the increased emphasis on STEM curriculum and careers, innovation must be part of the calculation.

This case study is significant because it provides building blocks needed to transform STEM education to STEAM education. More importantly, the present study is unique in that research exists on the importance of STEM and the arts individually but is limited when combined. The fundamental goal in education is to make educational results evidence-based using measurable data like test scores ("Arts Education Partnership," 2012). Research in the arts demonstrates the benefits of the arts, ultimately keeping the arts as a fundamental part of education in the United States (Ruppert, 2006).

STEM and art combined, are referred to as STEAM. While many educators theorize as to the necessity of the combination, Steve Jobs often discussed the link between artistic design and creative thinking; he credited the necessity of creativity with his own achievements (Wynn & Harris, 2013). It is also worth noting that in the future scholars predict that the best leaders will have an art and design background (Maeda, 2012).

When students participate in the arts, the experiences contribute to the students' developmental thinking, social, and motivational skills, all of which are required for school and work (Arts Education Partnership, 2012). Arts education is disappearing from schools around the country due to budget cuts and shifting priorities (Ruppert, 2006). Yet, studies have shown that when the arts are integrated into a curriculum, student performance improves (Ruppert, 2006).

With the growing emphasis on STEM education and importance of STEM careers globally, it is important to gain an understanding of students' perspectives, regarding the impact of arts participation on learning comprehension in STEM coursework. Researchers note that every student learns differently. For example, according to Ruppert (2006), learning in the arts helps students cultivate the awareness that they can be instruments of their own learning. Learning through the arts contributes to the expansion of students' intellectual aptitudes (Ruppert, 2006). Students in this case study connected their experiences in the arts to comprehension and achievement in STEM coursework, which provides evidence to share with the school district, surrounding school districts, and at the state level. While STEM is growing in status in school districts across the country, the STEAM model has not gained in popularity. Professor Georgette Yakman has trained approximately 2000 teachers from 34 different countries including the United States, Korea, and Qatar, in the area a STEAM education (Yakman, 2016). Yakman believes by incorporating the arts into STEM, students will improve their comprehension and be better at problem-solving (Yakman, 2016). The possibility of creating a STEAM model for school officials to replicate could benefit students in school, their careers, and the goals of the United States to compete globally. STEAM collaboration allows for a richer educational experience for students (Saraniero, 2014).

Research Questions

This case study on how participation in the arts impacts learning comprehension for high school students during STEM coursework at two high schools in Southwest Florida, was guided by the following research questions:

Research Question One

How do arts students perceive skills learned in arts classes impact the comprehension of STEM material?

When a student participates in arts classes, they incorporate what they have learned and practiced in the arts classes, such as creative problem solving, development of their arts skills, and trial and error, ultimately being able to apply what they learn in arts classes to other disciplines (Eisner, 2002). By participating in the arts, students develop new patterns in their brain and create their own artifacts, allowing deeper understanding with new content (Schlegel, et al., 2014).

Research Question Two

How do arts students perceive practices and teaching strategies used by teachers during STEM classes inspire creativity?

When teachers provide students with various learning models in which multiple intelligences are incorporated, student comprehension, achievement, and interest increase (Eisner, 2002). Additionally, when teachers integrate the arts into other disciplines, learning new content can be less threatening (Wynn & Harris, 2013).

Research Question Three

How do students perceive their experiences in the arts impact their creative problem-solving in STEM coursework?

There are similarities between artists and scientists when displaying creativity and intuition and developing solutions when solving problems (Arcadias, & Corbet, 2015). Additionally, creativity has shown to be broken into phases of incubation, illumination, and

verification which can be linked with various learning experiences in the sciences (Simonton, 2012).

Research Question Four

How do teachers implement the arts into STEM courses at various grades and age levels?

Students and teachers will share the various techniques and strategies used by the teachers through in-depth interviews that will be recorded that helped with their learning comprehension and how their creativity may have evolved at various grade levels (Yin, 2014). Teachers are able to witness growth in students throughout the course of time and therefore have the ability to provide insight in regard to students' progress.

Definitions

Terms used in this case study are defined in this section and are supported by the literature.

1. Arts – The term *arts* in this study will refer to visual and performing arts, including painting, drawing, graphic arts, two-dimensional and three-dimensional, music, dance, and theatre (Eisner, 1994).
2. *Creativity* – Creativity in this study will refer to the imagination or development of non-traditional ideas (Eisner, 1994).
3. *Innovation* – Original methods or new ideas implemented into the learning process will be referred in this study to as innovation (Daugherty, 2013).
4. *Multiple intelligences* – A theory developed by Howard Gardner, that humans possess multiple types of intelligences will be referred to in this study as multiple intelligences (Gardner, 1995).

5. *Problem-solving* – Problem solving is the term used in this study to refer to the process students use to work through a problem to discover an answer (Eisner, 1994).
6. *STEAM* – STEAM is an educational framework that combines the arts with science, technology, engineering, and mathematics education (Yakman, 2016).
7. *STEM* – An educational framework that combines science, technology, engineering, and mathematics education will be referred to in this study as STEM.

Summary

The purpose of this qualitative case study was to understand the impact of participation in the arts on the STEM coursework learning comprehension for high school students at two high schools in southwest Florida. This case study focused on how students apply the skills learned through the arts, and how the students apply what they acquired through their arts courses to their STEM coursework and comprehension.

There has been an increased emphasis on STEM education across the United States (Masson, Klop, & Osseweijer, 2016). However, students may not be reaping the full benefits of a complete education and career preparedness in STEM fields (Jang, 2015). This study investigated the impact of participation in the arts on the learning comprehension of high school students during STEM coursework at two high schools in southwest Florida. Research exists among science, technology, engineering, and mathematical education; however, very little has been done to see how the arts impact student comprehension in those subjects.

CHAPTER TWO: LITERATURE REVIEW

Overview

The second chapter of this case study provides a theoretical framework for the basis of the research and an overview of literature relating to the arts and STEM. Education has become a series of assessments through standardized tests, in which the goal is to educate, develop, and prepare the whole child for the future. STEM subjects can be measured through standardized tests (Miller P. H., 2011). However, one area of education that is difficult to assess is the arts, therefore downgrading the arts as an essential part of one's education. Chapter Two presents a synthesis of STEM related studies and various disciplines in the arts. Additionally, the literature presented in this chapter provides a foundation to the argument for STEAM education rather than STEM education.

Theoretical Framework

The arts are needed for the cognitive, social, and emotional development of children (Gormon, 2010). Both Gardner's multiple intelligences (1995) and Maslow's hierarchy of needs (1943) help to enlighten this case study. In addition, Elliot Eisner's theory states the arts serve as models of educational practice at its best (Eisner, 1994).

Gardner (1995) asserts that the way students engage in the learning process, analyze what they have learned, and communicate what is learned, is the actual way learning takes place, not memorizing content (Owens, 2001). Gardner's Multiple Intelligences Theory (1995) suggests that an individual's intelligence comes in various forms (a) linguistic; (b) logical-mathematics; (c) music; (d) bodily-kinesthetic; (e) spatial; (f) interpersonal; (g) intrapersonal; (h) existentialist; and (i) naturalist (Smith, 2008). Gardner's theory may have begun as just that, theory; however, schools immediately put his theories into use (Gardner, 1995). Educators generally recognize

Gardner's theory of multiple intelligences, that students possess different strengths and abilities (Brummelen, 2009). It is important to note that Gardner defines intelligence as one's biological and psychological potential and that his MI theory is based on empirical evidence (1995). The intelligence focused on linguistic and logical-mathematics is viewed as an essential area of the MI theory in schools today (Smith, 2008). While Bailey (2009) states that the musical, bodily-kinesthetic, and spatial intelligence are normally associated with the arts, they are often overlooked. Emphasizing linguistics and the logical-mathematics intelligence, while overlooking the intelligence associated with the arts does a disservice to students who may have biological and psychological strengths in other areas. A student's learning style is their preferred way to learn new content (Kanar, 2014). Additionally, when subjects in school are approached from varying perspectives, more children will be reached, comprehension can be demonstrated in several ways, and a child's education becomes more personalized (Gardner, 1995). The student's comprehension refers to the ability to grasp the meaning of course material and be able to state it in their own words (Nilson, 2010).

Maslow (1943) stated that all people have a desire and need for self-esteem and self-actualization. Maslow's (1943) Theory of Human Motivation discusses the hierarchy of needs where human needs are placed on a scale of importance, arguing that the most important needs of a person must be met before other needs. For example, students must first have their biological needs met; food, sleep, and water. Second, students need to feel safe, secure, and orderly in their environment. Third, students desire to feel a sense of belonging within their relationships. The fourth area on the hierarchal scale, states that students need to feel respect for themselves and possess self-esteem. Lastly, students need to have self-actualization and to develop autonomy and realize their full potential (Owens, 2001). Far too often students are

motivated by grades rather than by being involved in the process of learning (Yokana, 2014). While grades can be a temporary motivator, students develop their self-esteem and self-awareness when they figure things out on their own and when they find their purpose in life. Teachers have the ability to help students realize their full potential. Self-esteem is based on the desire for a person to gain strength, achievement, adequacy, and confidence to live and be useful in this world (Maslow, 1943). Self-actualization is more specific and refers to self-fulfillment and realizing one's full potential (Maslow, 1943). Simply stated, a person must do whatever it s/he is designed for; a musician must make music, and an artist must make art (Maslow, 1943). Maslow's theories align with biblical principles and teachings; God blesses everyone with gifts they are to use. If STEM curriculum across the country formally adopted the arts as a necessary component, in theory, those students who are blessed with gifts in the arts, could comprehend and achieve more effectively in STEM coursework and possibly earn positions in STEM fields.

Elliot Eisner, an educator in several fields, including the arts, conducted qualitative research and was a curriculum reformer. He believed children learn how to discover the meanings of things through forms of representation. Students acquire meaning and understanding by interacting with the world (Eisner, 1994). Humans have the ability to distinguish qualities in their environment, recall those qualities, and are able to use their imagination to manipulate those qualities (Eisner, 2002). Mental images formed by the imagination are created from empirical qualities that are sensed as a response to the images (Eisner, 1994).

In order for the United States to be a global competitor and win the future, children will need to take on scientific jobs (Metcalf, 2014). The United States has emphasized the formal setting of STEM education (Nite, Capraro, Capraro, Morgan, & Peterson, 2014) while quietly overlooking the influence the arts have in STEM courses. The effects of arts education on other

subjects is the greatest when the arts are intentionally integrated into other areas (Eisner, 1999). STEM is a standards-based discipline where science, technology, engineering, and math teachers teach an integrated approach to instruction (Brown, 2012). As with other core subjects, STEM courses can be evaluated by assessments; the arts normally cannot be assessed in traditional formats (Miller, 2011). Technology is generally assessed by outcomes, content and methodology, and the relationship between process-based assessment (Abass, 2012). Whereas visual and performing arts assessments may be based on the experienced judgment of the teacher, explicit standards, or promotion (Stake & Munson, 2008). For example, Gardner views professional artists, plumbers, mechanics, and first-rate quarterbacks as professions in which high intelligence can be displayed in nontraditional ways (Miller, 2011). Traditional assessments, in which students are evaluated in the areas of science and mathematics, are measured with standardized tests. Standardized tests do not measure creativity (Sternberg, 2015). Research done in the arts needs to have the data looked at creatively in order to generate support for the research, not rely on the results of standardized tests (Thelwall & Delgado, 2015). Visual and performing arts offer non-traditional modes of instruction and learning. Elliot Eisner (2002) presented three criteria for evaluation methods in the visual arts: coherence, consensus, and usability. Opportunities for nontraditional educational experiences are equally as important as the traditional modes of education (Miller, 2011). Elliot Eisner (2002) has argued that the arts can serve as models of educational aspiration and practice at its best (Eisner, 2002). STEM by itself does not consider the learning elements found in the arts, elements that help students in developing solutions and original ideas (Riley, 2013). As the world changes, educational needs and goals evolve and change as a response to global needs (Daugherty, 2013). Arts advocates emphasized connections to the community in the 1970’s, art criticism and aesthetics in the

1980's, culture in the 1990's; now the importance of technology and innovation in the 21st century are emphasized (Bobick & DiCindio, 2012). Due to the increase in standardized assessments and STEM curriculum, other modes of education can become ideas of the past.

The arts are disciplines where students learn to think critically and how to analyze. A cognitive event involves any type of thinking (Eisner, 2002). Therefore, cognitive functions performed through the arts include high-level problem solving that comes from the students' interaction and experiences in the world (Eisner, 2002). If the goals of the U.S. center on 21st-century skills in STEM fields, and the arts help students learn at a higher level, incorporating the arts into a STEM curriculum would be beneficial to the students and the goals of the country. Gardner (1995) argues students should not be required to practice one modality of learning but be able to synthesize through several areas of intelligence, such as musical-rhythmic, visual, and kinesthetic learning (Owens, 2001). Therefore, what the students learn and how they learn it become life skills for adult problem solving (Owens, 2001). When students receive an arts education, they are better able to synthesize and carry over skills learned through the arts into their STEM subjects, learning and comprehending at a deeper level.

Students who learn better through visual means, and who practice creative problem-solving in arts classes could apply those skills in STEM coursework. According to Brinkman (2010) as students develop their creativity, their interests grow, they develop persistence, and they learn to tolerate ambiguity (Brinkman, 2010). Once a student can represent what they have experienced, the representation helps to expand consciousness (Eisner, 1994). Exposure to an arts curriculum could potentially allow students who had not considered a career in the much-needed STEM fields (Stevenson, 2014) to steer in the direction of STEM because they were able to realize their full potential through participation in the arts. In summary, Elliot Eisner's theory,

the arts can serve as a model of educational practices at its best (Eisner, 1994), combined with Howard Gardner's theory (1995) regarding the various types of intelligences such as musical-rhythmic, visual and kinesthetic, along with Maslow's theory (1943) regarding the importance of self-actualizing, all support art students, and could help educators steer the focus away from standardized testing as the end-all of educational standards.

The theories guiding this literature review and research intend to provide relevance to the combination of Gardner's modalities of learning (1995), with a focus on visual, rhythmic and kinesthetic learning, while addressing the importance of a child's self-esteem and development of their full potential based on Maslow's Hierarchy of Needs (1943), along with Elliot Eisner's theory (1994) that arts education fused with core subjects is education at its best.

The arts are unique to education in that they allow students to develop their problem-solving skills. What students see is not simply a function of what they take from the world, rather what they make of the world (Eisner, 2002). The arts teach students how to observe, visualize, manipulate materials, and aid in the development of the imagination (Yokana, 2014). Since education serves in the process of how to invent oneself, when students participate in the arts, they are essentially creating their lives by expanding their consciousness, shaping their dispositions, satisfying their quest for meaning, and sharing cultures (Eisner, 2002).

In an art class, students may be instructed to draw something, requiring them to look closely in order to see shapes and lines of the object they are trying to draw. Similarly to an artist a scientist must look closely at their work, both having to observe deeply (Yokana, 2014). However, the arts are unique, in that the arts require students to use their imagination more freely. When students use their imagination, they can see what is possible and what lies beyond what is right in front of them (Eisner, 2002). Art provides editing experiences while working, so

students can achieve precision or quality (Eisner, 2002). Once a student achieves a goal, figures something out on their own, and learns to comprehend new content in school, it aids in their self-esteem and self-actualization, part of Maslow's Hierarchy of Needs. When considering the importance of the role the arts play in other disciplines, top-ranking individuals in the sciences, engineering, and mathematics have offered great insight over the last one hundred years. Nobel laureates in the sciences were found two times more likely to be musicians or photographers than the average scientist, and approximately 20 times as likely to be active in the visual or performing arts. (Root-Bernstein, 2015). This provides validation to Gardner's MI theory that so many of the greatest minds in disciplines such as science and mathematics seem to also have experiences in the arts. It is plausible to conclude that these high achieving professional and Nobel laureates, may not have reached their full potential without having an arts background.

Related Literature

Research has been conducted in the areas of creativity, the arts, and STEM education in recent decades. However, implementation of the arts into STEM coursework is not readily practiced in education (Bequette & Bequette, 2012). The literature discussed in this review provides background information on STEM and arts education with the suggestion of renaming STEM to STEAM. Additionally, the role arts education and creativity play in American society and schools will be addressed. Lastly, the role teachers and schools can play, while infusing the arts into the STEM curriculum will be discussed.

History of STEM

STEM is the collaboration of four disciplines: science, technology, engineering, and mathematics, (Moore & Smith, 2014). The term or acronym "STEM" was coined by biologist and academic administrator, Judith Ramaley (Bell, 2015). Initially the acronym was "SMET";

however, in 2001, Ramaley who was the President of Winona State University at the time, thought STEM" had a more appealing sound (Bell, 2015). Science, technology, engineering, and mathematics are all fields that are outcome based. Ramaley intended to develop a curriculum where science and math served as "bookends" for technology and engineering, not necessarily an integrated curriculum (Bell, 2015).

STEM courses are deliberate connections that drive teaching practices through student observation, inquiry, and problem solving (Riley, 2013). Engineering is now integrated into the standards: students learn the principles of engineering and are involved in the engineering design practices (Miller, 2016). It is becoming more common for concepts to cross content areas. The concept of system models, for example, is used in the research of nuclear energies and ecosystems, where science standards focus more on core ideas and practices of the sciences, not just the facts (Miller, 2016). In the last decade, STEM has been promoted by politicians and government agencies, (Daugherty, 2013). Generally, students engage in lessons in order to learn how to solve meaningful world problems (Moore & Smith, 2014). Science is about investigating and experimenting: it allows children to develop their curiosity. Science also addresses questions like, "how do plants grow," and "how does ice melt?" (Sharapan, 2012). Whereas technology is associated with digital cameras and computers, it also includes simpler tools like scissors and pencils. Engineering allows students first to identify a problem, and then develop a solution. For example, children could use clay in order to meet the challenge of making a figure or model stand up. Lastly, math includes counting, sorting, identifying patterns, and language. For example, comparison words like bigger, smaller, higher and lower, help students use math skills to sort objects, (Sharapan, 2012). STEM education has become a focus in the U.S. because the country has fallen behind in scientific innovation, (Sharapan, 2012).

With the recent increase in STEM education, schools are receiving funding to expand these programs, leaving funding for the arts out of the calculation. Educators in STEM believe in order to expand STEM fields, transformation must occur in all learning environments, at more institutions, in every state and every classroom (Elrod, 2018). While importance has been given to science, technology, engineering, and mathematics education since President Dwight Eisenhower, the emphasis on education in the STEM subjects are being emphasized in PK-12 more so in the last decade (Daugherty, 2013). Currently, the U.S. has placed great emphasis on STEM education, with the theory that STEM is where the future opportunities lie. The government devotes $3 billion towards STEM education each year, more than other countries (Pittinsky & Diamante, 2015). Data have shown that federal and state agencies, politicians, for-profit and non-profit groups are promoting and funding STEM initiatives with the goal of making America an economic and political power (Daugherty, 2013). Students in Asian and European countries are excelling in STEM subjects; American students have been falling behind (Wynn & Harris, 2013). The rationale for the increase in STEM education comes from the low assessment scores in the past 10-20 years in PK-12 education in the United States (Daugherty, 2013). According to Daugherty (2013) students in America need to be well-versed in STEM subjects to compete in the 21st-century workplace.

Children are often asked throughout their schooling “What do you want to be when you grow up?” In elementary school, students of all ethnic backgrounds and genders express great interest in STEM fields, but that interest drops off once students reach high school and college (Pittinsky & Diamante, 2015). According to Pittinsky and Diamante (2015) the reason participation in the STEM fields drop off in high school, and college is due to the increase in difficulty. As the subjects get tougher in high school and college, there is less fun to be had as

when students were in elementary and middle school, and therefore less interest.

Renaming STEM to STEAM

A few studies have shown that infusing the arts into STEM enables students to see the world from different perspectives (Wynn & Harris, 2013). The arts play a key role in the development of the imagination and refinement of the senses; in essence, the arts allow students to have experiences that encourage exploration (Eisner, 2002). Creativity is needed to have innovation (Partnership for 21st Century Learning, n.d.). Daugherty (2013) has stated that to have optimal innovation in U.S. education, there needs to be a strong STEM and arts partnership. Authentic experiences in the arts and STEM courses can provide problem-solving skills within a student's community, and ultimately society. According to Daugherty (2013) research has shown that a key prospective component in fostering an innovative workforce in the STEM fields is the arts. Creativity is needed for the well-being of individuals as well as social and economic innovation (Collard & Looney, 2014). In order to make strides in the sciences, creativity must be understood (Hennessey & Amabile, 2010).

James Bequette, a curriculum and instruction professor and art education coordinator at the University of Minnesota and Marjorie Bequette, evaluation and research director at the Science Museum of Minnesota, both see a place for art and design education in the STEM conversation. Bequette et al. (2012) tracked the beginning of STEM education while investigating the incorporation of art and design, with the goal of renaming the approach STEAM. The researchers detailed the connections of problem-based learning (PBL) with the pedagogy of primarily engineering and art, which develop higher levels of thinking for students (Bequette & Bequette, 2012). PBL within art and engineering create authentic learning experiences as students investigate and take from real life experiences including aesthetic

analysis, which is firmly associated with the arts (Bequette & Bequette, 2012). PBL can be used as a tool to motivate students in various disciplines, especially the arts and engineering. When students use one mode of thinking from one discipline to understand another, they are able to synthesize concepts and theories (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014). When looking at the outcomes of engineers, city planners, architects, and other related fields, students studying in these areas learn how things work, how they look, and how to balance the function with the aesthetic views (Bequette & Bequette, 2012).

Education in the twenty-first century requires deeper and authentic learning with the high-quality output (Miller, 2014). Teachers working with PBL projects take the time to focus on the depth of the content, things that spread through the entire school year (Miller, 2016). The process of designing and creating bring about numerous ways of thinking and outcomes. An outcome may be in the form of an idea, concept, or an object made through an art medium (Bequette & Bequette, 2012). For an artist or designer, they go through steps in order to solve a problem, referred to as design thinking or habits of the mind (Bequette & Bequette, 2012). James Bequette and Marjorie Bequette (2012) invite art educators to get involved and collaborate with the STEAM education conversation and how it relates to 21st-century goals. It is important to note that James Bequette and Marjorie Bequette did not create the acronym STEAM, Rhode Island School of Design (RISD) has been the forerunner in the STEAM movement (Design, 2017). RISD's objectives for STEAM education is to change research policies to place art at the center of STEM while encouraging the integration of art in K–12 education and to influence employers to hire artists and designers in order to drive innovation (Design, 2017).

Engineers and designers approach problem-solving in similar ways. First, both an engineer and a designer must define what the problem is they are trying to solve. Both then

brainstorm and research as they problem solve. Also, the engineer and designer may come up with several solutions as they refine their work. While people in all types of occupations plan, an artist or designer plans arrangements of elements in order to create something visual (Bequette & Bequette, 2012). Both engineers and artists seek answers to problems in a visual format while believing that design thinking is a cognitive process (Bequette & Bequette, 2012). Additionally, Albert Einstein believed the greatest scientists were artists too: that both are alike in the way they are motivated by their ideas and imagination (Gurnon, Voss-Andreae, & Stanley, 2013)

According to Toni Wynn and Juliette Harris (2013), education needs to move toward a STEM + arts curriculum, ultimately creating the teacher team. Their goal is to infuse the arts into STEM, creating a different way of seeing and dealing with the world. STEAM provides opportunities for teachers to partner with each other so that students may learn about various disciplines simultaneously. Wynn et al. (2013) provide best practices for teachers, on how to incorporate skills in creative problem-solving. The teaching techniques build on one another in a sequential format, allowing students to apply creative ideas and thoughts in various disciplines. Lessons and professional development projects for educators are an essential part of the methodology. Steve Jobs, when working for Apple, often linked technology to creativity and artistic design as his main factor for his accomplishments (Wynn & Harris, 2013). Studies dealing with creative or visual experiences show it does not matter how the arts are taught for the experiences to benefit the learning outcomes in STEM (Root-Bernstein, 2015).

When children go through their elementary schooling, they become more curious in areas of science and mathematics. In high-level math courses, efforts become solo (Wynn & Harris, 2013). Unfortunately, when science and math become just quantitative, students lose the connection between math and real-life applications and can lose interest in science as the content

becomes more difficult (Wynn & Harris, 2013). If a student leans more toward the right-brain-oriented areas such as art, quantitative orientation loses appeal. In an environment where disciplines collaborate, such as STEAM, mathematics may be less intimidating while remaining challenging (Wynn & Harris, 2013). STEAM engages students in problem-solving, allowing students to use their creativity, ultimately creating life-long learners. The most successful artists and art students have shown highly developed technical skills and are highly intellectual (Wynn & Harris, 2013). STEAM allows science students to develop their imaginations and become more innovative while allowing art students to become better technicians and conceptual thinkers (Wynn & Harris, 2013).

Borrego and Henderson, (2014) stated that increasing the use of evidence-based teaching in STEM higher education could be relevant. Research is showing the importance and value of STEM education (Borrego & Henderson, 2014). However, training at the undergraduate level is low (Borrego & Henderson, 2014). In order to incorporate the arts into STEM, future participants need to be trained and prepared for the scope and methods of STEM courses (Borrego & Henderson, 2014). Interestingly, elementary aged students have more interest in STEM that high school or college students (Pittinsky & Diamante, 2015). The reason maybe that STEM education is considered fun in elementary school but then gets harder in high school and college (Pittinsky & Diamante, 2015). Although there has not been a mass surge in students graduating with STEM related college degrees, STEM jobs grew three times faster than non-STEM jobs between 2001-2011 (Pittinsky & Diamante, 2015). In order for the U.S. to compete internationally, have a stronger national defense, and foster healthier lives for its citizens, a STEM workforce is an integral part of the equation (Maeda, 2012). There have also been reports stating the U.S. is lagging behind other countries, adding to the fear that students will not be able

to compete in a global economy (Riley, 2013). To achieve the goals the White House has set forth for the nation, convergent thinkers and innovators need to become part of the STEM workforce (Maeda, 2012). Integrating more STEM education could aid in a positive shift, preparing students for a global economy (Riley, 2013). STEM jobs are expected to grow 17 to 18 percent by 2020 (Pittinsky & Diamante, 2015). In the U.S. priority has been given to align standards in order to make education efficient and measurable (Eisner, 2002), yet students in the U.S. still are not well prepared in science and mathematics (Pittinsky & Diamante, 2015). Supporters of integrating the arts into the STEM curriculum allows for a richer educational experience: "STEAM is complimentary with twenty-first-century skills, particularly the 4C's of creativity, collaboration, critical thinking and communication, and is gaining traction across the country with support from the National Science Foundation, the National Endowment for the Arts, the U.S. Department of Education," (Saraniero, 2014). By integrating the arts into other subjects, students have more authentic learning experiences by making connections in more than one subject (Richard & Treichel, 2013). Also, inquiry with openness in various disciplines enhances the learning experience for students (York-Barr, Sommers, Ghere, & Montie, 2006).

Wynn and Harris (2013) stated, by adding arts to the STEM curriculum, American students could turn things around. Despite the fact there are students who would consider themselves art students, all students can benefit from art experiences. Experiences in the arts provide students with a means of using their imagination and exploration (Eisner, 2002). Additionally, the arts deliver opportunities for students to slow down and really think in order to develop a road map for brainstorming, experimenting, and synthesizing information (Yokana, 2014).

Role of the Arts and Creativity

Arts education fosters a learning environment that develops patience and resilience and nurtures creativity (Tan, 2017). Far too often the arts are not emphasized enough or are completely deleted from a child's educational experience. According to Elliot Eisner (2002) the arts in America are part of the core subjects; however, they are not really considered necessary (Eisner, 2002). Arts are important in developing areas of the brain that are also used in STEM (Marcoux, 2013). Students can illustrate their ideas and new concepts, build models, or express their ideas through music, poetry, and theater. Many elementary school teachers already incorporate the arts into learning other disciplines, (Sharapan, 2012). Art education allows for problem-based learning, while students imagine their possibilities, (Bequette & Bequette, 2012). In art classes, students are asked to reflect on experiences and ideas and are taught to ask deep questions about humanity (Maeda, 2012). According to Wynn and Harris (2013), the arts are needed in order to have innovation. The arts help develop creativity and critical thinking due to the experiential nature of the arts (Grant & Patterson, 2016). Unfortunately, many school leaders view the arts as extra, not a need in a child's education. However, a key component in fostering an innovative workforce in the STEM related fields is the arts, (Daugherty, 2013). According to art educator, Elliot Eisner (2002) some cultures view the arts as a subject reserved for the privileged or society's more elite individuals, while other cultures see the arts as something fit for slaves or the offspring of artists. When the arts were introduced into the curriculum, the reason was based on a utilitarian rationale rather than academic (Daugherty, 2013).

Too often, teachers take pride in the uniqueness of their own discipline and that their area of expertise has little in common with other subjects (Daugherty, 2013). That type of mindset creates isolation in the school, and it is not natural for the student learner to keep subjects

isolated into pockets of content. Research has shown when students interact with other students, teachers, and ideas from other disciplines that knowledge, insight, and more effective conclusions result (Daugherty, 2013). Additionally, studies associated with the arts have shown an arts education benefits all students, especially students who are at an economical disadvantage (Ruppert, 2006).

Art educators must advocate for the arts by explaining to administrators, teachers, and parents how the arts allow students to explore, be creative, and problem solve. With the popularity of STEM education rapidly growing, it is plausible that by implementing the arts into STEM, students could benefit more from the collaborative efforts. Even in the medical field, the visual arts can be an asset. Physicians, nurses, and medical students who were part of controlled studies showed benefits from participating in courses when drawing and painting were used as part of the education of visual observing skill building (Root-Bernstein, 2015). The arts create a learning environment that is favorable to the teachers' and students' success by creating an environment that promotes innovation, engagement, increased student attendance, effective teaching practices, and positive professional settings (Ruppert, 2006). `

Creativity is a natural part of self-expression, social development, and innovation, (Collard & Looney, 2014). It is defined as a moment of insight, spontaneity of expression, and brainstorming (Hanson, 2014). According to Baldacchino (2013) creativity is linked to experiential learning and multiple intelligences through the arts. The modern work force requires creative problem solving, and individuals who can come up with new ideas. Unfortunately, words like 'creativity' and 'innovation' are not well defined in education, (Collard & Looney, 2014). Creativity is correlated to openness to experiences, (Simonton, 2012); however, there are no perfect formulas that apply to developing creativity. Sternberg (2010) conducted a study

which found that creative people possess six different, yet related sources: intellectual abilities, knowledge, styles of thinking, personality, motivation, and environment. Creative people are able to see problems in new ways and are not bound by conventional thinking (Sternberg, 2010). There are individuals who are identified as being creative from an early age, sometimes referred as ‘gifted.' Those individuals sometimes may arrive at the best solution to a problem in a short period of time, or with great simplicity (Collard & Looney, 2014).

Another study was done in conjunction with the Chicago Arts Partnerships in Education (CAPE) where public schools brought artists from the community into the schools to work with teachers in order to develop curricula units in which the arts were integrated into other subjects. The CAPE schools were shown in a comparative study, to outperform the students who did not have exposure to the integrated arts curriculum on standardized tests (Ruppert, 2006). Also, research has shown that the arts help expand the right hemisphere of the brain which is the part of the brain where creativity is fostered (Daugherty, 2013).

McGrath and Brown (2005) conducted a study with the intention of proposing that the visual arts could help students improve their cognition in STEM education (Daugherty, 2013). What they found reinforced the importance of learning through the arts as a way of using students’ visual senses in order to heighten learning and occupy the higher cognitive areas of the brain (Daugherty, 2013). Due to the results of their study, McGrath and Brown (2005) concluded that the visual arts could improve cognition in STEM education. Problem-based learning (PBL) can support creativity in STEM courses, bringing creative lesson plans can help diverse learners and improve motivation and critical thinking skills, (Meyer, 2012). In 2008, The Conference Board and Americans for the Arts conducted a study on the connections between creativity and workplace readiness. The study revealed that employers prefer creative individuals to those with

technical skills (Daugherty, 2013). The results of the study showed a preference for individuals who can problem solve, develop original ideas, display curiosity, integrate information across disciplines, and identify new patterns (Daugherty, 2013).

What Schools and Teachers can Do

In early childhood education, the arts are part of the curriculum. Elementary schools require the arts (ArtScan, 2014). Teachers of all grades need to allow students to explore, be creative, and to share what they have learned, (Marcoux, 2013). Most schools across the country have some type of arts program in their school system with teachers trained in the specific discipline, such as fine arts, visual arts, or performing arts (ArtScan, 2014). Teachers need professional development opportunities that incorporate hands-on training in order to implement the same in their classrooms (Admiraal et al., 2017). Schools that value creativity tend to produce better students than schools that do not value creativity (Sternberg, 2010). Students need to have their senses exposed to things like museums and art galleries. Teachers should get local civic groups, businesses, artists, and the governments in on the discussion, in order to sustain the arts, (Clark & Button, 2011). STEM teachers should re-evaluate how to incorporate art into their discipline, (Bequette & Bequette, 2012). Incorporating the arts into STEM courses provides opportunities for teachers to collaborate (Wynn & Harris, 2013). STEM teachers do not need to be experts in the arts, (Marcoux, 2013). Teachers realize that students experience great integrity and feel a sense of achievement when students articulate an idea through something made with their hands (Maeda, 2012).

In addition to helping students set goals and providing guidance, teachers often assess students' strengths and weaknesses while they themselves are evaluated on whether they differentiate their instruction. Teachers deal with the challenges of implementing all the

educational standards and best practices while still providing innovative instruction (Riley, 2013). Teachers want their students to succeed in every aspect of life and develop their own self-actualization. Educators need to provide environments for students to inquire, explore, synthesize, and construct their knowledge (Cheng, Li, Sun, & Huang, 2016). Schools continually assess procedures in order make improvements (Blankstein, 2004). Therefore, trying to foster growth, inspiring students, teaching each student at their individual level, all while keeping up with changes in the world today, educators are constantly trying to determine the perfect recipe to meet the needs of students simultaneously while keeping up with progress. As part of their training, elementary school teachers learn how to incorporate the arts into their teaching practices. But at the secondary level, if a teacher chooses to incorporate the arts into their methods, it is an occasional practice. This is because of the "teach to test" practice; teachers are pressured into teaching just the facts, rather than encouraging students to think on their own or problem solve creatively. In order for students to develop their minds, teachers need to provide opportunities that allow students to participate in tasks that require speech and writing – the arts provide this opportunity (Eisner, 2002). Teachers in STEM disciplines need to integrate the disciplines, not departmentalize (Corlu, Capraro, & Capraro, 2014)

Teachers generally desire to help each one of their students succeed. One-way teachers tap into the idea of reaching each child is to find where each child's talents lie. At the core of the Christian worldview of education, is the premise that all people have been given gifts by God that they are to use to glorify Him. Every child is born with gifts and talents. "Having gifts that differ according to the grace given to us, let us use them: if prophecy, in proportion to our faith; if service, in our serving; the one who teaches, in his teaching," (Romans 12:6-7, English Standard Version). Education needs to offer a balanced curriculum and provide opportunities to

reach students at every level and foster growth. Students who tend to be artistic and creative naturally, may often have difficulty learning new content in the other subjects by traditional means. There could be phenomenal future STEM professionals sitting in traditional classroom settings, learning in traditional formats, but never receiving the opportunity to flourish in a STEM career because their gifts, talents, and strengths were ignored during their education.

All states allocate funds to the arts, even during recessions; however, the amount of money differs from state to state and year to year (National Assembly of State Arts Agencies, 2014). Policies related to art education are developed through actions of state governments: governors, legislatures, commissioners, and boards of education (ArtScan, 2014). In 27 states the arts are considered core subject (ArtScan, 2014). It also important to note, there have been many longitudinal research studies that showed students who participate in arts education have improved scores on standardized tests in various subjects including math (National Assembly of State Arts Agencies, 2014). Art educators aid in the students' development of creativity while learning the in the arts classroom. In order to help students to develop their creativity, students must practice how to develop new ideas, then analyze their ideas and how to sell their ideas (Sternberg, 2010). Traditionally when you spend more, you get more; so far the evidence in science and math has shown American students in all grades, do not perform well, and yet it is not an issue of spending (Pittinsky & Diamante, 2015). Every year, the U.S. government provides $3 billion to STEM education, much more than countries that outrank students in STEM (Pittinsky & Diamante, 2015). Schools in the U.S. tend to favor students who display analytical skills and strong memories over creative children (Sternberg, 2010).

Infusing the Arts in STEM

Marcoux (2013) looked at the connections between technology, specifically electronic devices and computers that students use daily, and how art and design are visible in aspects of technology. Evidence has shown that learning and practicing forms of visual and performing arts enhance areas of the brain. Therefore, by adding arts to the curriculum of STEM, students would potentially show gains in achievement. The art experiences involved with the learning outcomes in STEM areas included computer-aided design, visual thinking exercises, drawing, painting, and sculpting. Additionally, drawing has been associated with kinesthetic thinking, which has been linked to engineering tasks and skills such as designing and building robots (Root-Bernstein, 2015). Studies show that infusing the arts into STEM allows for different ways of seeing the world (Wynn & Harris, 2013). Authentic experiences in the arts and sciences can provide problem-solving skills within a student's community and society (Clark & Button, 2011). Wynn and Harris (2013) explained that innovation increases quantum advances in all fields. Leonardo DaVinci, the great Renaissance master, may have marketed his own skills as an artist but was also an engineer, mathematician, scientist and botanist among other things. There are more technical drawings by DaVinci involving science and engineering than paintings (Zollner & Nathan, 2011). Leonardo DaVinci was an innovator way ahead of his time. He devoted sections of his drawings to hydraulics, diving suits, cranes, transmission of motion, lifting technologies and spinning machines (Zollner & Nathan, 2011). Additionally, Leonardo DaVinci used techniques referred to as sacred geometry and complimentary diagonals. While one may not initially notice the use of sacred geometry in Leonardo's work, essentially every painting he completed is set-up, planned out, then divided into triangles, circles, parallel lines and

intersecting points. Leonardo DaVinci used mathematics, an essential part of one's education, ultimately to complete his art.

In Figure 1, when looking at the parallel lines at the hairline, the top of the eyes and the upper lip, each parallel line divides the composition of the Mona Lisa into horizontal thirds. The triangle that peeks above her head, when flipped vertically, creates complementary diagonals, that when intersected, then create a third eye between her eyes. A common drawing technique when drawing out the human face is to divide the face into five eye-widths across. When inner triangles are added, *Mona Lisa's* corner of her lips line up with the corner of her eyes. Then several perfect circles are formed with each set of intersecting triangles. Also, when inner dividing lines are drawn through the middle of the triangles, a line intersecting through the middle of the eyes, through the nose, then meets at the chin. Additionally, parallel lines of the triangles connect through the eyes than through the tip of the nose.

Geometry and complimentary diagonals can be seen in the illustration of Leonardo DaVinci's *Mona Lisa* (See Figure 1).

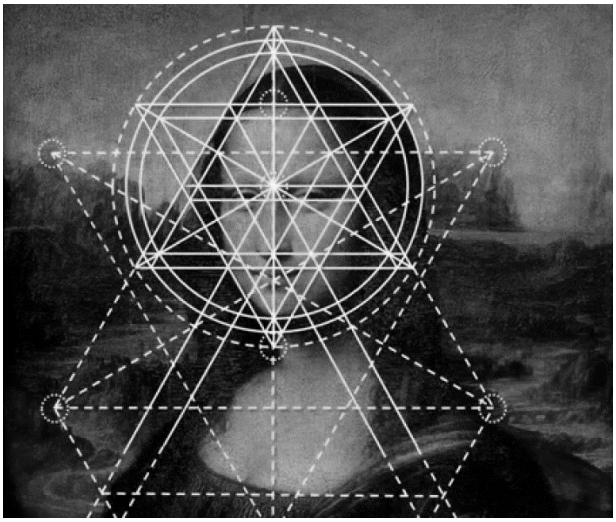

Figure 1. Illustration of Leonardo DaVinci, *Mona Lisa,* showing the geometric planning of the composition, permission from Dr. John F. Sase.

Leonardo DaVinci's *Last Supper* in Figure 2 can also be divided up into mathematical sections using rectangular grids and vanishing points. Leonardo DaVinci groups the 12 disciples into four groups of three, keeping the focal point on Jesus in the center. Several horizontal lines are drawn in Figure 2, that line up the crowns of the heads, the hands on the table, the hand gestures of the disciples, and the pieces of bread on the table. Also, the composition is divided into thirds vertically. Lastly, lines from the coffered ceiling, the tapestries on the wall, and the perspective of the room all line up behind the head of Jesus.

Geometry and complimentary diagonals can be seen in the illustration of Leonardo DaVinci's *Last Supper* (See Figure 2).

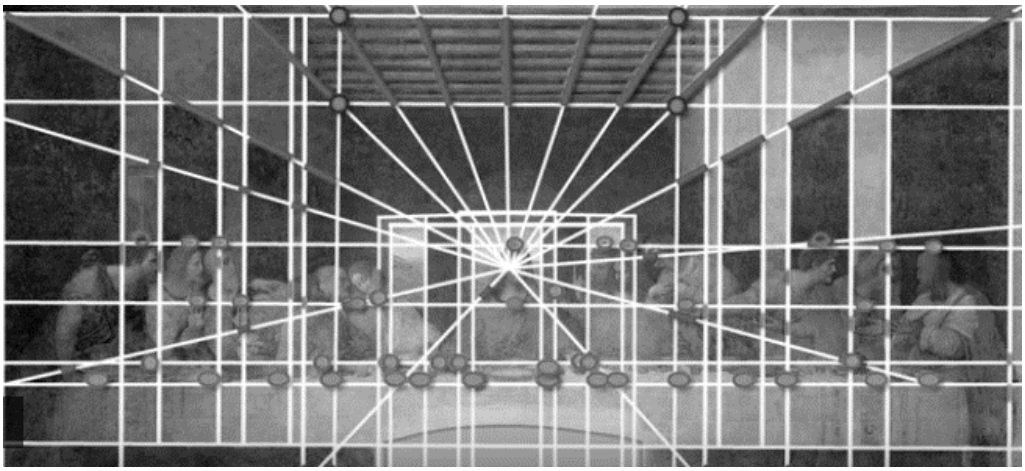

Figure. 2 Leonardo DaVinci *Last Supper*, showing the geometric planning of the composition, permission from Dr. John F. Sase.

According to Daugherty (2013) to have ideal innovation in U.S. education, there needs to be a robust art and STEM partnership. The skill of observation may be foundation for STEM professionals; however, it is overlooked in training and education for those wishing to pursue careers in STEM fields (Root-Bernstein, 2015). Some studies have suggested adding the arts to STEM could improve the workforce of tomorrow. The arts do not just make things look

aesthetically pleasing to the eye; they provide innovation through analogies, structures, models and skills (Root-Bernstein, 2015).

Connections Across Disciplines

Studies have found correlations between creative people and their hobbies or minor occupations referred to as avocational interest; creative people, when compared to an average person, tend to have more interests and venture into other areas (Root-Bernstein, 2015). The arts have positive effects on many areas in and out of the classroom: "Both psychology and psychoanalysis support approaches to teaching and learning in the arts, both have been interested in the nature, development, and functioning of the human mind, strongly influencing our contemporary understanding of what it means to be human within a physical, perceptual, emotional, and social world, and help us form ideas about what human productions are and can be" (Thomas, 2012). Statistics have shown better academic results from students who participate in the arts (National Assembly of State Arts Agencies, 2014). It has been determined that the most successful STEM professionals are more likely to have skills and side interests in the arts (Root-Bernstein, 2015). Successful STEM professionals argue that success in their fields requires a strong visual and spatial imagination, hand-eye coordination, and artistic sensibility (Root-Bernstein, 2015). All of these things are fostered through the arts. The global economy is driven by creativity, making the arts essential to a child's education (National Assembly of State Arts Agencies, 2014). When business leaders were surveyed, 85 percent reported there are not enough applicants with innovative and creative skills (National Assembly of State Arts Agencies, 2014). Companies today require workers with high-order thinking skills and creativity (National Assembly of State Arts Agencies, 2014). When creativity is added to a specific field, the ideas of that field can be propelled further (Sternberg, 2010). Statistical studies of STEM

professionals have revealed relationships between artistic, musical, literary, and craft activities when compared to Nobel Prizes and the sum of patents or companies established (Root-Bernstein, 2015). Nobel Prize winners, along with individuals with patents or who have started their own company, are more likely to have had a background in the arts.

Creativity can be learned through experiences and practices; it does not have to be inherited (Root-Bernstein, 2015). Even Nobel Prizewinner in science in 1906, Santiago Ramon y Cajal from Spain, believed creativity and imagination separated the average scientists from the great scientists. Scientists must be able to think in three-dimensions, graphically and have spatial imagination along with verbal and mathematical skills (Root-Bernstein, 2015). Leonardo DaVinci's creative and innovative mind seemed to anticipate industrialization a few hundred years before the industrial revolution (Zollner & Nathan, 2011). Additionally, sensorimotor experiences stem from the exposure to the arts, while imaginative engineers work is solely non-verbal and non-mathematical (Root-Bernstein, 2015). The creative aspects of technology do not rely on words, rather images in mind, so it is relevant to note, engineering students may be able to design things on a computer, but they need their hands to make things (Root-Bernstein, 2015). One of the greatest mathematicians of all times, Sofia Kovalevskaya, who was also a playwright and a poet, placed art at the center of her thinking. Kovalevskaya stated that mathematics was a science that required creativity (Root-Bernstein, 2015).

According to Sternberg (2010), creativity is a decision and is a skill that can be developed (Sternberg, 2010). Since creativity is needed for innovation, it is something that should be part of every child's education. There are many ways an individual develops their creativity and decision-making skills (Sternberg, 2010): (a) redefine problems, (b) question and analyze assumptions, (c) do not assume that creative ideas sell themselves, (d) tolerate ambiguity, (e)

allow mistakes, (f) encourage collaboration, and (g) see things from others' perspectives. A creative person simply buys low and sells high, meaning a creative person pursues unknown or unpopular ideas believing the idea may have potential. They will then persevere through the resistance others put up toward their unpopular idea (Sternberg, 2010). Sternberg (2010) calls the idea of buying low and selling high the investment theory.

The most commonly used assessment to measure creativity over the last 40 years has been the Torrance Tests of Creative Thinking (Torrance, 1974). Sternberg was inspired by Torrance. However, he used his own investment theory on creativity through studies and research in which he concluded creativity is a decision that one makes (Sternberg, 2010). His investment theory states that six interrelated yet distinct factors are needed for creativity: knowledge, intellectual ability, styles of thinking, personality, motivation, and environment (Sternberg, 2010). In one of Sternberg's studies, 80 people were presented with different kinds of reasoning problems in which there was only one best answer (Sternberg, 2010). An example of one of the studies dealt with predicting future states from past states, but the participants were not given complete information. For example, participants had to make predictions based on a problem where four kinds of people on a planet called Kyron: blends, who are born young and die young, chefs, who are born old and die old; balts, who were born young and died old; and prosses, who are born old and die young (Sternberg , 2010). An incorrect answer can demonstrate creativity; a creative person will draw upon existing knowledge then see different outcomes. Many times, it is assumed having a high IQ is associated with success, which is not always the case. Creativity can be learned through experiences and is not correlated with IQ (Root-Bernstein, 2015).

Another study conducted on creativity involved 60 participants. The participants were given inductive reasoning problems; completing a series, analogies, and classifications. The participants had to solve problems based on the premise that preceded the problem that was conventional (dancers wear shoes) or different (dancers eat shoes) (Sternberg, 2010). In his research Sternberg (2010) found correlations with novel or nonconventional responses as they were related to creative responses; the creative participants were more fluid in their ability to come up with an answer (Sternberg, 2010). Simply stated, creative people can think in a broader way when dealing with new ideas or concepts.

There are different types of learners in every classroom. Some students learn best through visual means, some can simply listen to instruction and absorb the content, while others can read their textbook then learn and retain information. Education should be personalized; children do not have the same types of minds, and individual differences should be considered (Gardner, 1995). So many students comprehend new content and even excel in subjects when they are given the opportunity to infuse the arts into what they are learning. If educators ignore or deny the different types of minds, education becomes uniform and is likely to serve a minority of students (Gardner, 1995).

Data in the Arts and Sciences

There have been correlations found in various studies between the highest level of successful individuals in mathematics, science, and engineering when those high achievers also have an arts background (Root-Bernstein, 2015). Correlation is not causation, but the evidence is of high interest to educators and those supporters of STEAM. One study looked at the learning of social studies and science for third and eighth graders. One group consisted of 225 third graders from a very low-income area in North Carolina. The other group was eighth graders from middle

to upper-class families in Maryland and California. The study broke the children into random groups in which they were assigned one of three instructional methods: memorization in group one, analytical thinking in group two, and a combination of creative, practical, and analytical thinking for group three. The first group was taught course content in a way that the students would have to memorize information. In the second group, the focus on the instruction was in analytical or critical thinking. The third group of students was taught in a combination of ways that emphasized analytical, creative, and practical thinking (Sternberg, 2010). All three groups completed multiple-choice assessments. Regardless of subject or grade level, the students who participated in the third group tested better than groups one or two (Sternberg, 2010). Simply stated, when creativity was added to the instructional methods, students outperformed the ones who did not have a creative component in their learning. This method showed that the students were able to expand on their strengths in order to translate the material (Sternberg, 2010).

Studies done in 1926, 1931, and 1975 showed college students majoring in a science who were also involved in other avocations, such as photography, drawing, dancing, crafts, mechanics, electronics, and woodworking showed higher achievements in science when compared to other the other college students who did not show any interest in the arts (Root-Bernstein, 2015). Another study of professionals in Israel discovered a correlation with creativity and intellectually stimulated avocations. While a study of mathematics in 1904 stated that the majority of mathematicians reported they had avocations in music, poetry, and art, similarly in 1902, 52% of mathematicians reported having musical avocations (Root-Bernstein, 2015). Similar to the math studies, studies of scientists have also found correlations between the success of scientists and avocations in the arts. In 2013, a study was done on individuals who had careers in science and were graduates of Michigan State University. The college graduates who either

founded a scientific company or who produced patents, were more likely to have participated in drawing, painting, photography, musical composition, dancing, or other crafts, when compared with other graduates working in the science field who had not produced a patent or founded a company (Root-Bernstein, 2015). Companies in the U.S. must compete in the international marketplace, which has shown that products must be more and more creative and unique (National Assembly of State Arts Agencies, 2014). In addition, engineers who excelled at research or innovation, were more likely to tolerate ambiguity, display empathy for others, possess skills at inducing patterns, be more artistic, and were usually cultured (Root-Bernstein, 2015). Additionally, the US National Academy of Engineering members are seven times more likely to participate in crafts like woodworking and metalworking when compared to the general population (Root-Bernstein, 2015).

Entrepreneurial endeavors in engineering, math, and science have a statistical correlation when those individuals participate in the arts throughout their lives (Root-Bernstein, 2015). While correlation is not causation, it is evident that successful STEM professionals who have avocations in the arts use their skills in their fields. The marketplace needs creative people who are innovative with products and services, making art education imperative to compete in the global marketplace (National Assembly of State Arts Agencies, 2014). Professionals in the STEM fields value the arts; a 2013 survey of mid-career scientists and engineers revealed that 82% of them believed the arts should be incorporated into STEM education (Root-Bernstein, 2015). This survey mirrors the results of a 1947 survey where 80% of the scientists listed in *American Men of Science* stated that their avocations in art related areas had a direct effect on their vocations (Root-Bernstein, 2015). It has been found that arts and crafts can provide anyone involved with STEM opportunities to develop their observation skills, their imagination, and

abstract thinking (Root-Bernstein, 2015). Furthermore, the arts can provide analogies that help solve STEM problems (Root-Bernstein, 2015). According to Root-Bernstein (2015) individuals in STEM fields have stated their experiences with the arts aided in their mental skill development. Scientists utilize mental tools that are normally associated with the arts; observing, play acting, imaging, modeling and synthesizing (Root-Bernstein, 2015).

Mathematician Benoit Mandelbrot, someone who claimed to mix math and art every day, was the inventor of fractals. He stated his draughtsman and his free hand art skills contributed to the development of his imagination (Root-Bernstein, 2015). “I always started with a quick drawing, which soon felt lacked something, and was aesthetically incomplete. It would improve if transformed by operations called simple projection or inversion with respect to some circle. After a few transformations of this sort, almost every shape became harmonious. This playful activity transformed impossibly difficult problems into simple ones” (Mandelbrot, 2012, p. 70). In mathematics, in order for students to exhibit growth in abstraction and generalizations, teachers should cultivate experiences and reflection, not stand and deliver (Zemelmen, Daniels, & Hyde, 1998) When neuroanatomist Ramon y Cajal was preparing neuroanatomical elements, he would do freehand drawings in order to interpret what he saw (Root-Bernstein, 2015).

Many STEM professionals have reported the necessity of being able to manipulate materials as an artist would (Root-Bernstein, 2015). According to art educator Elliot Eisner (2002), the arts make individuals more aware of the world around them. Hands on activities are often overlooked in schools and real-world applications. Nobel Prize winner in chemistry in 2002, John E. Sulston, attributed his success in chemistry to being a hands-on person, an artisan, a maker, and a doer (Root-Bernstein, 2015). Another Nobel Prize winner, Martin Perl, who earned that distinction in physics in 1995, similarly articulated how critical the concepts where

he learned in shop class; shop practices, equipment design and engineering drawing (Root-Bernstein, 2015). “What we see is not simply a function of what we take from the world, but what we make of it,” (Eisner, 2002). Constructing models and working with hand tools in shop classes proved to be invaluable to Thomas Steitz, the Nobel Prize winner in Chemistry in 2009. He stated the knowledge and skills he learned in his shop courses helped him at home and in the laboratory (Root-Bernstein, 2015). One method used to develop solutions to problems is analogizing which is the process of recognizing similarities. The arts have been used by STEM professionals to identify physical or structural similarities in STEM functions (Root-Bernstein, 2015). When a student is developing their creativity skills, they simultaneously develop their perceptual, interpretive and investigative skills (National Assembly of State Arts Agencies, 2014). The Nobel Laureate in 1912 in medicine, Alexis Carrel credited his surgical stitching skills to his mother who was a lace maker (Root-Bernstein, 2015). If the arts can provide creative stimulation in the sciences as suggested by STEM professionals and Nobel Prize winners, in theory, the arts should benefit all students (Root-Bernstein, 2015).

Summary

With the growth and emphasis on STEM education, many educators feel the arts should be included in creating a STEAM model for education. As the review of the literature in Chapter Two of this case study suggests, there is sufficient research on STEM curricula noting the importance of the arts and the need for creativity and innovation.

The theories that inspired this research are based on Gardner’s multiple intelligence (1995), Maslow’s hierarchy of needs (1943), and Eisner’s theory (1994) of how the arts should be an integral part of all school curriculum. High school art classes meet several aspects of the MI theory; musical-rhythmic, visual, and kinesthetic.

The review of the literature demonstrates the history of STEM, the need for innovation, and how STEM could be renamed STEAM. The global economy requires workers not just to be knowledgeable and productive, but creative and innovative (National Assembly of State Arts Agencies, 2014). The STEAM movement provides an opportunity for the U.S. to maintain its role as an innovator in the world (Maeda, 2012). The arts assist students in life by helping them develop social skills, problem-solving skills, aid in motivation and develop self-respect (National Assembly of State Arts Agencies, 2014) and this research could be beneficial for arts programs in any school by validating the importance of the arts in a child's education.

CHAPTER THREE: METHODS

Overview

The purpose of this qualitative case study was to understand the impact of participation in the arts on the STEM coursework learning comprehension for high school students at two high schools in southwest Florida. This case study discovered how students applied the skills learned through the arts, including painting, drawing, graphic arts, two-dimensional, and three-dimensional, music, and theatre, and how the students applied that knowledge and those experiences to their STEM coursework and comprehension. This case study is framed by Maslow's hierarchy of needs (1943) in which Maslow describes the individual's need for self-esteem, Gardner's theory on multiple intelligences (1995), and Eisner's theories (1994) on the impact of the arts on other areas of the curriculum.

Chapter Three addressed the research design that was used, restated the research questions, and described the setting and participants. In addition, Chapter Three explicated the procedures for conducting the study and defined my role as the researcher. Finally, the methods of data collection and analysis was explained, the steps that ensured trustworthiness was detailed, and ethical considerations acknowledged.

Design

This is a qualitative investigation that used a case study approach. This qualitative research study explored a contemporary phenomenon in a real-life context (Yin, 2014). A case study approach was selected because the participants' own perception of the impact the arts have on their comprehension in STEM coursework was detailed through interviews. A case study approach was appropriate for the study because the investigation focused on specific participants, six to eight high school students and four to six STEM teachers, at two locations, within a real-life setting, over a period of time, and included a variety of data (Creswell, 2013).

Case studies are a common form of research used in a variety of fields such as psychology, social work, education, community planning, and sociology (Yin, 2014). According to Creswell (2013) case studies have been popular in psychology, medicine, and law. The need for a case study may come from a need to comprehend some social phenomenon (Yin, 2014). Simply stated, a case study provides a researcher the opportunity to focus on a case or cases, while studying real life perspectives from small groups, school performance, or even organizational processes (Yin, 2014). An investigator in a case study will use various ways to gather information to explore a contemporary bounded system over a period of time (Creswell, 2013). Therefore, because there has not been much discussion or research on how the arts influence STEM, seeking participants who have experienced both could provide insight to educators in the future, and further STEAM research. Furthermore, multiple cases exist where students and teachers are involved in both the arts and STEM courses at different schools, making this a collective case study (Creswell, 2013). In a collective case study, a researcher purposefully selects multiple cases to show the varying viewpoints of each case (Creswell, 2013). In the present case study, the intent was to illustrate the experiences of multiple cases: students and teachers in the arts and STEM programs at a two high schools in southwest Florida.

Research Questions

Research Question One

How do arts students perceive skills learned in arts classes impact the comprehension of STEM material?

Research Question Two

How do arts students perceive practices used by teachers during STEM classes inspire creativity?

Research Question Three

How do students perceive their experiences in the arts impact their creative problem-solving in STEM coursework?

Research Question Four

How do teachers implement the arts into STEM courses at various grades and age levels?

Setting

The setting for this qualitative case study was two different schools in the same school district. One of the sites for the case study was a unique high school that has an established visual and performing arts academy, referred to as a VPA, that has also incorporated a STEM program. The pseudonym that was used for this school during the study is South County School. The South County School has approximately 2,300 students with a student population that consists of the following: 69% White, 15% Hispanic, 10% Black, 5% mixed, less than 1% Asian. More than half of the students receive a free or reduced lunch. Almost a third of the student population is exceptional student education (ESE), requiring special services. The South County School site was chosen, not just because of its convenience, but also because of its distinctive combination of arts and STEM programs of study for the high school students. The graduation rate for this VPA school is 82%, and the school grade has been a "B" for several years. This school has twice been selected by the state of Florida as an *Arts Achieve* school, which recognizes the artistic achievements of the students, curriculum, and rigor at the school.

South County School opened in 2001 as an academy high school, where students select a major as they enter the ninth grade. South County School was on a block schedule, consisting of four 90-minute periods each day. South County School eliminated block scheduling in 2008, and funding ceased for the academy programs. The arts program maintained its high standing in the

community with arts competitions and rigor even with the switch from 90-minute periods to a 48-minute period. In 2014, the former visual and performing arts academy was given the distinguished title VPA. The program is continually changing as school leaders try to alter the master schedule for the coming school years, implement an audition and portfolio process of acceptance, and secure funding for adjuncts to teach other sections. A new *National Art Honor Society* has been added to a notable group at the school in the last year. The STEM program was hatched in 2011, when the school brought in an engineering teacher and obtained a STEM grant. Since 2013, the students in the STEM program have competed in an annual event district wide, which includes robotic and design competitions.

The second location for this case study is North County School (pseudonym), another suburban comprehensive high school in Florida with close to 2600 students. The school is an International Baccalaureate (IB) school with an actively growing STEM program. It is an older school in the same school district as South County School and has been in existence almost 60 years. The student population consists of the following: 70% White, 13% Hispanic, 10% Black, 4% mixed, less than 3% Asian. Approximately 36% of the students receive free or reduced lunches; neither one of the high schools is a Title I school. The graduation rate for this IB school is 87%, and the school grade has fluctuated between an “A” and “B” school for the last five years. The school also has earned the distinguished *Arts Achieve* award from the state of Florida, while maintaining a long running *National Art Honor Society* on its campus.

Participants

There were 11 total participants in this study. I interviewed seven student participants for this study; four participants were selected from South County School, and three students from North County School. The participants were enrolled in STEM courses, including a technology-

based and engineering courses, and at least one arts class simultaneously at the time the interviews were conducted. Students were in grades 10-12 at the time of the interviews and were from one of two suburban high schools in Florida.

Additionally, I interviewed four teacher participants who teach a STEM course and have at least one of the student participants in class. Both high schools are unique because they offer specialized programs. South County School is a VPA school (a school with an identified special focus on the visual and performing arts) and has an award-winning STEM program. North County School is an International Baccalaureate (IB) school with an actively growing STEM program. Students were identified first through the assistance of guidance counselors. Guidance counselors have access to student schedules and computer software that identifies students who meet the criteria of the participants needed in this case study: art and STEM courses simultaneously. Students were selected based on the following criteria: students are simultaneously enrolled in an arts course and the STEM programs at the student's school, to add creditability to the study (Creswell, 2013). Research participants were given information about the case study, so they could make an informed decision whether they decided to participate in the study (Leedy & Ormrod, 2001).

Purposeful sampling was used in this case study. Both the participants at South County School and North County School were provided information explaining the research problem and phenomenon of the study (Creswell, 2013). The participants were informed so they understood the research problem of the case study (Creswell, 2013). The participants' rich descriptions of their experiences provided multiple perspectives and diverse views in this case study (Creswell, 2013).

Procedures

After I successfully defended the present study proposal, approval from the Institutional Review Board (IRB) was sought and approved (see Appendix A). The school district for the South County School and North County School was subsequently solicited for permission to conduct the research.

Once the school district approval was obtained, the next step in conducting the present research was to request permission from the principals of both South County School and North County School and then inform and ask for permission to conduct interviews and use the arts rooms for the interviews (see Appendix B). I provided the principals with my research plan, purpose, and research questions. Secondly, I informed the arts and STEM teachers with the purpose of this study (see Appendix C).

Guidance counselors at South County School and North County School aided in the identifying of the student participants at each school site to secure the total of student participants needed for the case study. Participants were required to be simultaneously enrolled in arts and STEM courses. Participants were identified with the use of district software that searched student schedules for the courses they were enrolled in. Once students were identified and notified of the research, I introduced myself, and invited students to participate. Once parents and participants signed and return the double-sided consent-assent form, initial meetings for interviews were scheduled with the students (see Appendix D).

Students, parents, administrators, and teachers were informed of my research methods and data collection beforehand. It was important for me to gain the confidence and trust of the participants (Creswell, 2013). To achieve data triangulation, three types of data were collected

including open-ended student individual interviews, open-ended teacher individual interviews, photographs of student work, and classroom observations (Creswell, 2013).

Individual interviews were held in the students' arts classes. The interviews were held in the arts rooms due to the format of the arts classes; classrooms are set up where students work independently on projects or in work stations. Interviews were in a location of the classroom pre-arranged with the arts teachers, so that classroom disruptions were kept to a minimum. All interviews were recorded using the app *Dragon Dictation* on an iPhone for later transcription.

Additionally, student work was photographed and images were converted to PDF files, to be accessed and saved in Microsoft Word. All data that was collected was backed up electronically on a hard drive and external flash drive.

Observations of participants served as another source of evidence in this case study, allowing for casual data to be collected (Yin, 2014). The analysis of the data included a constant-comparative approach in which the data collected from the participants was compared to existing data as themes and findings emerged. Memoing and notetaking also aided in the analysis of data, which included jottings, narratives, and drawings (Yin, 2014).

The Researcher's Role

As an art educator, I have a deep passion for the arts, and understanding of arts students. My role in this research was to conduct the interviews with the participants in this case study and to collect and analyze all the data. My assumptions in this case study are framed by my personal experiences as a former arts student and current arts educator. While in high school, I recognized my learning style was visual, and I flourished in environments that encouraged creative problem-solving rather than rote learning or memorization. Being required to memorize facts and details in order to pass a test was stressful and nonproductive for me. Throughout all my studies, the arts

have been part of my learning style, and how I comprehend new material. I believe that students in STEM courses most likely find success in STEM courses when they combine skills learned in the arts courses with STEM content.

I believe in the importance of all different styles of learning. With the recent growth in STEM education, I see a need for the arts to play an integral part in this movement. Therefore, I interviewed seven high school students who participate in both the arts and STEM programs, to understand the impact of participation in the arts on students learning comprehension in STEM coursework.

I am an art educator at the South County School. While the participants from that site were not my students, I realize they may be familiar with my position at the school. There are no students at North County School, who knew of my position within the school district at the time of the interviews.

My research allowed students to tell their stories and experiences, while they explained the learning strategies that worked best for them. I acknowledge that I may have a biased reason for conducting this case study and recognize that I must rely strictly to the results provided by participants without manipulating the participant's feedback. I have been an art educator for over 20 years, and I am currently a VPA department chair. During that time period, I have worked with many core subject area teachers on cross-curricular lessons, participating in the role of an arts expert. Additionally, I have facilitated academy showcases in which the core subject teachers displayed arts-integrated projects at an arts show. I have had arts students participate in the STEM competition for four years and have witnessed how creativity influences engineering and science. I believe that by allowing students to tell their own stories, share their own

educational experiences with the arts and STEM courses, and by providing open-ended questions, they will provide the connections between the arts and STEM.

As part of my introduction to each student participant, and to ensure trustworthiness, I informed the participants of my own experiences as a high school arts student. I explained how my experiences prompted the desire for this case study while stressing they share their own honest experiences.

Data Collection

For the present case study, data was collected using interviews, photographs of student works, and observations. Interviews were general, open-ended questions that focused on the arts and STEM. Student works were viewed and photographed to document evidence of the participants' arts and STEM comprehension. Observations of participants occurred in their assigned classrooms, in which I observed activities, conversations, and interactions (Creswell, 2013).

Open-Ended Student Interviews

I interviewed seven arts students who were also enrolled in STEM courses. Additionally, I interviewed four STEM teachers who have the student participants in class. Responses to open-ended semi-structured questions were recorded using my iPhone with the recorder application *Dictation Dragon* and then transcribed to text. Recorded transcripts were saved in Microsoft Word documents on a hard drive and an external flash drive. Each interview lasted from 30-45 minutes, providing enough time for rich descriptions and responses. I used three personal days and time after school, spread out over a month to conduct interviews. Interviews took place in the students' art rooms. I have chosen the arts rooms because many times it is a comfortable environment where students work independently on projects. I will not be a distraction to the arts

teachers there, whereas in a STEM classroom, an interview could disrupt instruction. Interviews with STEM teacher participants took place in each teacher's individual classrooms.

Open-Ended Student Interview Questions

1. Please introduce yourself.
2. Describe your experiences and what you believe are your strengths in the arts.
3. What arts media do you enjoy working with?
4. Tell me about an arts project you believe you successfully completed. Why do you believe you were successful with the project?
5. How do you define creative problem-solving?
6. Tell me about a STEM class lesson you believe you comprehended well. Why do you believe you were successful with the project?
7. Describe your comprehension of new STEM material when your teacher allows you to integrate creativity and arts skills into an assignment.
8. Describe your comprehension of new STEM material when the delivery or instructional method does not incorporate the arts.
9. Describe an assignment or assessment you believe you did well because of your creative solution.
10. Is there anything else you would like to mention about your experience with arts and STEM coursework?

The first three questions were intended to put each participant at ease with the me as the interviewer. The questions were meant to build trust and rapport with the me, so that the participants felt comfortable throughout the interview. According to Yin (2014) there are five levels of questions in a case study. Questions one through three fall under Level 1 questions;

friendly, personal views, and nonthreatening (Yin, 2014). It is important that participants provide detailed and honest responses to the questions; therefore, establishing a level of comfort in the beginning of the interview allowed for ease of responses with further questions.

Questions four through six were intended to provide an opportunity for students to explain events when they felt confident, when self-respect and autonomy were part of their story. Defining creative problem solving is placed between questions four and six because it is important for students to identify how their creative skills play a part in other areas of learning. Questions four through six follow a logical sequence from themes in the questions to the design of the study (Creswell, 2013). Participants described their successes and problem-solving approaches within their coursework.

Questions seven and eight were intended to provide participants with the opportunity to describe how their learning comprehension of STEM content may have been affected by their creative approach. These were key questions to the research; what the difference is with learning new STEM content when creativity or the arts are part of the learning process. Questions seven and eight focus on understanding the phenomenon in the study (Creswell, 2013).

Questions nine and 10 allowed participants to provide a final analysis of their own learning styles and opinions in regard to their learning experiences. Strong interview questions provide insightful perceptions and attitudes from the participants (Yin, 2014).

Open-Ended Arts and STEM Peer/Teacher Interviews

Open-Ended STEM Teacher Interviews

Interviews with four STEM teachers who have the student participants of the study in their classes were also conducted. In addition to interviewing students on my personal days, once interviews were finished with students, I interviewed STEM teachers individually regarding their

personal insight of the participants in the case study. Teacher interviews provided insight into the participants' behaviors and motives (Yin, 2014). In addition to providing insight regarding the student participants, peer reviews of the students' achievements and data collection provided an external check of my research questions and methods (Creswell, 2013). Responses to open ended questions were recorded on a smartphone, and then transcribed to text. Teachers were interviewed to offer feedback on the students' progress and creative problem-solving. Recorded transcripts were saved in Microsoft Word documents on the hard drive and an external flash drive.

Teacher Individual Interview Questions

1. Describe the methods of instruction you use in which you believe your students learn STEM content best.
2. What differences do you see between the STEM only students and the arts + STEM students?
3. What arts media do you believe your students enjoy working with?
4. Tell me about an arts project you believe your students successfully completed. Why do you believe your students were successful with the project?
5. How do you define creative problem-solving?
6. Tell me about a STEM class lesson you believe your students comprehended well? Why do you believe your students were successful with the project?
7. What are your thoughts about converting STEM to STEAM at the high school level?
8. Is there anything else you would like to mention about your students in this study?

The questions listed above are intended to get general feedback from STEM teachers on what they have seen in their classrooms when they implement the arts and how arts students compare

to non-arts students when it comes to performance and learning comprehension in their classes. The general purpose of interviewing STEM teachers is to corroborate certain findings, while maintaining an open-ended nature to the questions (Yin, 2014).

Photographs of Student Work

Students were asked to provide examples of their work from arts and STEM courses. Students provided assessment information in their own words, lesson objectives, what they learned from the assignment, and what connections they made. To collect evidence of the students' work, projects from STEM coursework such as visual aids were photographed with a digital camera.

An example of a student project can be seen in the illustration of the human heart (See Figure 3).

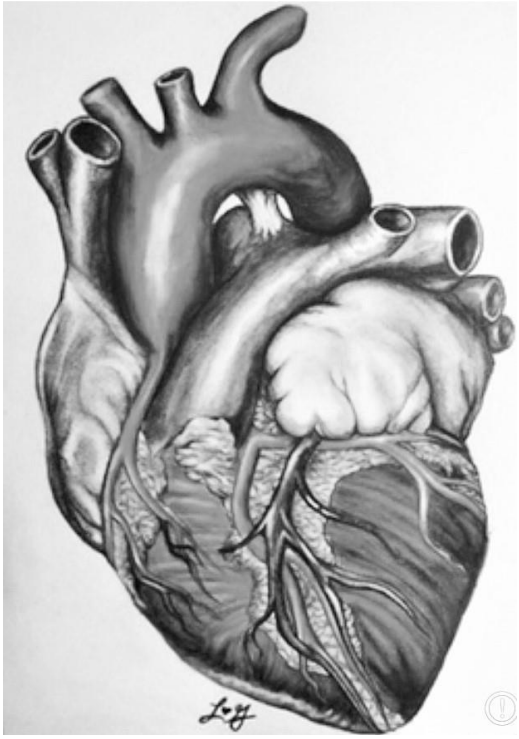

Figure 3. Student drawing, showing the human heart, permission from Lindsey Gill.

Observations

This case study took place in arts classrooms, creating an opportunity for direct observations (Yin, 2014). The classroom teachers introduced me and provided my purpose for being in the classroom, as a doctoral candidate conducting research on how the arts impact learning comprehension in STEM coursework. This allowed participants to feel more relaxed with my presence in the classroom to conduct my observations. Observation is an important tool for a researcher who is collecting data. A researcher needs to note the phenomenon in the setting through the researcher's own senses (Creswell, 2013). The phenomenon of interest in this case study is not based on historical facts, rather environmental and social conditions that can be observed (Yin, 2014). The observations took place while participants were in their classrooms, where their workspace and environment could be observed, providing additional information about the participants (Yin, 2014). My role as the researcher changed and evolved during the observations (Creswell, 2013), creating dialog with the student participants. As the observations were conducted, I recorded the physical environment, activities, and my personal reactions (Creswell, 2013).

Data Analysis

My role as the researcher for the present study required that I concurrently analyze data as it evolved. The approach to analyzing the data must be circular rather than linear in approach, meaning I could not analyze one point then go onto the next. A circular analysis involves moving from the various forms of data collection, from participants and circling through how the data are interrelated (Creswell, 2013). Therefore, I used a constant-comparative approach while analyzing the data. Constant comparative data analysis allowed the comparison of findings as data emerged during data collection. According to Yin (2014) the findings during data collection need to be

descriptive, while exploring and explain the meaning in the findings. To organize the data, I used reading and memoing as part of the spiral data analysis. I reread the transcripts, so that I could be immersed in the details. The process of rereading the transcripts allowed me to get a sense of the whole interview before breaking the interview into pieces (Creswell, 2013). Adding notes, memos, key phrases, and ideas into the field notes also aided in the process of exploring the data (Creswell, 2013).

As a researcher collects data, they anticipate pertinent implications will come to the surface (Creswell, 2013). Real-life happenings intertwine in a multifaceted manner, rather than in a linear form, creating a need for direct interpretation of data (Yin, 2014). The researcher determines configurations in two or more categories, which will take the form of a table, conceivably a 2 x 2 table, which illustrates the association of two classifications (Creswell, 2013). After the data was assembled into a Word table, I was able to see if there were similarities and differences between participants. This enabled me to look for patterns within categories (Creswell, 2013). Some participants had similar experiences when enrolled in arts and STEM courses. Teachers noticed how arts students used their creative influence when problem-solving or how the students approached new content.

Classifying the data by using categorical aggregation to categorize the participants' feedback, place unorganized feedback into categories, and ascertain patterns and themes, helped me to document the account of the cases being studied (Creswell, 2013). I viewed the data and then simply pulled meanings from the single instance without looking for numerous occurrences, making a direct interpretation (Creswell, 2013, p. 199). I tweaked the data, and then reconstructed the data in more consequential ways.

Lastly, I interpreted the data as part of the analysis for the case study. In the present study, the participants' interviews were analyzed, then the feedback categorized to create a detailed description of each case and generate overall themes.

Trustworthiness

Numerous procedures were taken to ensure the trustworthiness of this qualitative case study, including credibility, dependability, confirmability, and transferability.

Credibility

The credibility of this case study depended on the richness of the information the participants provided and my ability to accurately describe the details. I had to clarify my researcher bias to validate my research. As the researcher, I commented on past experiences, preferences, and preconceptions, (my own experience with arts). As the researcher, I inevitably allowed my experiences to influence the approach to the case study. My analytical abilities relied on a proficiency, keeping up with linked research, safeguarding accuracy, and striving for credibility (Yin, 2014). Lastly, thick, and detailed descriptions of participants, settings, and the feedback from interviews became an imperative part of the research.

Dependability and Confirmability

Dependability refers to the consistency of the findings that are discovered through the interviews. Through student interviews, patterns and connections were made through the feedback from the participants. Additionally, peers in the field of education who have successfully completed the doctoral journey offered insight. The guidance and advice of a peer who has successfully completed their dissertation is invaluable, therefore utilizing the expertise and experience, of those professionals was also used. I had peers review my findings because, research checked by an external source verified the dependability of my research (Creswell, 2013). Confirmability demonstrates that the findings in this case study were supported by

empirical facts. Both dependability and confirmability are addressed through the rich details within the context of the study.

Transferability

Another way to confirm trustworthiness in a case study is to determine if the findings can be transferred in other education settings. Transferability in this case study, refers to the possibility that findings could be transferred in other contexts (Yin, 2014). The arts were shown to help students comprehend the material of the students' in STEM courses, future students enrolled in STEM courses could then be encouraged or even required to participate in some form of the arts. In addition, STEM teachers were able to add their insight to the students' success in the STEM coursework and assessments.

Ethical Considerations

One conceivable ethical issue when conducting a case study is confidentiality. To ensure valid feedback and for participants to feel at ease and give honest feedback during the interviews, I used a pseudonym for all participants. Informed consent forms for parents and assent forms for student participants was used to secure permission to interview participants. To assure participants and their parents that no harm was done during the research and that the research could benefit the field of education, the purpose of the study and interview questions were provided before any participants agreed to participate. All data collected was saved on password-protected devices. Also, teacher participants were provided with an overview of the study, the purpose, and how this study could benefit education. My position at the school had no influence on the study. The participants shared their experiences. Lastly, participants were informed that

they could have decided not to participate in the study at any time during the study, without any reason or penalty of any kind.

Summary

A case study design was used in this qualitative research because the research involved a study in a real-life setting (Creswell, 2013). The student participants in this case study shared their experiences with the arts and STEM courses. The settings were a VPA and IB public high school in the same school district in southwest Florida. Before any students were solicited for participation, I had to obtain permission from the IRB and the school district to conduct interviews. I acknowledge I did not allow any bias to come through as the participants told their own story. During the interviews, participants answered 10 open-ended questions. All the questions had a clear purpose, which allowed the participants to share their experiences in the arts and STEM openly. Teachers who were involved in the STEM courses were also interviewed with questions relating to their fields. The data was analyzed with Word tables, allowing me to interpret the data directly and to see if any natural generalizations could be made. To determine if this case study shows trustworthiness and is valid in the field of education, credibility, dependability, confirmability, and transferability were all evaluated. Transferability was evaluated because of the possibility that the findings could be transferred in other contexts. The richness of the information the participants made available, provided credibility to the study. Results of the study were confirmed through peer reviews of the findings. Lastly, the ethical considerations in this case study centered on the privacy of the participants and securing the data. All the participants had a pseudonym chosen for them, and all devices where data was stored are password protected.

CHAPTER FOUR: FINDINGS

Overview

The central focus of the present case study was to discover the impact of participation in the arts on learning comprehension for high school students during STEM coursework at two high schools in Southwest Florida. This chapter reports the findings of the case study and includes individual descriptions of the study participants, presentation of the themes and accompanying subthemes that emerged during the data analysis, and responses to the research questions according to the findings of the study.

Participants

I interviewed seven high school students and four high school teachers in this case study. The participants are from one of two public high schools, in the same school district in Southwest Florida. Student participants were interviewed during class time; permission was given prior to the interviews. Teacher participants volunteered time after school or their planning period for their interviews. Artifacts of student work were provided by participants. Some of the photographs were provided to me through email. Most of the artifacts, I photographed during follow-up visits to classrooms.

All of the participants were eager to share their experiences and thoughts during the interviews. Table 1 (below) contains student participant profiles previously described: the age of the student participants, gender, and their most active area or interest in the arts.

Table 1

Student Participant Profiles

Name	Age	Gender	Arts Area of Interest
Andre	18	M	Music
Gavin	16	M	2-D Art
Lynn	17	F	Theatre
Robert	17	M	Music
Steve	17	M	3-D Art
Theo	17	F	3-D Art
Zach	18	M	2-D Art

Andre

Andre, an 18-year-old student participant in the study, is a senior at the South County High School and has been involved in the music and engineering programs since he was in middle school. As a high school student, he has successfully completed the Advanced International Certificate of Education (AICE) in chemistry and is currently enrolled in AICE physics. Andre has taken algebra II honors, tested out of college algebra and statistics, and is currently enrolled in Advanced Placement (AP) calculus. Presently, Andre is taking his fourth year of engineering at the high school level. He also participates in the school orchestra program. Andre can play the cello, piano, and is learning the guitar right now. Reading music is practically effortless to Andre. Even in middle school, playing music came easily to Andre without much practice. Andre stated, “the arts, music particularly, I have kind of a natural affliction, I’ve always been good at it.” Andre described music as his passion; nevertheless, he plans on going into engineering as a career.

Gavin

Gavin is 16 years old and a junior at the South County school. Currently he is in engineering III and his third year of taking visual arts classes. He has participated in engineering

competitions and art shows over the last two years. Additionally, Gavin is enrolled in advanced topics in mathematics and Pre-AICE physics. Gavin enjoys drawing with traditional art media and working with computers, especially CAD software. Gavin explained that visualizing his ideas before he makes something, whether by hand or on a computer, comes effortlessly to him. "Whenever I create art, I am visualizing in my head what my project will look like before it is even finished, it makes to process easier and fluid for me." Gavin described himself as detail oriented and analytical. "Analyzing all of the details of something before I make it and while I am making it, I think helps me be successful."

Lynn

Lynn was another student participant in the present study. She is 17 years old, a senior at the South County school, and a member of the Visual Performing Arts Academy (VPA). She has taken musical theatre, acting I-III, and is currently taking acting IV, a directing class and is enrolled in engineering II. Lynn plans on going into marine biology and possibly studying for her LPN so she can work while going through college. Lynn has been acting in plays and performing in musicals since the age of eight. She describes acting and singing as her passion, "my entire life I have had a passion for things like Jane Austen and Shakespeare." Lynn has participated in 12 shows since the age of eight. Lynn also enjoys the technical side of a theatre production, especially operating the soundboard. She explained "there's several aspects that I love, singing, acting, costume design and I especially love doing the soundboard and adjusting the mics."

Robert

Robert is a 17-year-old senior at the North County school. Robert has been very involved in the music program at his school. Robert has been a member of his high school's marching band all four years of high school. He plays tenor saxophone in which he is the section leader

and has played that instrument since the sixth grade. He also plays the piano and clarinet. Robert is very proud of his role in the school's marching band. In addition to his involvement in the music program at his high school, Robert is in the International Baccalaureate (IB) career program with a focus on engineering at his school. He stated he is looking at going to college for biomedical engineering. "I am interested in dealing with prosthetics and artificial organs, it is of great interest to me and seems like an emerging field."

Steve

Steve is a 17-year-old senior at the South County school. He had two years of visual arts and is currently in ceramics. Also, Steve is in his fourth year of engineering. Steve has successfully completed the required math and science courses for graduation; physics, biology, chemistry, algebra I, algebra II, geometry and is currently enrolled in advanced mathematical topics. Steve is not sure if he wants to go to college. He describes himself as an outdoor enthusiast who enjoys working on cars, boats, fishing, and fixing and building things. "I like working with my hands, whether it's making something out of clay or fixing a broken-down boat, I am determined to be successful with whatever I am working on." Steve also described himself as a patient and determined young man. Long, involved projects or fixing things attracts Steve whether in or out of school.

Theo

Theo is a 17-year-old senior at the North County school. She is currently enrolled in ceramics III honors, and engineering, design and development class. Moreover, Theo is taking AP physics and has a 4.7 weighted grade point average. She loves math and found calculus and statistics to be some of her favorite courses. In her free time, she enjoys painting and drawing but doesn't feel those are areas of particular strengths. Wheel throwing and building vessels from the

coil method in ceramics are her favorites. Theo prefers to make practical pieces or utility type of objects such as bowls and cups rather than sculptures. “My strengths in ceramics, at least, are going on the wheel, throwing bowls and vases, and making vessels from coils, stuff that be utilized.” Theo plans on going to college after she graduates and majoring in engineering.

Zach

Zach is an 18-year old senior who has been in engineering classes since middle school. He always wanted to be an engineer until recently. Zach is in his second art class. He has always loved sewing and designing with fabric. As a senior, Zach decided to pursue a major in fashion design and has recently applied to college. He describes himself as creative person and enjoys brainstorming ideas for projects and fashion. Zach confidently declared, “My strengths in the arts is problem solving. I am really good at creative thinking, coming up with ideas, imaging solutions and working through the bumps in the road.” Zach considers himself bright and a nonconformist to the routine and standardization of the traditional public-school system.

Table 2 (below) contains teacher participant profiles previously described: the number of years they have taught, the subject they teach, and whether they think STEM should become STEAM.

Table 2

Teacher Participant Profiles

Name	Years Teaching	Subject	STEM to STEAM
Mrs. Amber	3	Technology	No
Mrs. Bozeman	18	Science	Yes
Mr. Dilbert	7	Engineering	Yes
Mrs. White	14	Mathematics	No

Mrs. Amber

Mrs. Amber is a teacher participant in the present study. She has taught technology classes for three years. She used to teach Microsoft products, but is presently teaching an Adobe Photoshop class. Students work towards getting a certification in her classes. The Adobe Photoshop class is not an art class; it is a technology class in which students learn how to use the various tools in the program. Mrs. Amber uses *Lanschool* when she teaches; a program that allows the students to see a mirror image of the teacher's computer. Students have to follow along with Mrs. Amber's steps, and she can also answer questions and help students directly on the student's computer. "While I am demonstrated a lesson using *Lanschool*, students watch my computer on their own computer screens, then are given time to complete the required steps. If they finish the assignment early, I require them to be editing something, anything for that matter in Photoshop. The students have to continually be working in the program to continue learning it." Mrs. Amber does require students make things in Adobe Photoshop, so the products created are visual in nature.

Mrs. Bozeman

Mrs. Bozeman is a teacher participant in the present study. Mrs. Bozeman has been a high school science teacher for 18 years. She earned her bachelor's degree in secondary education with a specialization in biology, and a master's in education, curriculum and instruction. Currently she is teaching biology and human anatomy and physiology. In addition to having students conduct labs, she also incorporates visual instructional methods and practices into her classes. "I find by chunking new ideas and incorporating a variety of teaching methods into every lesson, my students do very well on their assessments when compared to using only one teaching method. Also, I use guided notes, where I print notes and diagrams from my

flipcharts, but leave certain areas blank for students to fill in as I cover the lesson." In her anatomy classes, students have to learn the names of all of the bones and muscles. Mrs. Bozeman has students create three-dimensional models out of various materials.

An example of a student project can be seen in the illustration of the human hand (See Figure 4).

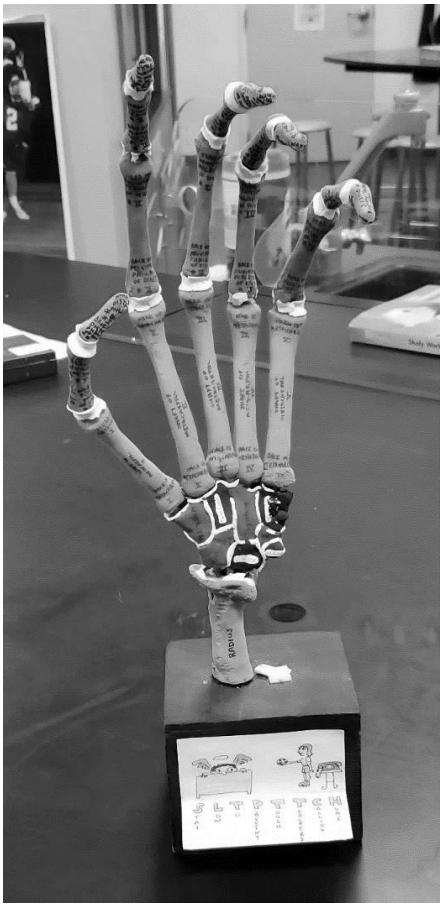

Figure 4. Student model of human hand, showing the names of the bones, permission from Mrs. Bozeman.

Mr. Dilbert

Mr. Dilbert is teacher participant in the present study; he earned his college degree in electrical engineering and computers. He worked as an electrical engineer before becoming a public-school teacher in Florida. He has taught seven years at the South County school. The classes he currently teaches are applied engineering I-III and a fourth-year class called technical

knowledge. Mr. Dilbert's practical knowledge as an electrical engineer for twenty years has helped him bring real-world experiences to his classroom. "Coming from an engineering background, the best way to teach engineering is to teach students the concept but then make the students apply the new knowledge." Mr. Dilbert believes the most effective way to teach his students is through several steps. First students are presented with the new lesson or concept. Students are then instructed on the software or method of building something in engineering. Then there is an activity or lab that goes with what the students have learned. Students are required to design and build something as part of the lesson. These methods allow the students to master the content. His engineering classes earn industry certifications, compete at the local level in STEM competitions, and compete at the state level.

Mrs. White

Mrs. White is a teacher participant in the present study. She has been teaching mathematics for 14 years in Florida, some of which were online. She has taught algebra I-II, advanced topics, and AP statistics. Mrs. White brings visuals into her mathematics lessons and has examples of student work hanging all over her classroom. She also enjoys varying her instructional practices to meet the needs of all the different types of learners in her classes. "I feel it is important to make learning relevant to the students' lives, so I always try to bring real-world applications into my lessons."

Results

This section is organized thematically and according to the research questions. The themes, subthemes, and codes that were generated from the data are displayed in Table 3. More than 60 codes emerged during analysis of the data, and from the codes, seven distinct clusters emerged as subthemes. The subthemes were subsequently placed into overarching naturally

occurring groups, resulting in the three major themes of the study: Life Skills, Success in the Classroom, and Proficiency. Table 3 below shows the results of the major themes, sub-themes and codes that emerged during data analysis.

Table 3

Themes, Sub-Themes and Codes

Major Themes	Subthemes	Codes
Life Skills	Learning Patience	Projects take time to develop and create (14) Building or creating takes time (13) Struggling while learning develops patience (11) Practice a skill repeatedly (9) Work through mistakes (7) Research all aspects of an assignment (7) Preparing for a performance (6)
	Practice	Years of involvement (14) Start learning young (12) Schedule time (11) Sketching ideas (9) Repetition (9) Sketching ideas Trial and error (8) Achievements after practicing (7) Learning through steps or procedures (7) Time consuming (6) Determination (5)
Success in the Classroom	Learning Visually	Building projects with hands; creating visuals 13) Use of diagrams, images and photographs (13) Clear comprehension with visual aid (11) Creating things through visuals (11) Drawing a picture (6) Visualizing while working (6) Use of 3-D printer (4) Dissections allow for visual learning (3)
	Brainstorming	Group work (9) Problem-solving (9) Experimentation (8) Open-ended projects (7) Think outside the box/outside guidelines (7)

		Various solutions to a problem (5)
	Real-World Knowledge	Hands-on activities (8) Make functioning items (8) Opportunities for real experiences (7) Make something that is useful (7) How students are going to use knowledge (6) Make content/material pertinent (5) Practical (5)
Proficiency	Time	Experimentation (8) Combined instructional methods (8) Blended strategies (7) More time helps learning comprehension (7) Time to learn in various ways (6) Time to plan (6) Fully understand (6) Time for discussion (6) Time provided for research (6) Breaking content into smaller parts (5) Instruction over several class periods (4) Time for formative and summative assessments (4)
	Collaboration	Students brainstorm together (8) Develop own solutions (8) Helps students with mastery (6) Analyze ideas/solutions (6) Students put ideas/concepts in their own words (5) Dialog using terminology (5) Students with varying gifts/talents (5) Take ownership (4) Students teach each other (4) Balanced teams/groups of students (4) Flexibility (4) Student centered (3)

Theme Development

The central focus of the present case study was to discover the impact of participation in the arts on learning comprehension for high school students during STEM coursework. The individual interviews of student participants provided the participants with an opportunity to explain how they believe they learn best. The major themes of the study emerged from analysis

of the student participants' discussions of their experiences in the arts classes and STEM classes. Additionally, when interviewed individually, the four STEM teachers in the study reinforced the themes discovered during analysis of the student data. The STEM teachers in the study discussed their own teaching practices, arts students, and non-arts students in their classes.

Major Theme One: Life Skills

The first major theme that emerged during data analysis was life skills. The central theme to one's education centers on preparing the individual for life. Students want to be prepared for their adult lives. Students learned the life skills of being patient while learning something new, and the value of practicing something new until one masters the new skill. The process and purpose of an education is concerned with fostering a student's ability to construct and develop a deeper meaning of what they are learning (Eisner, 1994). During interviews in this case study, student and STEM teacher participants answered several interview questions. Some participants provided visual examples of their work. Through this process, the first major theme of life skills evolved. Science teacher, Ms. Bozeman explained "my students want to know why they have to learn something, where they are going to use this knowledge, and how they can apply this knowledge. If students understand the why, where and how, they are more inclined to take it seriously, and take the time to really absorb, rather than try to memorize the information" (Ms. Bozeman interview, 10/19/18). She explained further, when a student values what they are learning, they are more patient with themselves while learning new concepts and material. While participants may not have used the terminology of life skills, student participants described ways they used the arts in varying situations, including their STEM classes. Students need to be patient when learning something new. Patience allows for perseverance. Student participant, Lynn, who has been heavily involved in theatre for many years describes "I had two weeks to learn the lines

of the main character Theseus in *A Midsummer's Night Dream*. It was hard for me for two reasons, the short amount time to learn my lines and the gender of the character, me being a girl, having to play a guy. My main thing was repeating the lines and having my friend read back my lines when I got them incorrect, if I got the lines right, my friend read the next cue line for me" (Lynn, Interview. 10/19/18). Students described how practicing something helps them master the skill. Whether its years of theatre and musical practice or practicing math problem mastery, practice does make perfect.

Steve described how he has developed the ability to work on cars and boats, something he will most likely continue into adulthood. Several student participants described learning patience through trial and error, problem solving, and persevering through their arts classes. Robert, a senior in high school, described his schooling experience as he became more involved with the marching band and IB program at his school. Robert learned to be patient with himself as he struggled and learned new things. He also described how important practicing something was to him in order to improve. Through the interviews, student participants described how practicing a musical instrument or lines for a play built their confidence and help foster the notion practice makes perfect. Developing patience and the value of practicing something new are skills that transfer into various areas. Students can apply these life skills in other classes and in their future careers.

Learning patience. The first subtheme discovered within Major Theme One was learning patience. Student participants felt through the arts they learned how to be patient when working with musical instruments and making objects or drawings from scratch. Developing patience through the arts was transferred into the students' science, technology, mathematics, and especially their engineering classes. Students felt that by allowing themselves time to learn

something new, making mistakes and struggling at times were part of the learning process. All the student participants were able to describe projects in their engineering classes that took time to develop and create. Another theme that emerged was practice. Students consistently described how they practiced playing a musical instrument, memorizing lines for a play, and sketching to develop art skills.

Robert explained his experiences with the school marching band. Every summer the marching band practices not only their instruments and marching skills, but also their half time performance for the football games. Robert described the time and devotion he needed to assure he knew the musical selections to play on his saxophone, but the timing and his specific placement at any given moment of the routine for halftime. Robert also describes having to be patient with himself and others. Robert believes playing any instrument is a time commitment. Fortunately, Robert came from a family where everyone plays an instrument. The support and encouragement from his family benefitted Robert's interest and schedule.

In addition to being a member of the marching band, Robert is also in the school's IB program, which signifies he takes challenging and rigorous high school courses. He enjoys his marine biology, engineering, and computer technology classes. Robert is looking at majoring in biomedical engineering, dealing with prosthetics and artificial organs. Robert is interested in this because he feels it is an emerging field. Robert enjoys learning new things and takes pride in his accomplishments. He described experimenting with new concepts and ideas as he is learning or "tweaking" something. Robert described working on a solo performance that he created himself. He performed at a district and state level with his solo. Robert's patience and dedication to perfecting his solo gave him momentum. At times Robert stated how he reflected on his own musical selection, he stated "I definitely need to work on this for a while."

Another project Robert worked on that required patience was a group project in his engineering class. Students were given the task of designing a fire house. His group had to work together, which was challenging at times because not everyone pulled their weight. “One flaw with this design project was the fact I took too much responsibility an did not rely on my team enough. I ended up creating a lot of I on my own, which was a little stressful, but it allowed me to sort of grow in my design abilities in *SketchUp*. Eventually my team helped, but it still took me a lot of time and work” (Robert, Interview, 10/24/18). Initially Robert sketched ideas that included all the necessities of a working fire house including a kitchen and sleeping quarters, all staying in the parameters of a certain amount of square footage. Students had to research costs, building supplies, codes, and the functionality of the working space. Robert described the fire house design as a team project, that took a lot of time and patience. His team used software called *SketchUp* to put all the elements of the fire house together. Robert’s team then presented their design.

Lynn, another engineering student who loves singing and acting describes herself as an arts enthusiast. She has been acting and singing her entire life. Lynn had to audition to be accepted into the VPA program at the south county school. She also has strong interests in science and engineering. Her experiences in the 12 different shows she has performed during her life, have taught her many lessons and helped her develop into the young lady she is today. Lynn has had to be patient with herself and peers throughout many performances while learning lines, memorizing parts, knowing when and where to walk on stage. Everyone makes mistakes, so learning to be patient with others, even though Lynn must depend on others, takes time. She has learned to roll with the changes, as she practiced her craft.

One performance Lynn described caused her some anxiety, but she persevered. The lead role in *A Midsummer's Night Dream* was removed from the performance two weeks before the first show. Lynn was assigned the lead role, Theseus, requiring her to learn all new parts in a two-week time span. Lynn was originally assigned to play the part of Philostrate. She also described the difficulty of playing the opposite gender. Lynn explained how she was required to be on the stage a lot. Through this experience, she developed her patience more so than previous performances due to the short amount of time she had to learn he lines. Lynn also learned that her patience and dedication paid off when it was showtime, Lynn stated "I had my lines down." Lynn explained one technique how she learned her lines so quickly; she repeated her lines with anyone that would rehearse with her and she recorded herself speaking the lines. "I realized through this experience I could accomplish anything if I set my mind to it and worked really hard. I am quite proud of myself for being able to learn my lines in such a short amount of time" (Lynn, Interview, 10/19/18).

Theo is a ceramics, drawing, painting-loving future engineer. She also thoroughly enjoys mathematics. Theo described herself as analytical and a problem solver. While she takes on large challenges in all of her academics, ceramics is where she has had most of her arts experiences in high school. Through hand building, modeling, and wheel throwing, Theo displays patience as she builds a vessel through a lump of clay. "When I learned how to throw clay on a wheel, I made so many mistakes. Pieces of clay were off center, causing the entire pot to be uncentered when finished. The most common problem was making the clay too wet in the beginning. When I added too much water, the clay would come completely off the base, so in time I learned the correct amount of moisture needed to build a clay pot on the wheel, it just took time and a lot of mistakes" (Theo, Interview, 10/24/18). Theo explained she gets ides from looking at artworks of

others whether online or through books. She then sketches out her ideas and concepts before beginning the hand building process. Theo explained how she likes making things that are functional, practical and the process to make it is logical. One of the projects Theo described that took some time to complete, that she was pleased with, was three coil shakers. She varied the size of the set but added similar motif designs and coloration. Her approach became systematic once she perfected how to make the perfect coil. After the coil method was mastered, she successfully attached each coil, one to another. She decided to use the end of a paintbrush to attach the coils. This method proved aesthetically pleasing to Theo as well.

Steve is in his fourth year of engineering and third year of an arts class. Currently, Steve is taking ceramics, but he has always enjoyed drawing as well. He also enjoys taking things apart to figure out how they work. Steve explained his determination when fixing things. He described an experience of being out on a boat, when the boat broke down and left him stranded. Steve's only choice in the situation was to fix the boat. As Steve took various parts and equipment apart, he eventually figured out what was wrong with his boat. The patience he has developed through some of his schooling prepared him for this occasion. Steve explained, through the processes of sketching, hand building in ceramics, and trial and error, Steve learned to take his time when trying to find a solution. "One of my favorite art projects was this scratchboard drawing of an octopus. I knew with scratchboard, there was no erasing, so I couldn't make any mistakes. I think it made me take my time and be very careful with every scratch mark I made. I knew when I was about half way done it looked pretty good, so it gave me the confidence to keep going. Eventually I finished it, it took a while, but I got first place in an art show! So, all of the time I put into the scratch art was worth it" (Steve, Interview, 10/11/18).

Zach shared his experience from the summer of 2018, where he took a fashion college summer camp for high school students in New York. In one of the classes, Zach worked with a team of people, all with a creative mind-set, who worked together to create a magazine. The magazine was a fashion-type magazine, that included articles and photo spreads. Zach explained how the students went out on the streets of New York City to get ideas. They had to brainstorm and problem-solve together which took patience for the entire group. Zach explained, it can be fun and test your patience at the same time when working with several people who all want to be heard and have their ideas expressed. "Sometimes people on my team would talk over each other, it was so annoying. But I realized, everyone just wanted to make sure we heard their ideas. We eventually started listening better to each other, and taking turns when sharing ideas, so I guess we figured out how to communicate as we went along" (Zach, Interview, 10/12/19).

Practice. The second sub theme that emerged from Major Theme One was practice. Through the interviews was how much students value practicing their craft was discussed often. Several of the students brought up how they took engineering in middle school, learned to play an instrument in middle school, and one female participant started performing in plays at the age of eight. When students practiced their craft, they learned to schedule their time better and found personal satisfaction when they saw the rewards of the practice. In performance, whether a musical solo, or a lead role in a school play, student participants realized how dedicating time to practice in the arts carried over into other courses. Participants realized the act of practicing transferred into solving problems in their STEM coursework.

Steve discussed in his visual arts classes how he lacked confidence in his abilities in drawing initially. Through continuous sketching for two-dimensional or three-dimensional projects, his sketching skills improved at a steady pace. Through those experiences in the arts,

Steve stated how his sketching abilities transferred into his engineering class. When beginning new projects in his engineering class, Steve likes to start out by sketching what his mind's eye sees. "As I have gotten better in my art classes with my sketching, I have also noticed, I have gotten better in my engineering class. I have to sketch ideas for engineering class, and maybe because I have gotten better in art, it's made me feel more confident when I am working on new projects in engineering" (Steve, Interview, 10/12/18). He has been able to transfer his beliefs about practicing to his projects and design development in his engineering class.

Lynn discussed the amount of practice-time she devoted to her theatre performances. She spends hours rehearsing by herself and with peers to learn lines for a school play. Theatre has been a passion for most of her life. Lynn explained how repetition through practice helps her. She has also helped with the sounds and lighting for performances. Recently, a friend was helping Lynn rehearse for a school play. As Lynn said her lines, if she was incorrect, her friend would read back her lines until Lynn got it right. The friend's cue that Lynn was saying the correct lines, her friend would move on to the next line. Lynn related this recent experience to a competition through the Technology Student Association. The Technology Student Association was having an issue with an on-demand video they had to work with, including the sound, microphone, and burning a CD. Lynn explained how some of her peers grew frustrated with the technological difficulties they were having. "We had a lot of issues with the microphone, with burning the CD's, so it kind of took a lot of us coming together and thinking like, okay, could this be it, could that be it? Is this it? What if it's this? Eventually we ended up solving it" (Lynn, Interview, 10/20/18). Lynn persevered, using trial and error and not giving up, to fix the problem. She knew if she continued to apply things she had learned previously, she would eventually be able to solve the problem.

Andre, a music and engineering student admitted when he practiced something, he became very good at, if he did not practice something, his position slid back to a middle tier. He explained how in middle school, he practiced the cello often, becoming one of the top musicians in the orchestra. As he entered high school, Andre began to take several rigorous courses, which ultimately cut into his practice time for music. "Arts I feel I have a natural affliction to it because I have always been pretty good. When I don't practice, I am one of the top in the middle tier. If I practiced, I could be at a higher level, I just don't have that much free time anymore for the practice required to be at the top" (Andre, Interview, 10/12/18). Andre explained how he learns thing quickly and feels fortunate to have that ability. With the guitar and keyboarding in high school, Andre explained, the more he practiced, then presented to the teacher, the further he was able to move forward. He acknowledged the benefits of practice, but honestly admitted his practice schedule was like peaks and valleys; sometimes he could practice a lot, and other times he could not. The time it takes to practice has currently transferred into Andre's AICE physics and engineering classes. When working on a lab in physics, Andre has learned to make the steps and procedures taught by his teacher, part of his own classroom student practices, from safety during a lab to writing a completed lab report. Andre described in detail an engineering project in which he and his group had to design something that launches a tennis ball. The teacher placed one restriction on the students, the tennis ball launcher had to function like a trebuchet, a type of catapult, but it could not resemble a trebuchet. Andre detailed the various other engineering ideas his group experimented and practiced with. One idea, Andre called a flywheel; there were two wheels rapidly spinning, the ball touches the wheels, and it should immediately shoot through. After brainstorming with the group, Andre and his peers decided to have a tennis ball on a tee. They had a golf club swing and hit it. "Last year in engineering we had to create something that

launches a tennis ball, but there was a very big restriction of nothing that resembles a trebuchet, or functions like a trebuchet. That messed up a lot of people, they all went for the same thing. We're going to do what is called a flywheel, which is you have two wheels rapidly spinning, the ball touches them, and they are spinning like this, so they immediately get shot through. I started thinking that was dumb, so after brainstorming with friends, I came up with the idea to have a ball on a tee and have a golf club fall and swing, then hit it. It didn't work that well. We should have practiced the idea some more, and changed some things like how to hit it, the position, weights and swing" (Andre. Interview, 10/12/18). After the project was finished, Andre explained although he and his group practiced several ideas, they felt they could have made some changes to their tennis ball launcher even after the teacher assessed their assignment. Andre thought they could have changed how the ball was hit, the position, weights and swinging. Ultimately, more practice may have proven perfect.

Gavin is a visual arts student who thoroughly enjoys his engineering class, so much so he plans on majoring in engineering in college. Gavin also enjoys science but has found this year, eleventh grade, to be his toughest school year in science. He described how in the past three years of his schooling, his art skills have steadily improved. Gavin initially took an art class as a ninth grader just to earn his high school arts credit. But he discovered half way through his ninth-grade year, he felt he was pretty good at art. During his tenth-grade year, he really saw himself improve, and found the most tedious projects to be his most successful. Gavin enjoys drawing with thin mark-making techniques such as pencil, colored pencil and scratch-art, all of which are time consuming and take lots of practice to develop skills with those media. "With colored pencil I didn't realize how much layering really is needed to make something look realistic. I used to want to rush through a drawing to get it done, no blending or shading. But then I realized, it's not

that difficult. I have to start light, and layer colors as I go. The more I tried this layering technique, the better my drawing got" (Gavin, Interview, 10/12/18). Gavin described how he first visualizes his ideas, then goes through various sketching phases until he feels confident to move forward with a final version. Gavin expressed how he becomes determined and never gives up when trying new things.

In his engineering class, one project Gavin felt proud of when finished was a portable arcade system. The learning intention was for the students to design and build a portable computer, that was small, and easy to use. So, he came up with the portable arcade. Gavin's practices which he developed through his visual arts classes helped prepare him for this occasion. Similar to Gavin's approach to art, first he would brainstorm, then sketch various ideas, then plan out his steps to create the final piece. Gavin applied the same practices to his portable arcade. He started out thinking and listing what he needed: a case, how to make it portable, materials. Gavin then began sketching out how he wanted the portable arcade to look. Once the simple sketches were complete, he moved onto creating his ideas in a program called *Solidworks*. Gavin explained his original sketches almost look exactly like the finished product. Gavin concluded the simplest way to complete his project was through 3D printing. "I started by asking myself questions, am I creating a portable system or portable computer? For simple use? And then I went through and changed it into an arcade system. Then asked myself, what do portable things have? A case? Alright I so I need a case. I can't just go buy one, everything has to be custom made. I completely mapped out everything, drew out a complete case design, it was 120 millimeters by 100 millimeters by 160 millimeters" (Gavin, Interview, 10/12/18). He measured all the dimensions of a Raspberry Pi, a small single-board computer. Then Gavin mapped out where everything was going to go, like puzzle pieces. When Gavin put all the pieces

together, everything fit the first time, which amazed Gavin. Gavin stated his practices in the arts really helped him through all the steps in developing and building his arcade computer.

Major Theme Two: Success in the Classroom

The second major theme, success in the classroom, developed from the sub themes of learning visually, brainstorming, and real-world knowledge. The arts experiences student participants described during interviews helped them with various other aspects of their education. One of methods the student participants stated they found helpful was learning with visuals. Participants described numerous ways in which visual aids, pictures, and diagrams helped them understand new ideas or concepts. During the interviews, I could see myself in some of the students. I was a visual learner throughout my schooling. Many of the students described examples or instances of learning something new through visual-aides or making something visual like a picture. According to Eisner (1994) visual representations help to expand consciousness, ultimately helping students to become more successful when learning new material. Student participants may not have all used the same vocabulary to describe the various visual aids, however, the effectiveness of learning through visuals was evident. Whether students completed drawings themselves, or had access to visuals, in either case, students described how viewing something made learning new content easier to comprehend.

When students participated in hands-on activities, they described how effective the process was when learning new things. Students described building, taking things apart, and manipulating various items while learning during the interviews. Additionally, learning through hands-on activities was discussed by all of the student participants. Students enjoyed working with their hands and felt they learned very well by using that method. Zach described how learning out of a book, reading, or taking notes, was not very helpful. Zach described how he

could only retain a small part of what he read from textbook, while creating something with his hands helped his learning comprehension. Creating something with the hands helped him to see how things work.

Students enjoyed brainstorming ideas, whether independently or with peers and felt it was helpful in finding solutions to problems. Students do not want to have someone just tell them the correct answer; they want to discover solutions on their own. The process aides in mastery on learning new concepts and creating new ideas.

Additionally, students were successful in their classes when they knew what they were learning was relevant and how to apply it in the real world. Mrs. White, a mathematics teacher and teacher participant in this study, explained how she tries to make content relatable for her students. When students know how to apply new material to their own lives, why they are learning something, and how they will use it, they tend to be more successful with learning comprehension. Students want to know why they are learning something and how they can apply it in their lives. Therefore, real-world knowledge is so important in the classroom. If students cannot see how or why they must learn something, the content is meaningless.

Learning visually. The first subtheme to appear within Major Theme Two was learning visually. Student participants all described various modes of instruction by their STEM teachers. STEM teachers used typical instructional methods; lectures, demonstrations, projects, labs, and discussions. One of the most common forms of learning the student participants described as useful was learning through visual means or working with one's hands. Many architects and engineers had their spatial sense cultivated by blocks, Tinkertoys and other three-dimensional toys: one famous example is Frank Lloyd Wright, who played with blocks at an early age (Zemelmen, Daniels, & Hyde, 1998).

Theo loves ceramics, watercolor, and drawing. She finds looking at visual examples of concepts, ideas, and learning the meaning of new vocabulary helps her most. Seeing what something looks like or giving a visual language to new things helps her learn new concepts and ideas better. Whether looking at a diagram, a chart, or a photograph in a textbook or a teacher's PowerPoint presentation, seeing something helps Theo understand, comprehend, or remember more effectively. When designing a new piece of pottery, Theo will research other vessels, looking on the internet and looking through art books. She looks for ideas to inspire her own. "I kind of have a photographic memory, I guess. Maybe that's why I like looking for ideas around me. Once I've seen something, I usually don't forget it. Then when I need a new idea for something, I kind of go through my memory of images, mixing things together, trying to come up with new ways of doing things," (Theo, Interview, 10/24/18). Theo looks at colors, textures, patterns, and shapes within other pottery pieces. Theo then decides how she is going to incorporate and synthesize features she found aesthetically pleasing into her own works of art. Theo felt learning things through visual was easy and natural. When her STEM teachers teach new content through visual means, Theo is able to grasp new content more rapidly. Theo stated she can learn through other modes of instruction; however, learning visually was her preferred mode of learning.

Zach, the budding future fashion designer overwhelmingly preferred learning through visual means. He admitted that other subjects can be difficult for him to learn new things if a teacher does not provide visual aids or visual outlets for learning. His engineering class provides many opportunities for learning through visual means. Zach described the assessments in engineering as a true measure of his learning. On the tests in his engineering class, the questions would provide visual diagrams and images. The images on the tests made questions easier to

interpret, and therefore Zach stated assessments in his engineering class were better assessments than other subjects. “I cannot stand having to read a textbook, then answer questions, take notes, then take a test. I’m terrible at learning that way. If I can look a picture of something, or even mess around with my hands, taking something apart, putting something together, I don’t even need to take notes. I don’t even have to study for a test. I guess that makes me a visual learner” (Zach, Interview, 10/12/18).

Gavin enjoys drawing and feels his drawing skills have improved throughout high school. Gavin explained in most of his classes, there is not much visual instruction or learning tools provided to him. When he is given the opportunity to learn through drawing, he does exceptionally well with comprehension. Gavin detailed dissection labs in his biology class., Gavin explained his thought process when dissecting a worm, frog, a mouse, and a rat and compared it to his peers. When the students are working through their lab, during the dissection, they are required to draw each organ. Gavin explained how many of his peers would draw simple shapes, such as circles and ovals for organs. “if you don’t have details what are you really looking at? It might be the lower intestine, this is the heart, but if you just draw a circle, and you are pointing at that circle, it’s just a circle. When you actually draw out that mouse or that rat and you can visualize and see where everything is it helps you. You don’t have to be an artist to understand it,” (Gavin, Interview, 10/12/18). Gavin explained with each dissection, he draws every detail as he sees it. This allows him to remember all the parts, their location, size, and shape long after the dissection. Gavin takes his time and enjoys working with the tiny details.

In Gavin’s engineering class, he explained how mathematics helped him visualize items they designed and printed on a 3D printer. Gavin found some mathematics, like algebra and geometry, useless to him unless he knew how and why he had to complete a problem. In Figure 5

and Figure 6, Gavin had to design and include the dimensions and weights of a tapered pin slot and radial swing block. For Gavin, when putting the mathematics and design together, he was able to an create accurate visual representation of the items.

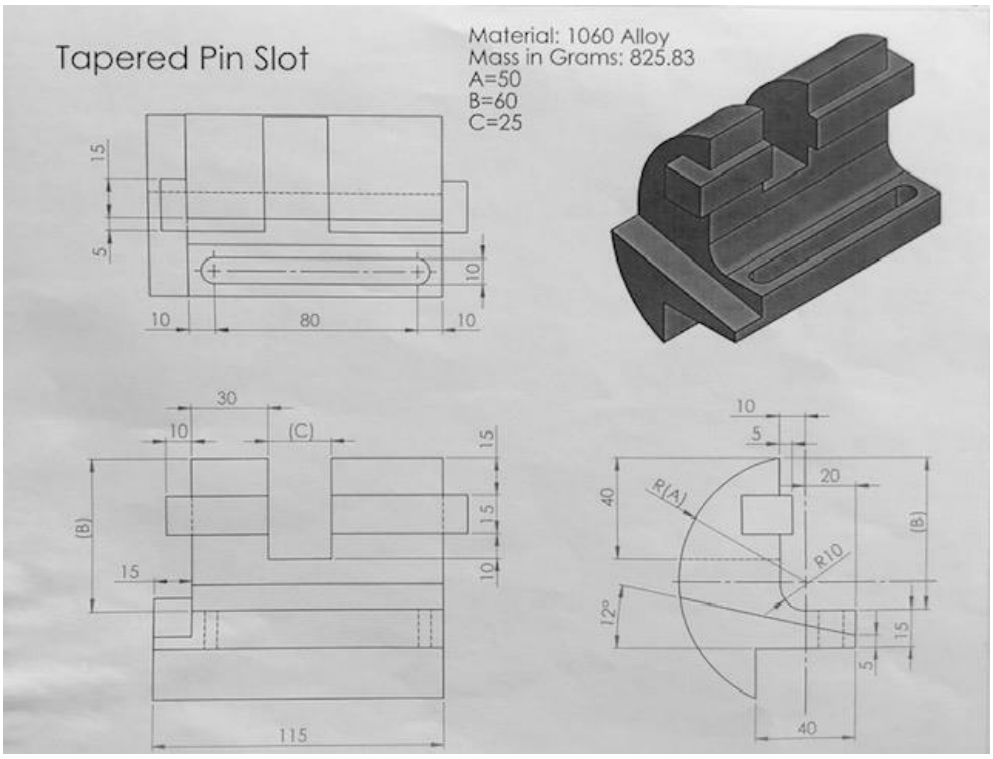

Figure 5. Student design and computer drawing of a tapered pin slot, permission from student participant Gavin.

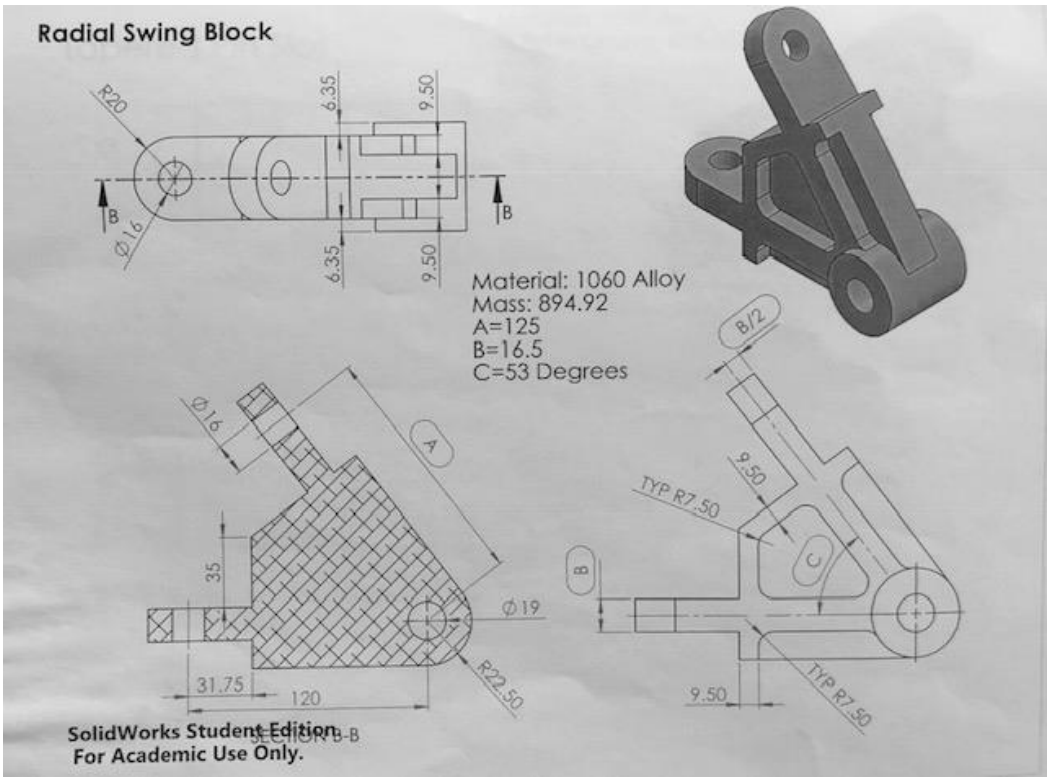

Figure 6. Student design and computer drawing of a radial swing block, permission from student participant Gavin.

During Steve's interview he discussed several times how he likes to work with his hands. Traditional educational settings do not align with Steve's preferred ways of working and learning. Steve explained, if he could figure things out while using his hands, his interest in the activity was maintained and he was determined to complete the task. Steve explained how his visual arts classes have helped him develop his hand-eye coordination, and how to express what he sees in his mind. Engineering class has helped Steve fix problems and build things. "Art has helped me explore more and to think about what I am drawing and how to draw it. In engineering class, we have to draw out everything before we start. It's like an assembly line, or step by step process" (Steve, Interview, 10/12/18). These hands-on experiences have followed Steve outside of the classroom as well. Steve enjoys working on boats and cars, so much that he

plans on becoming a mechanic when he graduates from high school. “When a teacher lectures, I just fall asleep. I like figuring things out, taking things apart, and fixing stuff, I think that’s why I like my ceramics class and engineering class so much, I get to work with my hands, and I like working with my hands. Engineering helps me figure out a problem and how to build stuff. That’s probably why I’d like to be a mechanic” (Steve, Interview, 10/12/18).

Zach discussed hands-on activities throughout his interview. When he travelled to New York to participate in a fashion summer camp, the entire experience involved hands-on activities from designing the layouts to finalizing a completed fashion magazine. “We sketched what each layout was going to look like, where images would go, where we want text and titles. Sketching out the layout helped us visually translate our ideas into this magazine spread we were designing,” (Zach, Interview, 10/12/18). In engineering class, Zach discussed hand-on activities as being his favorite way of learning. He built a robot that had to put a ball through a hoop and hit other targets. Zach worked with other students to complete this project. He explained how they would spend time into the evenings working on their robot design and programming. “I believe we were successful with the robot design because of the teamwork aspect: it was a lot of kids working together for one cause, which was to create a robot that could put a ball in a hoop. There was a programmer, a builder, an electrical person, and designer. We all came together to do it. I believe we presented so well because the objective was so clear. I did the designing and some of the programming, while my teammates helped out in their areas” (Zach, Interview, 10/12/18). Figure 7 shows the completed robot in a competition where the objective was to dunk a ball the fastest.

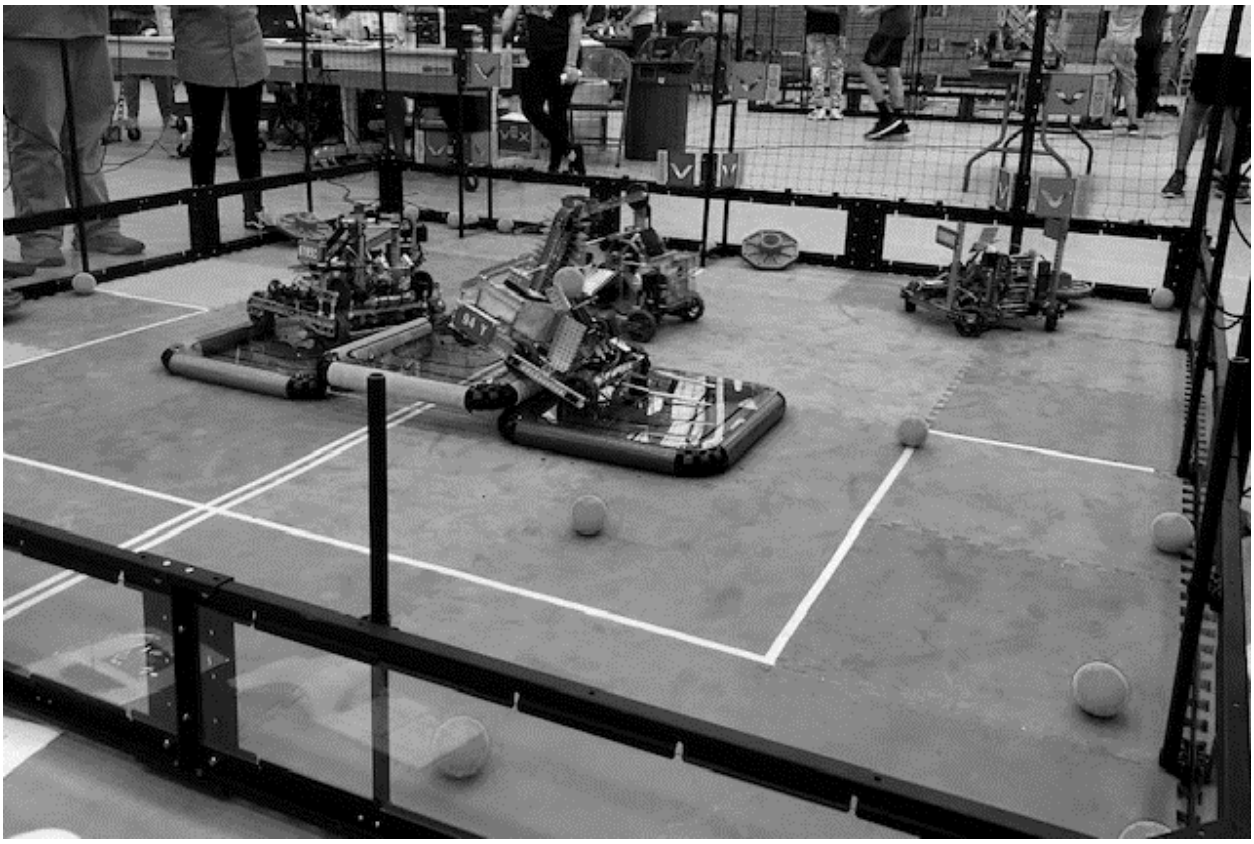

Figure 7. Student designed robot, permission from student participant Zach.

Zach viewed hands-on activities as fun and more interesting. Hands-on activities did not seem like work, even though Zach was learning through the process. Zach preferred learning new concepts and ideas through hands-on activities, it is his favorite way to learn, and he feels hands-on activities produce better outcomes. “I really think it’s a fun activity to do, and of course it’s necessary. As soon as the artistic side of it or the creative side comes into it, my mind just wanders everywhere. I can picture things in my head really well, my mind will just go a million miles a second thinking of all the ways to design the robot” (Zach, interview, 10/12/18).

Theo, as a ceramics student, gravitated towards hands-on activities in her schooling. She explained she enjoys painting and drawing but building and forming shapes with her hands is the most satisfying. “I’m not the best drawer or painter but I don’t think being good at it is exactly what makes you strong in it. I think it’s more about creating and expressing your ideas and

thoughts" (Theo, Interview, 10/24/18). Theo gets bored during lectures in any class: she loses focus. She absorbs new information when there is a collaboration of instructional methods. When her teachers combine activities and projects into new material, Theo learns and retains new content better. When a teacher is having students take notes in class, Theo finds herself drawing pictures or diagrams to keep herself engaged. "I really despise sitting through lectures when they are just spewing words at you and you have to write them down. That's not the best method for me because I get very bored" (Theo, Interview, 10/24/18). Theo stated the arts should be integrated into all classes, and that all students should be required to take arts classes because hands-on activities help everyone truly learn.

Brainstorming. The second subtheme to emerge from Major Theme Two was brainstorming. In order to initiate brainstorming, a student must first identify the problem or the task, then gather information about it to mix with the information they already know. Student participants enjoyed brainstorming as part of their educational process. Brainstorming allowed students some creativity to their problem solving. Student participants described how brainstorming was incorporated when students worked in groups, had open-ended project ideas, and through sketching ideas for projects. All of the student participants discussed brainstorming ideas in their interviews.

Lynn added a unique perspective in regard to brainstorming. Coming from a theatre background, besides acting and singing in theatre production, Lynn also enjoyed working with costume designs, sets, lighting, and sound. Lynn learned to experiment and practiced brainstorming when trying to come up with how the stage and actors should look. She was able to creatively think how an entire production should look while working with an entire cast. She also discussed her most challenging role in which she had to play a male character. Lynn

practiced different gestures and voices to develop the character. She simply brainstormed various approaches to play this character. As a member of the Technology Student Association, Lynn incorporated those brainstorming skills while in a recent competition. Her team was having technical difficulties during a competition. Lynn was able to problem solve and brainstorm possible solutions to help her teammates during the competition. Lynn stated her problem-solving techniques involved thinking of solutions inside and outside the box.

Robert described his own way of brainstorming involved creative problem solving as a way of viewing a task, seeing the obstacle and visualizing possible outcomes. He describe sorting out the obstacles as he works towards a solution. One of the examples Robert detailed in his interview is how he brainstormed ideas for a fire station. The project was a group assignment, Robert explained some of his frustrations working with several other students. “Sometimes it is frustrating when working with others. We all had different ideas, and each one thought their ideas were the best. But after working through some of the ideas, and eventually listening to each other, we worked through the project” (Robert, Interview, 10/24/18). Ultimately, his group successfully brainstormed together to design a fire house, keeping within the assigned guidelines. Robert’s group had to keep within building codes, specific square footage, and costs to design their fire station. In Figure 8, the floor plan of the fire house shows how the students placed rooms such as locker rooms, living room, a lounge, and a game room. Figure 9 shows the aerial view of the fire house in a designated location.

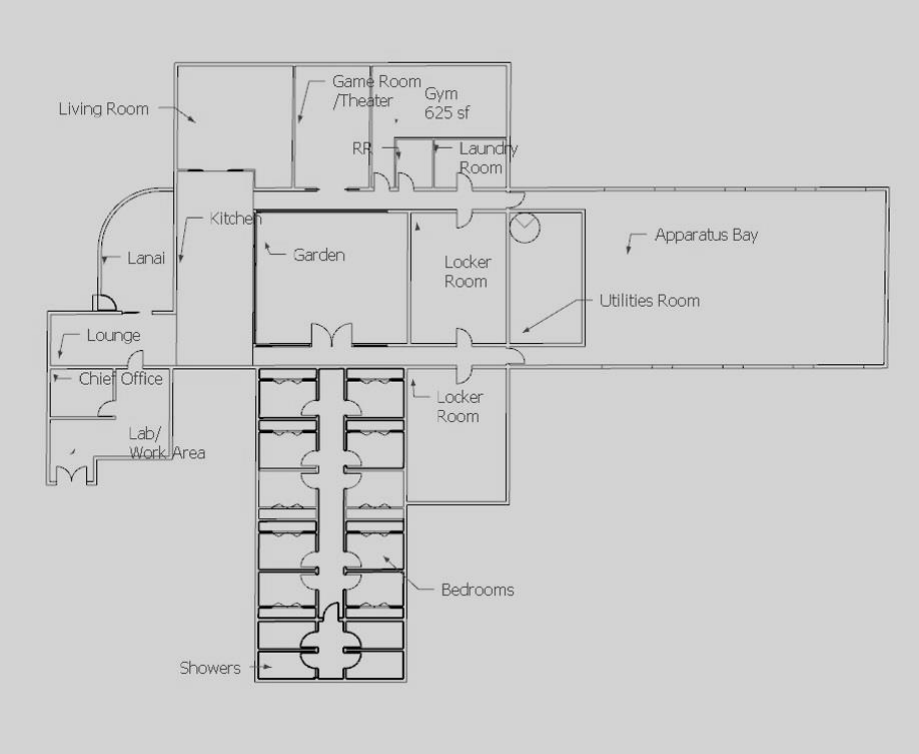

Figure 8. Student design and computer drawing of a floorplan for a fire house, permission from student participant Robert.

Figure 9. Student design and computer drawing of an aerial plan for a fire house, permission from student participant Robert.

Mr. Dilbert, the engineering teacher, tries to incorporate brainstorming into every project: "I believe my students are more successful in class, at competitions, and beyond my class because they are encouraged to brainstorm on their own and with their peers" (Mr. Dilbert, Interview 10/23/18). Andre, who is in Mr. Dilbert's engineering class, elaborated on how he enjoys brainstorming. He sees brainstorming as a way to develop creative solutions, a way to think outside of the box. Andre clarified there are times to stay within the guidelines and times when he feels it is necessary to go outside of the guidelines. Andre explained brainstorming steers him at times in a different direction than his peers when working towards a solution. Often, his solutions that stem from brainstorming are better than if he stayed within the guidelines. "I like to think outside of the box, because sometimes you need a roundabout way to do something; through brainstorming I can come up with those roundabout ways" (Andre, Interview, 10/12/18).

Gavin was able to recall an assignment from middle school in which his teacher required students to be creative with their solutions. His middle school engineering class required students to create a CO2 car. Gavin recalled having to put the CO2 capsule in the back of the car, puncture it, then race the car. Gavin recalled the experience fondly. "I absolutely love when we are allowed to go off on our own and do separate things, because it always sucks when we are doing a project and we're defined by these certain criteria and it has to be like this and has to look like that. Then everybody's project looks the same, but whenever we are given the creative freedom to brainstorm, we're allowed to go out and what we want and that actually breeds better ideas" (Gavin, Interview, 1012/18). The freedom to experiment and brainstorm was a learning experience that has remained with him well into eleventh grade. Gavin thought his teacher was trying to get students to open their minds, to see what would work or would not work. Through

the process of designing and racing the cars, Gavin figured the importance of weighing the car and cutting wood blocks to a 45-degree angle, various elements to make his car faster. Gavin believes mathematics is the language of physics, but the arts, creativity, and problem solving brings everything together full circle. Provided with the opportunity to brainstorm during a lesson or a project helps students in comprehending new content.

Real-world knowledge. The third subtheme within Major Theme Two was real-world knowledge. All four teacher participants discussed the importance of making content in their classes meaningful. Students want to know why they need to learn something and how they are going to use the knowledge in their own lives. Each teacher discussed the various ways they make the class material pertinent to the lives of their students.

Mrs. White, a math teacher explained how she makes trigonometry practical. She has her students go outside to measure the height of palm trees on the school campus, based off the shadow and angles of elevation. The palm tree measuring exercise is an example of how trigonometry students can take an equation, and then turn the math lesson into something practical. She also described an arts type of project in her trigonometry class: “They had to come up with their own real-world example where trigonometry was used in the real world. It was anything they wanted; they could use pipe cleaners where it would be a police officer and a gun and the trajectory. It could be a cat up in a tree. Some students used Legos, shoe boxes, painted things, and such. It was fun, but time consuming” (Mrs. White, Interview, 10/17/18).

Mr. Dilbert, an engineering teacher, incorporates real-life application into almost everything he teaches, especially in the level III and IV classes. His classes are hands-on, where the students use mathematic skills and creativity to design and build functioning items. Mr. Dilbert has used the machines designed by Leonardo DaVinci as real-life examples. His

engineering students have designed parks, three dimensional games on computers, trebuchets for launching, and robots with assigned tasks. Mr. Dilbert's students use a textbook as an outline, but students must research what they are designing, how to make it, and then they are required to build what they have designed, when applicable. After the engineering project is built, students must present their project to see if it functions. "One of my students brought in a door handle from his father's vehicle. The handle had broken and the student told his dad he could design and make a new handle with the 3-D printer at school. I gave him permission to work on this, because I believe if its practical knowledge, knowledge the student can use in real life, the knowledge is priceless to the student and will just foster a desire for learning" (Mr. Dilbert, Interview, 10/23/18). In figure 10, two students are shown creating a new handle by analyzing a broken handle from a vehicle. The new handle was created in a 3-D printer. One student brought a broken handle in from home at the request of the student's parent. Mr. Dilbert allowed the students to recreate the new handle, providing a real-life experience for the students.

Figure 10. Students recreating a new handle with 3-D printer, permission from student participant Zach.

Mrs. Amber had her students in the technology class bring in old photographs from their family members to touch up. She explained how her students really enjoyed learning various tools in Adobe Photoshop to touch-up and edit photographs of family members. The students were learning required tools in the software, while being able to take something away from the class when finished. “We had a lot of reinforcement on restoring old photos. The kids really perfected the blending modes, changing the opacity, the hue, the saturation and they did real well with the spot healing brush. I think they did well learning and mastering those tools because they were editing a real photograph” (Mrs. Amber, Interview, 10/19/18). Mrs. Amber had the student

work printed once they were finished. Students enjoyed taking the newly touched-up photographs to their families to show what they had learned and completed.

Mrs. Bozeman gives a bone lab quiz every year to her students in anatomy class. Students work from skeletal models in class to learn 206 bones. Students can choose how they make a visual: modeling clay, drawing, or paint. “My anatomy students do fairly well in class considering all of the terminology they have to learn. I think they enjoy learning about how all of the bones and muscles work together. Students often share stories of injuries they, or family members, have experienced, making the content of the class real life” (Mrs. Bozeman, Interview, 10/17/18). Mrs. Bozeman is able to relate her lessons to the students’ in a physical manner. Students can learn the function of bones, as a frame for the human body, how the bones protect organs, and how all the pieces work together in the human body.

Major Theme Three: Proficiency

The third major theme, proficiency, evolved from the sub themes of time and collaboration. Participants described the importance to have time to work on projects and practice a variety of forms of learning methods. Teacher participants explained the importance of time, time to plan for lessons, and time for students to brainstorm and investigate as they develop solutions. According to math teacher, Mrs. White “It takes time to plan lessons that incorporate various teaching techniques and it takes extra time for students to work in class on the various activities. While I think it pays off in the long run for the student, there just isn’t enough time in a school year to incorporate projects and activities into every lesson” (Mrs. White, Interview, 10/17/18). Lastly, collaboration was another practice teacher participants incorporated to a variety of projects. Student participants described the benefits of working with their peers. Zach described his experience of building a robot with his peers: “all of us have unique talents and

skills, so when we were designing the robot we were ultimately successful because we had several different types of people combining their ideas" (Zach, Interview, 10/12/18). All of the themes that emerged are intertwined in various teaching and learning practices that participants described through interviews. Examples of student work in STEM classes were provided by student and teacher participants that support the emerging themes.

Time. The first subtheme to appear within Major Theme Three involved time. As teachers explained some of their teaching practices, assessments of student comprehension were best when enough instructional and learning time was provided to learn new concepts. Teachers blend instructional practices by mixing traditional methods such as lectures, note taking, and reading from text, with group projects, brainstorming sessions, and having students make visuals.

Mrs. Bozeman uses a hook statement or maybe a story that relates to new material in her biology and anatomy classes. Then she breaks words down, since biology is mainly in Latin. Mrs. Bozeman chunks content into smaller sections for students before having them complete written summaries and notes. Mrs. Bozeman explained that she then has students draw structures; chloroplast, mitochondrion, abdominal. Mrs. Bozeman also provides students with research time because the students need to know the function of everything they are drawing. All these activities are then followed by formative and summative assessments. By providing the students the time to go through all of the various steps, she has found students do comprehend and retain the new material. She provides students the time to be creative with their solutions as they develop visual concepts to display their understanding of the new material. Mrs. Bozeman explained her methods of instruction, "I sometimes introduce a lesson with a major breakthrough in history, for example, the greater momentum now is recognized as having a function to the digestive system, not just webbing that holds abdominal muscles in place. Then I break words

down for the students, since much of anatomy and biology is in Latin. I also use guided notes to fill in for my biology students since the students do not always know exactly what they should write, all of which takes time to plan" (Mrs. Bozeman, Interview, 10/17/18).

Mrs. Amber, who teachers a technology-based class, emphasized the importance of providing students with time to complete projects. One thing Mrs. Amber discussed which was unique when compared to the other three teachers is that she encourages students to play around on the computer with the software, *Adobe Photoshop* used in her class. She requires students, if they finish one project early, to then experiment in the software program. "If there is any free time, I require my students to be in Photoshop, editing something, a face, or anything, as long as they are editing" (Mrs. Bozeman, Interview, 10/19/18). Mrs. Amber believes when students have the time to experiment freely, the play time encourages the students to develop creative ideas for future assignments.

In order to master new assignments and concepts in engineering, Mr. Dilbert pulls from many sources, things he has created, online, textbook, and presentations. "Everything we do will typically have a presentation or a lesson or instruction that will teach the kids a new concept or teach them how to use a new software tool or method of building something. Then there are the labs and activities that go with it, where the kids have to use what they have learned to be able to either build or design something or complete their project or an activity. If they can demonstrate all the things they learned, that shows they understood it and have mastery of it and that it is something they will remember. Where other classes they may learn something in a book. will study it and take a test, then forget everything a week later" (Mr. Dilbert, Interview, 10/23/18). His engineering students frequently are paired up with a partner or a team of other students. Students are required to then brainstorm together solutions for an engineering assignment.

Engineering students develop sketches by hand and on the computer. Students are then provided time to develop their designs by building it with supplied materials or display their designs with a 3D printer. Mr. Dilbert believes his combination of peer groups, brainstorming, sketching, and designing ideas aids in the full comprehension of his engineering students.

Mrs. White, a mathematics teacher, explained the way students learn her content best is through collaborating with others, working on tasks where students can be creative in their own element. For example, one of the mathematics assignments students learn about polynomials, in which students were all assigned different polynomials. Students were required to create a PowerPoint presentation and do an office mix where they record their voices over it. Students get to choose what real world examples they are going to use and how it applies to real life, why these polynomials are used in the real world. Students then present to each other. The entire process takes quite a bit of class time for students to work through all the requirements. The benefit of all the class time being used for the polynomial projects, is how well the students comprehend and retain what they have learned. Another example Mrs. White described that requires time is when she incorporates visual arts into her lessons. “It takes quite a bit of time in class to incorporate all of the teaching practices I know works best for my students. I try to incorporate technology with real world experiences, while having my students work together on math concepts” (Mrs. White, Interview, 10/17/18). For example, students had to graph the coordinates of several circles on graph paper and then had to turn those circles on an image. In Figure 11, the student created the suction cups from the tentacles of an octopus. In Figure 12, another student created eyes out of circles.

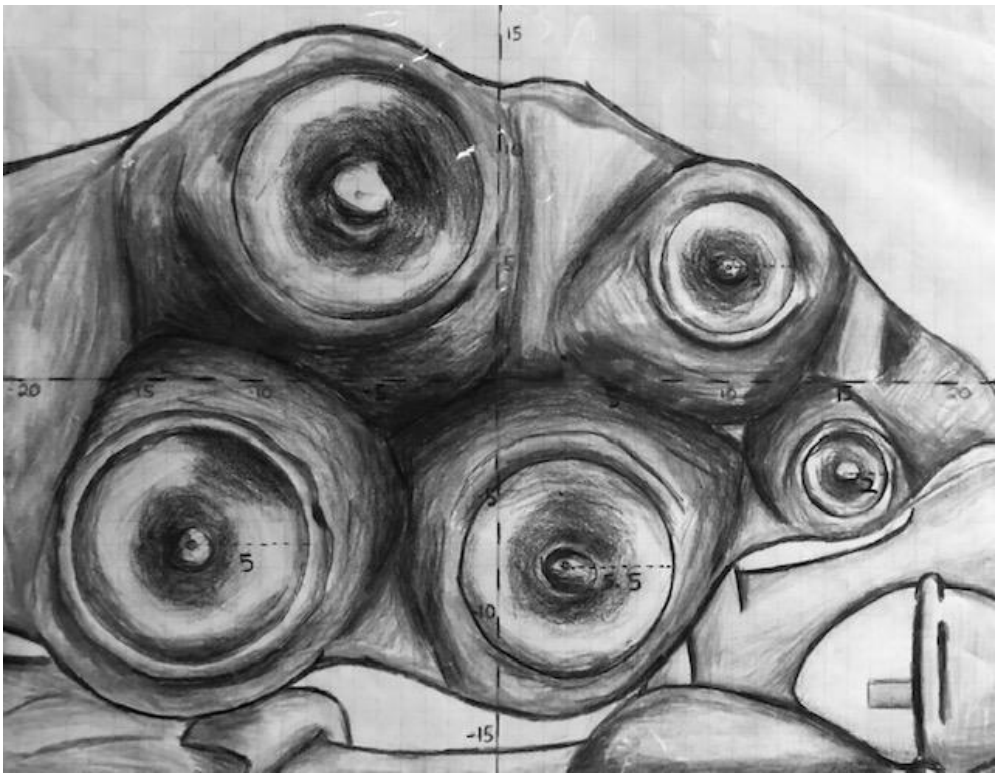

Figure 11. Graphed circles converted to suction cups from the tentacles of an octopus, provided by mathematics teacher, Mrs. White.

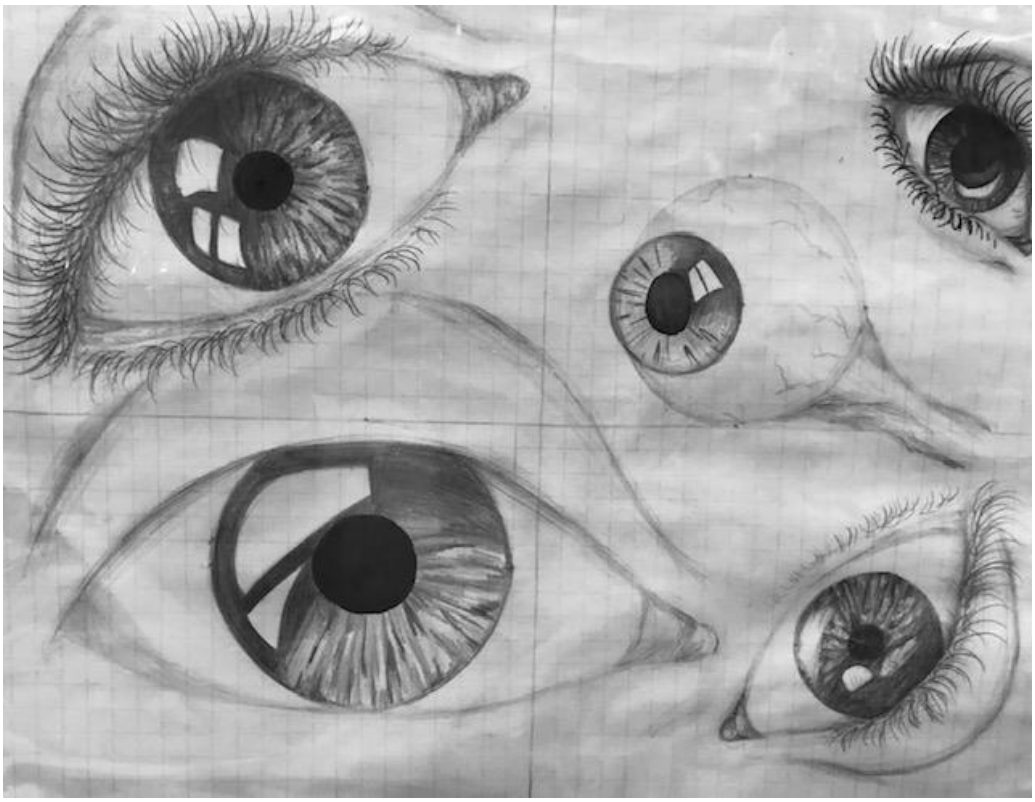

Figure 12. Graphed circles converted to eyes, provided by mathematics teacher, Mrs. White.

Collaboration. The second subtheme within the third major theme was collaboration. Technology, engineering, and mathematics teachers discussed how their students collaborate on projects and the benefits of working with peers. The technology teacher, Mrs. Amber, has her students develop a 15-step project in *Adobe Photoshop*. The students must first develop a graphic or edit a photograph, including a typed document with the steps to recreate the image. Students then switch with a partner in class who in turn must recreate the image in *Adobe Photoshop* using the 15 steps provided. Students then critique each other's final image and directions provided. Mrs. Amber found the students take ownership and pride in developing a project themselves. The students enjoy the flexibility of coming up with their own solution. Providing feedback to each other proves to be beneficial in a way that places the student in an instructor position. Mrs. Amber explained, "my students like working together. I think they like talking

about the project, what could have gone better, how to refine things what they would change afterwards, and so on" (Mrs. Amber, Interview, 10/19/18).

The mathematics teacher, Mrs. White, uses collaboration frequently with various concepts and equations. One exercise she uses in her class, is incorporating oversized post-it-notes to hang in the classroom. She posts the large papers around the room and puts students in charge of a topic on each post-it-note. One post-it-note might have the word polynomial written on it. Students have to write everything they know about polynomials on the post-it-note. Then Mrs. White gives students each a turn to discuss things in their own words. Mrs. White finds their collaboration helpful for all of the students; they help one another and help explain things in various ways. The students enjoy moving around the room and working together. Mrs. White stated, "I think students learn STEM content best when collaborating with others, working on tasks where they can be creative in their own element" (Mrs. White, Interview, 10/17/18).

Mr. Dilbert, the engineering teacher, incorporates group projects and collaboration in all four levels of his engineering classes. Mr. Dilbert explained the importance of mastery at every level in engineering class: one level builds upon the next. He has found when students combine teaching methods within labs and projects, while collaborating among peers, students enjoy working together. The students brainstorm solutions and ideas, while creating dialog using proper terminology. The entire process of working with peers helps students master the task assigned and helps to retain the knowledge learned. Mr. Dilbert explained, "students each have their own strengths, such as some being analytical with a problem while others are creative with their designs" (Mr. Dilbert, Interview, 10/23/18). The combination of students of different talents with various ideas actually brings balance to the collaboration. Solutions to a project that may not have been able to come to fruition are made possible with a team. This then allows the

engineering students to build upon what they have learned as they continue with the program each year of high school. Mr. Dilbert explained that some students are very structured in their approach to working through a project, whereas students who tend to be artistic, allow for ambiguity while working through a problem. When the structured students work with creative students, the collaboration can produce innovative projects in the engineering class.

Research Question Responses

There is a gap in the academic research on how the arts have influenced Science, Technology, Engineering, and Mathematics (STEM) education (Yakman, 2016). Therefore, central research question of this case study focused on how participation in the arts impact learning comprehension for high school students during STEM coursework at two high schools in Southwest Florida. Student participants enrolled in the arts and STEM courses, along with four STEM teachers, provided descriptions and insight into their experiences through individual interviews. The four research questions guiding this study were derived from Elliot Eisner's belief in arts exploration and cognition development (2002), Howard Gardner's theory on multiple intelligences (1995), and Maslow's theory of human motivation (1943) or Hierarchy of Needs served as a foundation for this study.

Research Question One

Research question one sought to discover how arts students perceive skills learned in arts classes impact the comprehension of STEM material. When a student participates in arts classes, they incorporate what they have learned and practiced in the arts classes, such as creative problem solving, development of their arts skills, and trial and error, ultimately being able to apply what they learn in arts classes into other disciplines (Eisner, 2002). By participating in the

arts, students develop new patterns in their brain and create their own artifacts, allowing deeper understanding with new content (Schlegel et al., 2014).

The first research question in this case study set out to determine how students perceive skills learned in their arts courses impact the comprehension of STEM material in their STEM classes. Student participants described their experiences in the arts and STEM courses and projects or performances that they have participated in high school. Several students went as far back as describing experiences in elementary and middle school. Through interviews with student participants, two themes emerged: (1) learning patience and (2) practice.

Andre explained how his patience and practicing skills evolved: "with keyboarding, it's very individual, I found the more I practiced the better I got. I could present my piece to the teacher, then move forward. Being patient with myself throughout the school year, as I worked at getting better, it just took me time, like in everything else" (Andre, Interview 10/12/18). Andre went on to describe how he learned "to think outside of the box or think in a different way when I took my time in engineering class on a project. Even in AICE chemistry, I sometimes need to be patient when we are working on a lab" (Andre, Interview, 10/12/18). One of the projects Andre had to design and build was like a trebuchet, in which his task was to design something that could successfully launch a tennis ball. "I have not had a physics class, so the trebuchet project was a bit challenging. Because engineering is the application of science and we do a lot of mechanical engineering to an extent and that's a lot of physics, so it took me longer than I expected to complete this project" (Andre, Interview, 10/12/18).

The only theatre student in this study, Lynn, provided detailed descriptions of various theatre experiences. It was her experiences with plays and musicals that taught her how to be patient and the importance of practicing something until you master it. "To learn my lines, I have

to rehearse a lot, it's as if I am living and breathing my part, becoming the character, in order to learn and memorize my lines, where I stand, how I walk and move on stage" (Lynn, Interview, 10/20/18). Lynn discussed other various projects or instances in which she needed to problem solve or work hard at learning something complicated. One of Lynn's favorite STEM lesson she was proud of herself for learning was how to do an electrocardiogram. "One of my favorite's was learning EKG's. I learned how to take them and started learning how to read the PQRS waves. That was one of my favorite things to learn about, a lot of people said it was hard, one of the hardest they had learned" (Lynn, Interview, 10/20/18). Lynn explained "We started with a textbook, but being in the medical CTE classes here, we have access to an EKG machine, hospital beds. Some people in class so others could put the leads on them. So, we learned from a book first, then demonstrations and then by practicing it ourselves, saying to myself, oh this is why this goes here, and this goes there, and that's why you do it that this" (Lynn, Interview, 10/20/18).

Robert, a member of his school's marching band, elaborated on his belief in the power of practicing. Robert had to create a solo musical piece for district and state ensemble. "I truly worked hard on creating my solo piece. I was prescribed pieces that are different levels and difficulties, and then basically had to practice and then eventually play it for a judge to give a rating at that point. It definitely was a lot of work and required a lot of dedication to the fact of creating musical ideas and being able to put time in for it and sit down and decide to work on it some more" (Robert, Interview, 10/24/18). Robert is able to transfer the skill and concept of practice into his other STEM classes. "Last year I scored a 5 in AP Calculus, practicing the theorems and concepts in calculus helped me do well on the exam" (Robert, Interview, 10/24/18).

Theo, a high school student who thoroughly enjoys ceramics expressed what she has gained through the arts "When I first started to learn how to throw clay on a wheel, it was frustrating, I didn't make anything worth keeping for a while. I knew I could not give up, I just have to keep trying until I do this right" (Theo, Interview, 10/24/18). Theo described her arts experiences, whether in watercolor, pencil drawing or clay, as a path through problem solving requiring patience and persistence. Developing her patience helped when Theo had to work with her peers on an engineering project. "We were assigned a project, this one we had to design a fire station, so we had to consider all of the constraints like the kitchen size, how many rooms are necessary because there are three sets of fire fighters who live in the station. As a group we had to collaborate and consider all of the constraints to formulate a floor plan and a technological and a model of it. Also, we had to interview firefighters to get their input for the design of the fire station" (Theo, Interview, 10/24/18). Theo needed patience throughout the entire engineering project of designing a fire house. First, she needed to be patient with the process of making the plans and outlining the approach to the project. Second, Theo had to be patient with her peers as they shared ideas, disagreed on some discussions and the development of the fire house. Theo felt the arts classes and various art media she has worked with, have helped her develop her patience.

Research Question Two

The second research question for the present study was focused on how arts students perceive practices and teaching strategies used by teachers during STEM classes inspired their creativity. When teachers provide students with various learning models in which multiple intelligences are incorporated, student comprehension, achievement, and interest increase

(Eisner, 2002). Additionally, when teachers integrate the arts into other disciplines, learning new content can be less threatening (Wynn & Harris, 2013).

The second research question in this case study set out to determine how arts students perceive the practices and teaching strategies used by teachers during STEM classes inspire creativity. Student participants described the practices used by STEM teachers that helped them learn best in their STEM courses. Each student participant described methods of instruction they encountered daily and found the most beneficial to them individually. Through interviews with student participants, two themes emerged: (1) learning visually (2) hands-on activities.

Gavin found learning visually and hands-on activities helped him to be successful in his STEM classes. “One of my strengths is the ability to visualize what I am creating. When I think of something, I can see it, which helps a lot” (Gavin, Interview, 10/12/18). Gavin’s art classes have helped him to learn how to draw and have helped him develop his creativity which has transferred to other classes. “In my engineering class, I had to design an arcade system. I brainstormed different ways to do this assignment, asking myself questions, like how can I do this, and what will I need to make this?” (Gavin, Interview, 10/12/18). Gavin was able to visualize various ways to design and build his arcade system. He then had to build the arcade system in his engineering class, all through sketches and hand-on activities. Gavin frequently made reference to the connections he has made from his visual arts classes to engineering and his science classes. “It’s very important to have creativity in projects. There are a lot of times where my teachers allow us to be creative. I think teachers need to understand that some kids need to learn visually and love making projects. It makes class more fun and I just learn better that way” (Gavin, Interview, 10/12/18).

Another student participant who preferred learning visually and through hands-on activities was Steve. Steve has always enjoyed drawing even though he felt he was just average in his art classes. Ceramics has also been a class Steve found he gravitated toward naturally. Outside of school, Steve explained how he enjoyed working on cars and boats. “I love working on things with my hands. I like taking things apart, see how they work and fixing things, maybe that’s why I like art too” (Steve, Interview, 10/12/18). The connection he has made from his art classes to working on cars and boats became obvious to Steve during his interview. Even when he talked about getting frustrated at times when making art or working on a car, Steve was able to see the connection. “I can get frustrated at times when I cannot figure things out. But I’m determined, I think the frustration makes me determined to get it done. I think I am more determined than other kids in my engineering class. Other kids sometimes get frustrated when their project doesn’t work. I just want to keep going until it works” (Steve, Interview, 10/12/18). Steve credits his ability to learn visually and through hands-on activities with his success in classes like engineering and other areas outside of school.

Zach enjoys working with his hands and sketching ideas for fashion designs. He usually sketches out his ideas, then cuts and sews his creations together. “I love designing clothes, it is what I want to do in college. First, I draw my ideas for clothing designs, before making them” (Zach, Interview, 10/12/18). Zach prefers to learn through visual means and creating things with his hands. While Zach does not plan on attending college for engineering, he finds the projects very enjoyable. Zach is able to sketch ideas and build things with his hands in engineering, similarly to his clothing design process. “One of my STEM projects that I comprehended well was the robotics. We had to work in class and after school in my engineering class. I believe I was so successful with it because of the teamwork, it was a lot of kids working together for one

cause, to create a robot. There was the programmer, the builder, the electrical person, we all came together to do it" (Zach, Interview, 10/12/18). Zach was able to use his own designing skills to contribute to the project, although he helped in other areas as well. Zach's main contribution dealt with the visual aspects of the robot and some programming and building which involved working with his hands. Zach's personal experiences with sketching and making clothing with his hands transferred into his engineering class with ease.

Research Question Three

The third research question of the study examined how students perceived their experiences in the arts impacted their creative problem-solving in STEM coursework. There are similarities between artists and scientists when displaying creativity and intuition and developing solutions when solving problems (Arcadias & Corbet, 2015). Additionally, creativity has proven to be broken into phases of incubation, illumination, and verification, which can be linked with various learning experiences in the sciences (Simonton, 2012).

Research question three seeks to determine how students perceive their experiences in the arts impact their creative problem-solving in STEM coursework. Students discussed how through their various arts disciplines, there was a level of ambiguity that was tolerated as they learned to problem solve. The one theme that continually surfaced was having the time, need, and ability to brainstorm when solving problems.

Andre, one of the students who is involved with the music program at his school, provided a descriptive definition of brainstorming: "brainstorming allows you to think outside of the box, when you need a roundabout way to do something. It allows you to tell the difference between when you need to stay within the guidelines versus doing things a different way" (Andre, Interview, 10/12/18). One of the examples Andre shared in regard to brainstorming was

a trebuchet project in his engineering class. “We had to create a mechanism that launches a tennis ball and was like a trebuchet in concept but could not resemble a trebuchet or operate like one. I was brainstorming with my friends, and we came up with an idea to make a flywheel, which has two wheels rapidly spinning, the ball touches them, then gets shot through. But then we brainstormed some more and came up with the idea of having a ball on a tee and have a golf club fall and swing then hit the ball” (Andre, Interview, 10/12/18). The trebuchet project in engineering class allowed Andre to come up with more than one possible solution. Ultimately Andre decided on the tee with a tennis ball with a golf club swing at the tennis ball to launch it like a trebuchet.

Gavin, a visual art student, finds the opportunity to brainstorm for a project to be beneficial in his studies. “In my art class, when we get an assignment, we first have to come up with ideas that fit the teacher’s requirements but still gives us freedom to choose an idea and work through it” (Gavin, Interview, 10/12/18). While in classes like engineering and science, Gavin has found that brainstorming provides an opportunity to try different solutions whether on engineering projects or science lab experiments. “I like when a teacher gives us enough time to try different solutions, then the pressure is off if we fail the first few attempts” (Gavin, Interview, 10/12/18). When Gavin was given the opportunity to brainstorm for project ideas or solutions to a problem, he felt the pressure was off of him, so he really focused on learning and discovering.

Robert, one of the music students in this case study discussed the variety of instructional methods teacher use in class, as a way of the teachers brainstorming methods of instruction. Robert enjoys learning through a variety of means: visually, auditory, working his hands, and one of his favorites that some teachers use is instruction with YouTube videos, especially videos that add some humor. “A lot of our expectations are set through standardized tests, the ACT and

SAT, which are based off not only knowledge that you gain in just basic skills in math and reading, but your ability to problem solve and critically analyze not only the text but individual problems and be able to look at how they relate to each other, and topics you've learned. So, when it comes to standardized testing, I believe it's an advantage to be able to critically analyze, think through the question and maybe take a step back but to view something on a larger scale than what was initially presented" (Robert, Interview, 10/24/18). Robert was able to connect his various learning experiences, from hands-on activities, brainstorming, group work, practicing concepts and learning visually, throughout his arts and STEM coursework, and attributed his success in standardized testing to the combination of those factors.

Research Question Four

The final research question of the present study inquired about teacher implementation of the arts into STEM courses at various grades and age levels. Students and teachers shared the various techniques and strategies used by the teachers through in-depth, recorded interviews which helped with their learning comprehension and explained how their creativity may have evolved at various grade levels (Yin, 2014). Teachers are able to witness growth in students throughout the course of time and therefore have the ability to provide insight in regard to students' progress.

Research question four sought to determine how teachers implement the arts into STEM courses at various grades and age levels. Through interviews, STEM teachers shared the various techniques and strategies used in the STEM class they teach that helped with their students' learning comprehension. Teachers described individual projects and how students felt about the projects and how the students performed. A science teacher who teaches biology and anatomy, a technology teacher who teaches Adobe Photoshop software, an engineering teacher, and an

algebra/geometry teacher were interviewed. All four believed in the importance of creativity, problem solving, and using the arts in their instructional practices. However, two of the teachers believed STEM education should retain that name. The arts need to be an integral part of STEM, but not become STEAM. The other two teachers believed STEM should become STEAM. The commonality that all four teachers shared was using visual arts in their teaching practice. How they implemented the visual arts was tailored to fit the class. Three other themes emerged through the interviews with the STEM teachers: (1) real-world knowledge, (2) time required to work on projects, and (3) collaboration.

Mrs. White, a math teacher, emphasized the importance of making what the students learn relevant to their lives. She believes making instruction relevant to the lives of her students also aides in making them proficient in math. One example Mrs. White described involved incorporating art into a trigonometry lesson. “Students have to come up with a real-world example where trigonometry was used in life. It was anything they wanted. It could be a police officer, their gun, and its trajectory. It could be a cat up in a tree. Students could use any materials to make their projects like Legos or pipe cleaners” (Mrs. White, Interview, 10/17/18). Another example Mrs. White described in which her students had to think of real-world examples “students had to take a real-world item and scale it down. One student took one of our classroom chairs and scaled it down to about an eighth of the size. They had to actually build a replica. One student did my lamp that I use, and another did the board. They had to show me their calculations once finished” (Mrs. White, Interview, 10/17/18).

Robert, one of the musicians in the study, described the amount of time it takes to get good at anything “My arts program has influenced my STEM career in the fact that dedication is needed not only to perform but to continue to work on skills as a musician. So, it requires a lot of

individual work and a mindset that is basically creating the want and need to increase your ability to be better eventually. So, this is a constant thing that musicians, it helps with everything else because we focus and learn from the start that getting better takes time, and it takes dedication to be able to go increase your ability on a certain task" (Robert, Interview, 10/24/18).

Collaboration is a key component in the engineering class. Mr. Dilbert explained while he uses some textbook activities and short lectures and demonstrations, group work is what his students participate in most frequently in engineering. Mr. Dilbert worked as an engineer for 20 years before teaching, so he is keenly aware of the importance of collaboration in the engineering field. He groups different students together with varying gifts and talents, and other times he allows the students to choose who they collaborate with. That way students have the opportunity to work with many different teams of peers throughout the school year. "Everything we do in engineering starts with a presentation, then activity, followed by a project design" (Mr. Dilbert, Interview, 10/23/18). When grouping the students, Mr. Dilbert has to keep in mind the various aspects of personalities as well as skills "when the groups collaborate on projects and designs, it helps to have an arts type of kid in the group, they can add some creativity to the design and possible solutions, just adding to the overall process" (Mr. Dilbert, Interview, 10/23/18). In addition, Mr. Dilbert noted the importance of collaboration among his STEM students, "while the kids are working together, they ask each other questions, discuss possible solutions to what they are working, all while learning. I find they kids really solidify what they are learning more effectively when they work together" (Mr. Dilbert, Interview, 10/23/18).

Summary

The purpose of Chapter Four was to present the findings of the case study. The descriptions of the participants were presented along with the data collected. The data analysis

was presented and the themes that emerged during the data analysis were described. The central research question of this case study focused on how participation in the arts impacts learning comprehension for high school students during STEM coursework at two high schools in Southwest Florida. There were three major themes and seven sub-themes that emerged; learning patience, practice, learning visually, brainstorming, real-world knowledge, time to work, and collaboration. The themes resulted through interviews based on four research questions.

CHAPTER FIVE: DISCUSSION

Overview

The purpose of this qualitative case study was to understand the impact of participation in the arts on the STEM coursework learning comprehension for high school students. Chapter Five of the present study includes a summary of the findings and a discussion of the findings in relation to relevant empirical and theoretical literature. In addition, the implications of the findings are presented with recommendations for specific stakeholders. The delimitations and limitations of the study are acknowledged, and recommendations for future research are posited. The chapter concludes with a summary.

Summary of Findings

Four research questions derived from Elliot Eisner's belief in arts exploration and cognition development (2002), Howard Gardner's theory on multiple intelligences (1995), and Maslow's theory of human motivation (1943) or Hierarchy of Needs served as a foundation for this study. Participants provided their opinions, thoughts, and experiences through individual interviews. This section provides a summary of the findings.

Research question one sought to determine how arts students perceive skills learned in arts classes impact the comprehension of STEM material. The themes that emerged from this research question were learning patience and practice. Student participants, regardless of their experience in the arts, all developed patience whether through rehearsing a musical selection, lines for a play, throwing on a pottery wheel, or developing their drawing skills. Patience allowed students to persevere when learning challenging concepts in their STEM classes. Through the arts, student participants were able to describe various ways they practiced their

craft and how practicing taught the students that they eventually learn to master new concepts through practice.

Research question two sought to reveal how arts students perceive practices and teaching strategies used by teachers during STEM classes inspire creativity. The themes that emerged from this research question were learning visually and hands-on activities. Student participants described ways they learned best in their STEM classes. One of the ways students felt they could understand new concepts or how things worked was through visual means by either making drawings or diagrams themselves or looking at visual examples, seeing a picture or diagram helped make sense of new vocabulary, concepts, and develop creative solutions to problems. Another practice student participants felt helped them develop ideas and projects in their STEM classes, was hands-on activities.

Research question three sought to determine how students perceive their experiences in the arts impact their creative problem-solving in STEM coursework. The theme that emerged from this research question was brainstorming. Student participants described how they creatively problem solve in their STEM coursework through brainstorming. Through brainstorming, students were able to come up with various solutions to problems that they felt the practices learned through the arts aided in the development of the solutions.

Research question four sought to reveal how teachers implement the arts into STEM courses at various grades and age levels. The themes that emerged from this research question were real-world knowledge, time to work, and collaboration. Teacher participants explained the importance of making content in the STEM courses relevant to the lives of the students. When the teachers were able to make new content relatable to students, the students enjoyed learning the new content and comprehended the new material well. Teachers described how students need

time to master new concepts in their STEM coursework. STEM teachers would provide a combination of instructional methods and the time needed to conduct the combination of methods for students to fully comprehend new material. STEM teachers used collaboration, where students are placed with a partner or in a small group to work together on a given task or problem to solve. Teachers explained how students interact through the learning experience and the benefits of collaboration in STEM courses.

Discussion of Findings

The findings of this case study are linked with the theories and empirical research presented in Chapter Two. Previous research addressed the arts and STEM subject areas, but not both together. The gap in the literature provided the basis for this research. The following sections explain how this case study relates to empirical and theoretical literature in regard to how the arts influence learning comprehension for high school students in their STEM classes.

Empirical Literature

The student participants in this study all were simultaneously enrolled in an arts class and STEM courses at the time of their interviews. The participants were able to richly discuss skills learned through the arts and how they implemented those skills into their STEM courses in order to learn and master new STEM content. Three of the four STEM teachers noted differences in their arts students while learning new things in the STEM classes.

In Chapter Two, there was a focus on the role the arts play in education and renaming STEM to STEAM, which was consistent in the findings of this study. The arts teach students to tolerate ambiguity, to be patient, and to value practice and brainstorming. Students also expressed the value of learning visually and through hands-on activities. Innovation is needed in the STEM workforce of the future (Daugherty, 2013). Many students described innovative ideas

for projects in their engineering classes. Those ideas stemmed from their brainstorming and practicing skills learned through the arts. Both the performing and visual arts help students develop patience, resilience and creativity (Tan, 2017), student participants reinforced these themes.

The literature empirically verified the role the arts play in education. According to Collard and Looney (2014) creativity is a natural part of social development and innovation. Student participants described how their arts experiences were applied to their comprehension in STEM courses. Additionally, the arts were shown to help develop areas of the brain that are used in STEM areas (Marcoux, 2013). Through interviews, student participants were able to reinforce the evidence described in chapter two regarding the role of arts education.

Research presented in chapter two reinforced the results of the study, renaming STEM to STEAM. While only two out of the four teacher participants stated STEM should be renamed STEAM, all four agreed the arts play a significant part in STEM education. The student participants all described rich experiences in the arts and how those experiences and skills learned through the arts helped them in their STEM courses. The arts enriched the STEM experience for students. A STEAM model would provide opportunities for teachers to incorporate best practices on how to combine skills and creative problem-solving (Wynn, 2013). The STEAM model in education engages students in problem-solving, encourages creativity, ultimately creating life long learners (Wynn & Harris, 2013). Student participants were able to transfer skills such as patience and practice learned through their arts courses, into their STEM coursework, aiding them in better comprehension and higher levels of mastery. When the arts and STEM are combined, students can develop their imaginations while developing their technical and conceptual thinking skills (Wynn & Harris, 2013). According to Daugherty (2013)

in order to optimize innovation in U.S. education, the arts and STEM need to be integrated creating a STEAM model.

Theoretical Literature

Three theories guided this study and sought to enlighten it: Gardner's multiple intelligences (1995), Maslow's hierarchy of needs (1943), and Elliot Eisner's theory stating the arts serve as models of educational practice at its best (Eisner, 1994).

Gardner's Multiple Intelligences Theory (1995) suggests that an individual's intelligence comes in various forms: (a) linguistic; (b) logical-mathematics; (c) music; (d) bodily-kinesthetic; (e) spatial; (f) interpersonal; (g) intrapersonal; (h) existentialist; and (i) naturalist (Smith, 2008). Educators are familiar with Gardner's theory of multiple intelligences, that students have different strengths and abilities (Brummelen, 2009). It is important to note that Gardner defines intelligence as one's biological and psychological potential and that his MI theory is based on empirical evidence (Gardner, 1995). Bailey (2009) states that the musical, bodily-kinesthetic, and spatial intelligence are normally associated with the arts and they are often overlooked, which is a disservice to students who may have biological and psychological strengths in other areas. A student's learning style is their preferred way to learn new content (Kanar, 2014). Additionally, when subjects in school are approached from varying perspectives, more children will be reached, comprehension can be demonstrated in several ways, and a child's education becomes more personalized (Gardner, 1995). The student participants described their own strengths and abilities as they discussed their preferred ways of learning new content. The rich descriptions provided during the interviews supported Gardner's theory regarding multiple intelligences and how students learn through a variety of modalities (Gardner, 1995).

Maslow's (1943) theory of human motivation deals with how individuals prioritize their needs, including their need for self-respect and self-actualization (Maslow, 1943). Students expressed how the arts and achievements in their STEM courses helped them to realize their full potential. Maslow (1943) has theorized all individuals have a natural desire to possess self-esteem and self-actualization, where they realize their full potential; a musician must make music and an artist must make art. Self-esteem refers to feeling good about one's self or having self-respect, whereas self-actualization specifically refers to realizing one's full potential (Maslow, 1943). Student participants described a variety of tasks, project and competitions where they found much success. The student participant's responses supported Maslow's theory on human motivation. Various achievements described by students, made students feel good about themselves and in many instances propelled students to persevere at times and take on bigger challenges in their schooling.

The last theory, based on Elliot Eisner's beliefs, practices, and research centered on arts education, encourages arts exploration, which plays a key part in the development of the imagination and cognition (Eisner, 2002). Students in each area of the arts, visual and performing, were able to provide rich descriptions of their arts experiences and how those experiences transfer into their STEM courses. According to Eisner (1994) the arts help students discover the meaning of things through the representation of forms. Often throughout the interviews of student participants, students discussed how the sketch out ideas for engineering projects and science content. The drawings, in which students gave form to their ideas and words, helped students comprehend and master new content in STEM coursework. When students interact with their world, they acquire meaning and understanding (Eisner, 1994). When students worked with their hands, they interacted with martials, helping them to comprehend

new content in STEM courses more effectively. Also, students enjoyed non-traditional modes of learning in their STEM courses especially when their teachers incorporated the arts into the lesson. The arts provide non-traditional ways of interaction and learning (Eisner, 2002). According to Eisner (2002) the arts teach students to think critically and how to analyze through interactions with their world. During the interviews with student participants, students individually described projects where they had to analyze a problem, then build, create or solve a problem. The skills learned through the arts successfully aided the students in their STEM courses such as labs in science, problem solving in technology, building projects in engineering, and new concepts in mathematics.

Implications

Arts education, whether performing or visual arts, has proven to be beneficial to the high school students in this study. All the student participants were able to describe skills learned through their arts courses, that they have been able to apply to their STEM courses. The goal of this case study is to fill in the gap in regard to STEAM education, where the arts are infused with STEM education. There are theoretical, empirical, and practical implications for this qualitative study that sought to determine how the arts influence learning comprehension for students in their STEM classes.

Theoretical Implications

During the development of Chapter Two, the literature review, I found there were many ways students learn throughout their schooling experience. Howard Gardner's theory on multiple intelligences was highlighted through the student interviews. According to Gardner (1995) several ways of learning, which surfaced during the interviws, are visual-spatial, body-kinisthetic, musical, and interpersonal. The student participants individually discussed their

preferred modes of learning. Student participants discussed learning through visual means and hands-on activities as the best modes of learning. Two of the student participants who are active with their school's music program, both expressed how important music was in their lives.

STEM teachers discussed in the interviews how students enjoyed collaborating with peers and how effective collaboration was for students learning new concepts. While discussing teaching practices, the STEM teachers discussed the positive effects when several modes of learning are combined. For example, a teacher may combine, reading, hands-on activities, and visuals all within the same lesson. When implementing several modes of learning, the STEM teacher must plan out time for students to work through the material.

Most of the student participants disliked lecture-based instruction, where they take notes, memorize the notes, then get assessed on what they were supposed to learn. Students found the stand and deliver method of instruction to be boring and the least effective. Students learned more effectively and were able to retain newly acquired information if they were provided visuals, such photographs, diagrams, and charts.

Student participants thoroughly enjoyed making things with their hands. The arts encourage working with one's hands and figuring things out as a student works through a problem or explores a medium. According to Bequette (2012) students learn how to problem solve, while imaging things through the arts. Creating and building things with their hands helps students bring to life what they see in their mind. Hands-on activities could fall under visual-spatial or bodily-kinesthetic learning based on Gardner's theory on multiple intelligence. According to Gardner (1995) visual-spatial learners think of what they are learning in a physical space, whereas bodily-kinesthetic learners learn through touching.

Through the student interviews, I witnessed the confidence each student participant exhibited when speaking to me. Once each student introduced themselves, they began to share their opinions and ideas. The student participants described what they were capable of doing, how they learned best, and described projects they felt they comprehended the objectives well. The confidence and pride in the student's accomplishments were evident as students provided rich descriptions of their experiences. According to Maslow (1943) self-actualization is described as discovering what an individual is capable of and the fulfillment being met.

I realized that the arts help students achieve self-actualization. Whether the discipline was music, theatre or visual arts, each student provided descriptions of positive learning experiences in high school. High school aged students deal with many negative things, much more now in the twenty-first century probably than ever before. To listen to high school students describe things they have learned in school with passion and enthusiasm was refreshing and uplifting for me. Another aspect that some of the student participants discussed was their hopes and dreams for their futures. According to Bequette (2012) art education aids students in imaging their dreams and possibilities. I found that art education provides students with a great sense of self during my interviews. Therefore, the findings of the present study, based on the theoretical underpinnings, imply that education decision-makers in schools should routinely make the arts part of the STEM education model, because they not only prepare students for college and careers in STEM, but the arts aid in the development of a confident and well-rounded individual.

Empirical Implications

While interviewing each STEM teacher individually, I was elated to find each teacher using a variety of teaching practices in their classes. Differentiated instruction has shown to help students from all types of backgrounds, with a variety of gifts, talents, and skill levels.

Additionally, feedback provided by the teacher participants detailed the valuable strategies they use in their classrooms to help students learn best. I have always heard the importance of making things real for students. Students want to know why they are learning something and how they are going to use what they have learned in their lives. Each one of the STEM teachers described lessons that emphasized real-world knowledge, and the importance to their students to apply newly acquired knowledge in the student's life. The findings of the present study imply that education administrators should ensure that subject content teachers outside the arts are provided with professional development focused on how to incorporate the arts into disciplines outside the arts.

Another topic that surfaced in the interviews with STEM teachers, was the amount of time needed to truly instruct new content for students. Teachers described lessons where they incorporated a variety of instructional methods and tools. By planning out a lesson over the course of many days, or even a couple of weeks, students were able to master new content. The downside to of planning out a lesson that incorporates various instruction methods, is the amount of time it takes in class for students to complete the various tasks. Teachers have to make the choice of how often to implement such strategies, and what content should they spend more time on. The benefit of using extra time, according to the STEM teachers I interviewed was how well students comprehended the material.

The last teaching practice that surfaced in the study, was collaboration. Collaboration relates a bit to the time component. STEM teachers have students either work with a partner, or in a small group occasionally when going through new content. All the STEM teachers felt collaboration was beneficial to student's learning comprehension, but collaboration also takes time. Students need time to brainstorm the possible solutions to a given problem, make decisions

on how they will approach the problem, then ultimately solve the problem. Teachers explained how students enjoyed the social aspect of working with peers, but how the students can relate to one another or maybe even explain things in a way that others can understand. The findings of the present study imply that students more effectively learn, problem solve, brainstorm solutions, and master content in their STEM courses. Therefore, education policy and decision-makers should ensure that collaboration is encouraged between students, faculty, administrators, and boards of education. For students to become fully prepared for college and careers in STEM, students need to be provided with the opportunities and education to propel them in STEM fields.

Practical Implications

Students reported their arts courses taught them patience and the benefits of practicing something. Learning a musical instrument takes patience. Students must devote years in some cases to develop their musical skills. While practicing the musical instrument helps to master playing an instrument, theatre education also aids in the development of patience and practice. Students learning lines must be patient with themselves and other cast members as they rehearse lines for a play. Practicing the lines is what helps a theatre student thoroughly learn their part in the play well enough to perform in front of an audience. In a visual arts class, students must be patient with themselves, as they make art that they may not find aesthetically pleasing or satisfactory, as they work through the art making process. Patience while making mistakes, and various renderings until a final piece of artwork is completed is part of the art making process.

Arts education is beneficial to all students (Ruppert, 2006). STEM education and careers in STEM fields are on the rise, and incorporating the arts would be beneficial to STEM. According to Bequette (2012) STEM teachers should be incorporating the arts into their

disciplines, because it will provide opportunities to the students and teachers. By incorporating the arts into STEM, students will be able to explore, synthesize, and make learning connections (Cheng, Li, Sun, & Huang, 2016). Developing patience and learning the value of practicing through the arts, can be transferred into STEM teaching practices, reaping benefits beyond high school.

At the beginning of this research I expected every participant to want STEM to become STEAM. To my surprise, the mathematics and technology teachers both thought STEM should remain STEM. However, both teachers stated that STEM teachers should be incorporating the arts into their teaching practices. Because both the mathematics and technology teacher do incorporate the arts into their practices, I could see they had a valid point. The engineering and science teachers both stated they would like the STEM model in education to become STEAM. There was no surprise, all the student participants would like to see STEM become STEAM.

Students developed skills and practices through their various visual and performing arts classes that clearly are valuable and essential in STEM courses. Student participants described the various ways they developed patience through the arts. Having patience in STEM courses and fields, allows individuals to persevere when they struggle through problems, whereas an individual who lacks patience may give up when they struggle with a problem. Students who learn to practice a musical instrument, their drawing skills, or lines in a play, all learn that practicing something over and over only helps them master a skill.

The arts provide opportunities for students to work visually with variety of materials and hands-on activities. Students participants all described in detail a variety of projects from their arts and STEM classes. Students want to be involved in the learning process. They do not want a teacher simply spoon-feeding the facts in order to pass a standardized test; students truly want to

learn, comprehend, and understand what they are learning. Being able to make something, whether by drawing or building, students analyzed as they problem solved and created something new. Student participants and STEM teacher participants all provided artifacts from the STEM classes. The examples were projects students were assessed on for comprehension of new STEM material. It was evident to me as I interviewed participants, that each one was proud of their final product, what they achieved and learned. The findings of the present study imply that STEM should be considered by school policy-makers and administrators as a requisite creative component of the entire school curriculum. Without a creative component, opportunities for innovation will be overlooked. The findings of the present study imply that school leaders should consider innovating through transitioning STEM to STEAM. A transition from STEM to STEAM could benefit students when learning new content and better prepare them for careers in STEM fields. The findings of the present study imply, from a practical perspective, that the STEAM model could and should be incorporated at every grade level, from elementary school through college.

Delimitations and Limitations

The following are the delimitations and limitations of the present study. The specific boundaries selected for this study provided the following delimitations. The case study was designed to include high school students only, from two different highs schools with similar demographics and size. Interviewing college students who participate in the arts and STEM would have provided a larger body of research; however, doing so was beyond the scope of the present study. When identifying, then trying to recruit student participants, one of the requirements I wanted was the students were enrolled in all four areas of STEM. The engineering classes did not have many female students enrolled. Also, I set out to include students from

various disciplines in the arts, including dance. None of the student participants were enrolled in dance at the time of the research.

A significant limitation of the present study was lack of gender and ethnic diversity in the participants. While the intent of the study was to have both gender and ethnic diversity, the demographics of the engineering classes at both schools were dominated by White male students; therefore, most of the study participants were White males.

Another limitation of the study included lack of diversity in personality type. For example, outgoing students wanted to participate, while the quiet and introspective students did not. Because very talented arts students can often appear outwardly subdued, an important, this shortcoming of the study could represent a missed research opportunity.

Lastly, the socioeconomic background of the student participants was beyond the scope of this study. Studies show that arts participation, due to possible financial implications, could have impacted student participation in the arts. For example, some of the student participants described being involved in the arts from childhood. In addition, one student had the experiences of being in plays since the age of eight and two of the students who had backgrounds in music, described music as being important in their families. Therefore, determining whether family input or upbringing impacted student experiences is a limitation of the study.

Recommendations for Future Research

The findings of the present study help fill the gap in the literature regarding how participation in the arts impacts Science, Technology, Engineering, and Mathematics (STEM) coursework for students at two Southwest Florida High Schools. However, there were other important related topics beyond the scope of the study and several areas of focus that became obvious fields in need of further exploration and research.

This case study could serve as a model for further research, conducting a study with individual student participants from high schools and STEM teachers. Other case studies should be conducted at different high schools and at different age levels. Charter and private schools may provide additional input as well. Elementary-aged children, middle school-aged children, college students, and adults working in STEM fields could provide valuable feedback as to how the arts influence their learning comprehension in STEM.

Both high school sites have populations of various races and socioeconomic backgrounds: out of the seven participants, there were only two females. One female was Asian, the other white. Out of the five remaining participants, all were white, and one male student was from Ukraine. Both high schools have Hispanic and African-American students in attendance but finding student participants who were enrolled in the arts and STEM programs simultaneously proved difficult. Future research that included a variety of ages groups, more females and more minorities should be conducted.

One final suggestion for further research would be to conduct a longitudinal study that would follow the student participants of the present study into their college experience, into their careers, and beyond, to determine whether the arts still continue to play a role in the comprehension of STEM subjects in college.

Summary

Students who participate in the arts, whether performing or visual arts, learn skills that have shown to be beneficial in several other areas (Eisner, 2002). The purpose of this qualitative case study was to understand the impact of participation in the arts on STEM coursework learning comprehension for seven high school students and four STEM teachers at two high schools in southwest Florida. Within the context of the study, the term “arts’ was used to

collectively refer to all visual and performing arts courses, including painting, drawing, graphic arts, two-dimensional and three-dimensional, music, and theatre. There were four research questions that were developed from Elliot Eisner's belief in arts exploration and cognition development (2002), Howard Gardner's theory on multiple intelligences (1995), and Maslow's theory of human motivation (1943) which served as a foundation for this study. The first theory steering this study was associated with Elliot Eisner who believed that the arts encourage exploration and play a key function in the development of the imagination and cognition (Eisner, 2002). The second theory that guided this study was Howard Gardner's theory on multiple intelligences (1995), which states when students are able to approach their coursework from various perspectives, learning comprehension can be displayed in varying ways (Gardner, 1995). Lastly, Maslow's (1943) theory of human motivation deals with how individuals highlight their needs, including their need for self-respect and self-actualization (Maslow, 1943).

The seven arts participants and four STEM teacher participants provided their opinions, thoughts, perceptions, and experiences through individual interviews. Participants were from different public high schools in southwest Florida, with similar demographics, both with arts and STEM programs. This case study served to fill a gap in the related literature, where the STEM model in education should become STEAM, where the arts are incorporated into existing STEM curriculum. Implementation of the arts into STEM coursework is not freely practiced in education (Bequette & Bequette, 2012).

This case study demonstrated that students benefit through participation in the arts by learning life skills, obtaining success in the classroom, and becoming proficient in learning new concepts, then applying those benefits in their STEM courses, making the implications clear. The benefits obtained through the arts are referred to as the major themes. The three major themes,

stemmed from seven sub-themes discovered in this study: learning patience, practice, learning visually, brainstorming, real-world knowledge, time, and collaboration. In order to be innovative, students need to have the experiences that the arts can foster in the right side of the brain, the side associated with creativity (Eisner, 2002). Through open-ended interviews and observations with the participants, data were collected and analyzed. The feedback provided by participants in the case study provided insight into how students use learning strategies, skills, and creative problem solving, resulting from their participation in the arts, and in their STEM coursework.

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APPENDIX A

IRB Approval Letter

September 21, 2018

Tiffany L. Jennings
IRB Approval 3395.092118: How Participation in the Arts Impacts Learning Comprehension for High School Students During Stem Coursework at Two High Schools in Southwest Florida: A Case Study

Dear Tiffany L. Jennings,

We are pleased to inform you that your study has been approved by the Liberty University IRB. This approval is extended to you for one year from the date provided above with your protocol number. If data collection proceeds past one year or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Your study falls under the expedited review category (45 CFR 46.110), which is applicable to specific, minimal risk studies and minor changes to approved studies for the following reason(s):

> 6. Collection of data from voice, video, digital, or image recordings made for research purposes.
> Your study involves surveying or interviewing minors, or it involves observing the public behavior of minors,
> and you will participate in the activities being observed.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,
G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
The Graduate School

APPENDIX B

INFORMED CONSENT

HOW PARTICIPATION IN THE ARTS IMPACTS LEARNING COMPREHENSION FOR HIGH SCHOOL STUDENTS DURING STEM COURSEWORK AT TWO HIGH SCHOOLS IN SOUTHWEST FLORIDA: A CASE STUDY

Tiffany L. Jennings
Liberty University
School of Education

Your child is invited to be in a research case study to understand how the arts influence science, technology, engineering, and mathematics (STEM) coursework. Your child was selected as a possible participant because of his or her participation in arts and STEM courses. I ask that you read this form and ask any questions you may have before agreeing to allow him or her to be in the study.

Tiffany L. Jennings, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to describe the arts' influence on students who participate in STEM coursework. With the recent increase in STEM education, art educators see a potential problem; students may miss key components of their education when art programs are undervalued or cut from schools all together.

Procedures: If you agree to allow your child/student to be in this study, I would ask him or her to do the following things:

1. Students will be interviewed two times during the semester. The first interview students will answer ten questions. Question six asks about STEM project(s) students have made. If the students agree to provide artifacts/projects to be photographed, another interview time will be set up, so that the student has time to bring the artifact to school. At that time, student participants will be given the opportunity to explain what the project was, and their own assessment of their work.
2. Each interview will be recorded and may last anywhere from 35-45 minutes. Interviews will take place in the students' art rooms.
3. Students will be asked to provide any artifacts of their classwork that they feel demonstrates learning comprehension. Any artifacts provided will be photographed.
4. Students will be observed in their arts classes for approximately 30-40 minutes while working on assignments.
5. Interviews will be transcribed from the recorded interview into a word document. You will have the option to review the transcription at that time.

Risks and Benefits of being in the Study: The risks involved in this study, if any, would be the short amount of time away from working on the student's art assignments during art class. However, teachers normally make accommodations to students on a weekly and sometimes daily basis when any student misses class time to work on projects. The benefits could affect future students by possibly showing how cognitive connections are made through the arts and STEM coursework. Very little research exists on the infusion of arts and STEM education. Through this

study, students who have experienced the blending of learning techniques, synthesis of ideas, and comprehension and mastery of new concepts through arts education while participating in STEM classes will be providing educators with their first-hand knowledge and experiences. Ultimately the educators will be learning from the students.

Compensation: Your child/student will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records.

- No students' names will be used in this study. Students' names will be replaced by a number or alias that they choose. Their identities will be kept confidential.
- The data collected will only be saved up until three years after the dissertation is defended. After that point, all data will be discarded.
- Recordings will be obtained using the application called "Voice Recorder" on the interviewer's smartphone.
- The recordings will then be transcribed and stored in Microsoft word on the interviewer's computer.
- All research will be used for educational purposes only.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect his or her current or future relations with Liberty University. If you decide to allow your child to participate, he or she is free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If your child chooses to withdraw from the study, you or your child should contact the researcher at the email address/phone number included in the next paragraph. Should your child choose to withdraw, data collected from him or her will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Tiffany L. Jennings. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at [redacted]. You may also contact the researcher's faculty advisor, Dr. Kenneth Tierce, at [redacted].

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd, Green Hall 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information to keep for your records.

The Liberty University Institutional Review Board has approved this document for use from 9/21/2018 to 9/20/2019
Protocol # 3395.092118

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. I consent to allow my child to participate in the study.
The researcher has my permission to audio-record my child as part of his or her participation in this study.

_____

Signature of Minor Date

_____

Signature of Parent Date

_____

Signature of Investigator Date

APPENDIX C

INFORMED CONSENT

HOW PARTICIPATION IN THE ARTS IMPACTS LEARNING COMPREHENSION FOR HIGH SCHOOL STUDENTS DURING STEM COURSEWORK AT TWO HIGH SCHOOLS IN SOUTHWEST FLORIDA: A CASE STUDY

Tiffany L. Jennings
Liberty University
School of Education

You are invited to be in a research case study to understand how the arts influence science, technology, engineering, and mathematics (STEM) coursework. You were selected as a possible participant because of your experience teaching STEM courses and because you also teach one of the student participants in this case study. I ask that you read this form and ask any questions you may have before agreeing to be in the study.

Tiffany L. Jennings, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to describe the arts' influence on students who participate in STEM coursework. With the recent increase in STEM education, art educators see a potential problem; students may miss out on key components of their education when art programs are undervalued or cut from schools all together.

Procedures: If you agree to be in this study, I would ask you to do the following things:

1. Provide time during your planning period in order to conduct the interview.
2. Participate in a recorded interview. The interview may last anywhere from 20-25 minutes, providing enough time for rich descriptions and responses. Interviews will take place in a location of your choosing: classroom, teacher-planning room, or conference room.
3. Interviews will be transcribed from the recorded interview into a word document. You will have the option to review the transcription at that time.

Risks and Benefits of being in the Study: The risks involved in this study are minimal, which means they are equal to the risks you would experience in everyday life. The benefits could affect future students by possibly showing how cognitive connections are made through the arts and STEM coursework. Very little research exists on the infusion of arts and STEM education. Through this study, students who have experienced the blending of learning techniques, synthesis of ideas, comprehension and mastery of new concepts through arts education while participating in STEM classes will be providing educators with their first-hand knowledge and experiences. Ultimately the educators will be learning from the students.

Compensation: You will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records.

- No participants' names will be used in this study. Participants names will be replaced by a number or alias that they choose. Their identities will be kept confidential.
- The data collected will only be saved up until three years following the successful dissertation defense.
- Recordings will be obtained using the application called "Voice Recorder" on the interviewer's smartphone.
- The recordings will then be transcribed and stored in Microsoft word on the interviewer's computer.
- All research will be used for educational purposes only.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not affect any current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If you choose to withdraw from the study, you should contact the researcher at the email address/phone number included in the next paragraph. Should you choose to withdraw, data collected from you will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Tiffany L. Jennings. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at tiffany.jennings@sarasotacountyschools.net or [redacted] You may also contact the researcher's faculty advisor, Dr. Kenneth Tierce, at [redacted]

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd, Green Hall 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information to keep for your records.

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. I consent to participate in the study.

The researcher has my permission to audio-record as part of participation in this study.

_____

Signature of Participant Date

_____

Signature of Investigator Date

APPENDIX D

Assent of Child to Participate in a Research Study

What is the name of the study and who is doing the study?
How the arts impact learning comprehension for high school students during stem coursework at two high schools in Southwest Florida: a case study by Tiffany Lynn Jennings

Why are we doing this study?
I am interested in studying how participation in the arts impacts Science, Technology, Engineering, and Mathematics (STEM) coursework.

Why are am I asking you to be in this study?
You are being asked to be in this research study because you are enrolled in the arts and STEM program at your high school.

If you agree, what will happen?
If you are in this study the findings could assist educators at the state and local levels when planning curriculum and instructional goals for their STEM programs. Likewise, once educators see the influence of the arts, they can implement the arts into STEM programs, solidifying STEAM (STEM + arts) in high schools and colleges. Equally, the results of this study will ultimately create students who are better prepared for their future, propelling the U.S. in STEM related fields globally.

Do you have to be in this study?
No, you do not have to be in this study. If you want to be in this study, then tell the researcher. If you don't want to, it's OK to say no. The researcher will not be angry. You can say yes now and change your mind later. It's up to you.

Do you have any questions?
You can ask questions any time. You can ask now. You can ask later. You can talk to the researcher. If you do not understand something, please ask the researcher to explain it to you again.

Signing your name below means that you want to be in the study.

_____

Signature of Child Date

Liberty University Institutional Review Board,
1971 University Blvd, Green Hall 1887, Lynchburg, VA 24515
or email at irb@liberty.edu.

APPENDIX E

School Approval Letter

April 22, 2018

[redacted]

Dear Mrs. Jennings:

After careful review of your research proposal entitled *How Participation In The Arts Impacts Learning Comprehension For High School Students During Stem Coursework At Two High Schools In Southwest Florida: A Case Study,* I have decided to grant you permission to conduct your study at North Port High School.

I confirm that I am authorized to approve research in this setting.

I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Liberty University IRB.

Check the following boxes, as applicable:

☐ Data will be provided to the researcher stripped of any identifying information.

☐ I/We are requesting a copy of the results upon study completion and/or publication.

Sincerely,

[redacted]

April 22, 2018

[redacted]

Dear Mrs. Jennings:

After careful review of your research proposal entitled *How Participation In The Arts Impacts Learning Comprehension For High School Students During Stem Coursework At Two High Schools In Southwest Florida: A Case Study,* I have decided to grant you permission to conduct your study at Riverview High School.

I confirm that I am authorized to approve research in this setting.

I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Liberty University IRB.

Check the following boxes, as applicable:

☐ Data will be provided to the researcher stripped of any identifying information.

☐ I/We are requesting a copy of the results upon study completion and/or publication.

Sincerely,

[redacted]

APPENDIX F

Interview Questions for Student Participants

Student Questions

1. Please introduce yourself to me.
2. Describe your experiences and strengths in the arts.
3. What arts media do you enjoy working with?
4. Tell me about an arts project you felt successful once it was complete. Why did you feel you were successful with the project?
5. How do you define creative problem solving?
6. Tell me about a lesson you felt you comprehended really well in from one of your STEM classes? Why did you feel you were successful with the project?
7. Describe your comprehension of new STEM material when your teacher allows you to integrate creativity and arts skills into an assignment.
8. Describe your comprehension of new STEM material when the delivery or instructional method does not incorporate the arts.
9. Describe an assignment or assessment you feel you did very well because of your creative solution.
10. Is there anything else you would like to mention about your experience with arts and STEM coursework?

APPENDIX G

Interview Questions for Teacher Participants

Teacher Questions

1. Describe the methods of instruction you use in which you believe your students learn STEM content best.
2. What differences do you see between the STEM only students and the arts + STEM students?
3. What arts media do you believe your students enjoy working with?
4. Tell me about an arts project you believe your students successfully completed. Why do you believe your students were successful with the project?
5. How do you define creative problem-solving?
6. Tell me about a STEM class lesson you believe your students comprehended well? Why do you believe your students were successful with the project?
7. What are your thoughts about converting STEM to STEAM at the high school level?
8. Is there anything else you would like to mention about your students in this study?

APPENDIX H

Recruitment Letter

July 2, 2018

Participant for case study research
STEM and arts student
Sarasota County Schools
Florida

Dear Student/Parent:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctorate degree. The purpose of my research is to determine how participation in the arts impacts learning comprehension for high school students during STEM coursework, and I am writing to invite you/your child to participate in my study.

If you/your child is enrolled in your/his or her school's STEM program and an arts course and are willing to participate/allow your child to participate, you/he or she will be asked to be interviewed, first to answer interview questions, then a follow up interview if your student chooses to provide artifacts/projects of their STEM classwork. Ten questions will be asked during the interview. Interviews will be audio recorded, then transcribed. As needed, participants will review the transcript with the researcher for accuracy of statements. Student participants will have the option to provide visual examples of STEM coursework that they feel demonstrates their own comprehension of the STEM material. Any visual examples provided will be photographed to be included in the study. Participants will also be observed in their arts class for approximately 30-40 minutes while working on assignments. It should take approximately 30-45 minutes for you/your child to complete each interviews. Your/your child's name and/or other identifying information will be collected as part of your/their participation, but this information will be kept confidential.

To participate/for your child to participate, complete and return the consent document and contact me to schedule an interview email: tjennings21@liberty.edu within a week of receiving this recruitment letter.

A parental consent document is attached to this letter. The consent document contains additional information about my research, please sign and have your child sign the consent document and return it to your/his or her STEM teacher or guidance counselor.

Sincerely,

Tiffany Jennings
Art Teacher at North Port High School

APPENDIX I

Recruitment Letter

August 12, 2018,

Participant for case study research
STEM teachers
Sarasota County Schools
Florida

Dear STEM Teacher:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctorate degree. The purpose of my research is to determine how participation in the arts impacts learning comprehension for high school students during STEM coursework, and I am writing to invite you to participate in my study.

If you teach in your school's STEM program, teach one of the student participants in this study, and are willing to participate you will be asked to be interviewed. Eight questions will be asked during the interview. Interviews will be audio recorded, then transcribed. As needed, participants will review the transcript with the researcher for accuracy of statements. It should take approximately 20-25 minutes for you to complete the interviews. Your name and/or other identifying information will be collected as part of your participation, but this information will be kept confidential.

To participate please email me at [redacted] to schedule an interview (include contact information).

A consent document is attached to this letter. The consent document contains additional information about my research, please sign the consent document and return it to me at the time of the interview.

Sincerely,

Tiffany Jennings
Art Teacher at North Port High School

APPENDIX J

Teacher Consent

Tiffany L. Jennings

Liberty University, School of Education

You are invited to be in a research case study to understand how the arts influence science, technology, engineering, and mathematics (STEM) coursework. You were selected as a possible participant because of your experience teaching STEM courses and because you also teach one of the student participants in this case study. I ask that you read this form and ask any questions you may have before agreeing to be in the study.

Tiffany L. Jennings, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to describe the arts' influence on students who participate in STEM coursework. With the recent increase in STEM education, art educators see a potential problem; students may miss out on key components of their education when art programs are undervalued or cut from schools all together.

Procedures: If you agree to be in this study, I would ask you to do the following things:

1. Provide time during your planning period in order to conduct the interview.
2. Participate in a recorded interview. The interview may last anywhere from 20-25 minutes, providing enough time for rich descriptions and responses. Interviews will take place in a location of your choosing: classroom, teacher-planning room, or conference room.
3. Interviews will be transcribed from the recorded interview into a word document. You will have the option to review the transcription at that time.

Risks and Benefits of being in the Study: The risks involved in this study are minimal, which means they are equal to the risks you would experience in everyday life. The benefits could affect future students by possibly showing how cognitive connections are made through the arts and STEM coursework. Very little research exists on the infusion of arts and STEM education. Through this study, students who have experienced the blending of learning techniques, synthesis of ideas, comprehension and mastery of new concepts through arts education while participating in STEM classes will be providing educators with their first-hand knowledge and experiences. Ultimately the educators will be learning from the students.

Compensation: You will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records.

- No participants' names will be used in this study. Participants names will be replaced by a number or alias that they choose. Their identities will be kept confidential.
- The data collected will only be saved up until three years following the successful dissertation defense.
- Recordings will be obtained using the application called "Voice Recorder" on the interviewer's smartphone.
- The recordings will then be transcribed and stored in Microsoft word on the interviewer's computer.
- All research will be used for educational purposes only.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not affect any current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If you choose to withdraw from the study, you should contact the researcher at the email address/phone number included in the next paragraph. Should you choose to withdraw, data collected from you will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Tiffany L. Jennings. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at [redacted]. You may also contact the researcher's faculty advisor, Dr. Kenneth Tierce, at [redacted]

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd, Green Hall 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information to keep for your records.

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. I consent to participate in the study.

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS IRB APPROVAL INFORMATION WITH CURRENT DATES HAS BEEN ADDED TO THIS DOCUMENT.)

☐ The researcher has my permission to audio-record as part of participation in this study.

_____

Signature of Participant Date

APPENDIX K

INVESTIGATOR AGREEMENT & SIGNATURE PAGE*

BY SIGNING THIS DOCUMENT, THE INVESTIGATOR AGREES:

1. That no participants will be recruited or entered under the protocol until the Investigator has received the final approval or exemption email from the chair of the Institutional Review Board.
2. That no participants will be recruited or entered under the protocol until all key personnel for the project have been properly educated on the protocol for the study.
3. That any modifications of the protocol or consent form will not be initiated without prior written approval, by email, from the IRB and the faculty mentor/chair, except when necessary to eliminate immediate hazards to the participants.
4. The PI agrees to carry out the protocol as stated in the approved application: all participants will be recruited and consented as stated in the protocol approved or exempted by the IRB. If written consent is required, all participants will be consented by signing a copy of the approved consent form.
5. That any unanticipated problems involving risks to participants or others participating in the approved protocol, which must be in accordance with the Liberty Way (and/or the Honor Code) and the Confidentiality Statement, will be promptly reported in writing to the IRB.
6. That the IRB office will be notified within 30 days of a change in the PI for the study.
7. That the IRB office will be notified within 30 days of the completion of this study.
8. That the PI will inform the IRB and complete all necessary reports should he/she terminate University Association.
9. To maintain records and keep informed consent documents for three years after completion of the project, even if the PI terminates association with the University.
10. That he/she has access to copies of 45 CFR 46 and the Belmont Report.

Tiffany L. Jennings

Principal Investigator (Print) Principal Investigator (Signature) Date

Co-Investigator (Print) Co-Investigator (Signature) Date

FOR STUDENT PROPOSALS ONLY:

BY SIGNING THIS DOCUMENT, THE FACULTY MENTOR/CHAIR AGREES:

1. To assume responsibility for the oversight of the student's current investigation, as outlined in the approved IRB application.
2. To work with the investigator, and the Institutional Review Board, as needed, in maintaining compliance with this agreement.

3. To monitor email contact between the Institutional Review Board and principle investigator.
   Faculty mentors/chairs are cc'ed on all IRB emails to PIs.
4. That the principal investigator is qualified to perform this study.
5. That by signing this document you verify you have carefully read this application and approve of the procedures described herein, and also verify that the application complies with all instructions listed above. If you have any questions, please contact our office (irb@liberty.edu).

Kenneth Randall Tierce, Ed.D.
Faculty Mentor/Chair (Print) Faculty Mentor/Chair (Signature) Date

*The Institutional Review Board reserves the right to terminate this study at any time if, in its opinion, (1) the risks of further experimentation are prohibitive, or (2) the above agreement is breached.