STEAM: A National Study of the Integration of the Arts Into STEM Instruction and its Impact on Student Achievement

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Chapter 1: Introduction

Problem, Significance, and Purpose

The purpose of this study is to examine the relationship between exposure to the arts and performance in Science, Technology, Engineering, and Math (STEM) subjects. Over the past decade educators have become increasingly focused on Science, Technology, Engineering, and Math (STEM) (Sousa & Pilecki, 2013). In 2004 and 2006, for example, over $3 billion of federal monies were allocated to fund STEM initiatives (Kuenzi, 2008). However, the early optimism surrounding STEM has tempered a bit as STEM enrollment rates in these fields have begun to decline. Perhaps in an effort to bolster enthusiasm for STEM, a new emphasis in adding arts to the mix has emerged. Prestigious educational institutions and innovative STEM programs are introducing arts into STEM to create STEAM (Sousa & Pilecki, 2013). The purpose of this study is to address the following question: do students participating in the arts demonstrate higher academic achievement in STEM learning versus those students not participating in the arts?

Rationale

This question is important because evidence for increasing arts participation to impact STEM learning can increase an understanding of how to improve current STEM initiatives. Educational reforms, especially those related to arts-based instruction, are being implemented both nationally and internationally. Of course, these efforts arrive on the coattails of severe budget cuts, nationalized standards, and economic and political unrest. Authors, activists, and noted scholars Catterall (2012), Dail (2013), Eger (2013), Maeda (2013), and Sousa and Pilecki (2013) have touted the potential of art-based activities for teaching and learning sciences and math. Combined, their work advocates for STEM employees that will embrace and confront twenty-first century challenges. An oppositional viewpoint interprets the arts as a distraction or detour of real learning and economic growth. Yet Maeda (2013) states that art "creates the innovative products and solutions that will propel our economy forward, and artists ask the deep questions about humanity that reveal which way forward actually is" (p. 1).

A second reason to examine evidence for STEAM is to investigate the possible connection between art and science achievement. A major premise driving arts reform and STEAM lies in the hope that creativity may deepen understanding of other subjects (Jones, 2010). Many critics of art-based reforms argue the superfluous nature of aesthetics in the classroom (Annis, 2013). It has long been accepted that arts are something extra, a task to explore after core subjects have been reviewed. Sciences and arts have long been isolated from one another. Advocates for STEAM call for the immersion of traditional STEM subjects with art (Dail, 2013; Eger, 2013; & Maeda, 2013). No longer, they argue, will learning be destined to occur in separate silos; it will be merged onto a common stage. On the other hand, political think tanks such as the Heritage Foundation have traditionally disputed governmental spending or backing of artistic endeavors (Jarvik, 1997). These conservative idealists content that arts should not be supported by tax dollars, as it associated with lewd material, cultural elitism, and is a wasteful use of resources. In order to better understand the implications of art in STEM, one should continue to investigate the ongoing discourse surrounding STEAM.

As it stands, traditional STEM education prepares students for highly technical jobs by a highly technical means in hopes that the United States workforce can propel its economic and political prowess back to dominance (ASHE, 2011). However, this push has grown stagnant. While graduation rates of STEM candidates have grown over the past decade, the quality of STEM employees has faced scrutiny and the U.S. continues to lag behind other international powers with regards to scientific, mathematical, or technological advances. Those knowledgeable of STEM education cite teaching quality, significant demographic gaps of graduates, and ill-prepared workers as major challenges of current STEM initiatives (ASHE, 2011).

Key Terms

Integrated curriculum. Research contends that “science has long infused the arts with curiosity for natural phenomena and human behavior” (Dail, p. 1, 2013). In this study, an “integrated curriculum” refers to a link of several concepts or disciplines of study for the sake of crossing traditional linear learning. To determine efficacy of Science and Art when used in harmony or in isolation, the principles of cross-curriculum learning become imperative. This instructional strategy allows students to implement several ideas or concepts from multiple subjects of study for an understanding of the underlying concepts (Lake, 1994). Allison Hoewisch (2001) states that “interdisciplinary instruction” (p. 155) is the inclusion and organizational alignment of discipline goals. In an integrated curriculum, the objectives of a math, social studies, or science class may be enhanced by congruently including other subjects such as art. Integrative instruction is also referred to as cross-curriculum, interdisciplinary, multidisciplinary teaching or distributed intelligence approach (Pea, 1993). These strategies and concepts are essential to understanding the discourse of adding Arts to a STEM paradigm.

Arts. For the purpose of this research, “arts” refers to those creative in nature: music, dance/movement, imagery, visual arts, literature, drama, and play or humor or any activity relating to such subjects and “arts consumption (attending, listening to, watching, or reading) and more arts creating (writing, composing, drawing, painting)" (Bergonzi & Smith, 1996, p. 7). These arts "are process oriented, emotionally sensitive, socially directed, and awareness focused" (Gladding, 1992, p.ix). An application of liberal arts include "formal academic studies that are intended to provide general skills and knowledge, as opposed to more specialized vocational skills" (Ferraro, 2007, p. 25). The subjects in this category would generally include "the arts, humanities, and literature" (Ferraro, 2007, p. 25).

STEM. STEM relates to the systematic and institutionalized training or education of students at the elementary, secondary, and post-secondary level in science, technology, engineering, and math. STEM also constitutes studies "in a wide range of disciplines and occupations, including agriculture, physics, psychology, medical technology, and automotive engineering" (Ashby, 2006, p. 4). Federal aid, along with universities and high school learning academies, have offered financial incentives to students and learning academies to encourage student participation in STEM programs. Recent trends suggest there is a growing deficit of minority, poverty stricken, and female STEM students. The number of students obtaining STEM degrees has fallen, with poor teacher quality and ill preparation cited as causes (Ashby, 2006). It is important to note the struggles of current STEM paradigms in order to fully realize the relief arts may provide.

STEAM. STEAM is a contemporary movement to introduce Art into the marriage of STEM. Journals and literature are dedicated solely to the topic of STEAM and the power of arts in education. The renowned Rhode Island School of Design, led by its president, John Maede has started a federal initiative to include arts and design into STEM to support advancement and prosperity ("STEM to STEAM," 2013). If amended, House Resolution 51 would encourage the inclusion of arts in STEM agendas and incorporate aesthetic studies in federal STEM initiatives (Michaud, n.d.). This merger would decimate the recent trend of slashing art budgets while propagating STEM spending (Sousa & Pilecki, 2013). The principles driving STEAM reside in the belief that students need both a natural and creative view of the world to compete in the global market of the twenty-first century (Sousa & Pilecki, 2013).

Organization of the Review

The review of literature will begin with an overview of works by Gardner (1993), Pea (1993), Sternberg (1999; 2003), and Wilson and Conyers (2013) to understand the conceptual framework of multifaceted intelligences. For historical perspective, a brief examination will describe the interplay between science and aesthetics. Trends dictate a migration from the marriage of technical and creative disciplines. However, accomplishments resulting from the merger of arts and science are indicative of a system desired by STEAM advocates.

Furthermore, research has been divided into two subgroups of thought: Arts and Interdisciplinary Action. The arts component of the literature provides an overview of the cognitive capabilities that research finds associated with arts. Primary importance of this topic lies in its ability to support arts in learning. Before applying the arts-based research and implications to STEM programs, it was important that scientific evidence support the application of arts and creativity to all domains of education. Empirical evidence supports the involvement of arts to improve academic quality. Findings from brain-based research offer scientific evidence to support the positive impact arts have on mental capacities. Evaluating art and creativities causal relationship to memory will emphasize the impact of art on various learning styles. Portions of the literature featuring interdisciplinary paradigms are important to document specific applications of arts in STEM initiatives.

To answer the question why arts and STEM?, one can examine the criticisms of professional administrators and their pleas for more creativity (Driver, 2001). Historically speaking, “journal articles dating back as early as 1959 identify creativity as being essential to the competiveness and national security of the United States” (Wallace et al., p. 3E-1, 2010). In a global market, businesses, corporations, and governments are looking for an edge over the competition.

Creativity is often linked to art in research studies and journals. Going beyond the cognitive power of the arts, it is believed that participating in art, music, dance, poetry, etc. may provide more creative outlets for STEM students, serve as a viable recruiting tool for future students into technical fields, and derive joy from the learning experience (Welch, 2011). Art and its creative processes may allow students to explore and unlock multiple intelligences. Creativity, specifically creating teachable moments to warrant creativity, is discussed extensively in the review.

Finally, a review of arts in relation to qualitative and scientific applications is surveyed. It is believed that these components give the reader a strong scientific overview of the impact art has on brain functions and learning. This serves as an important foundation for the discussion concerning integrated curriculum. The purpose of the arts section is to provide the background and scientific trends supporting aesthetics in education. While historical accounts have recorded the merger between arts and science for centuries, current technology and scientific advances have allowed for a more thorough understanding of art’s impact on neurological processes.

Another theme embedded in the literature review is Interdisciplinary action. This subgroup of information defines the importance of careful planning, collaboration, and impact of introducing arts into other disciplines. This theme is pivotal to the discourse of STEAM. A major component of STEAM initiatives require introduction and integration of arts-based education into technical domains. This portion of the literature traces the importance of interdisciplinary instruction and identifies STEM programs that have started to introduce arts into the curriculum.

The clash of arts (abstract) and math/science (literal) creates a dynamic collaboration worth analyzing. Many advocates for STEAM deem this interaction necessary for students to "embrace innovative, alternative views, minority influence, or diversified solutions that may be required to effectively address complex issues" (Kawaski & Toyofuku, p. 2, 2013). By partnering across the curriculum with other teachers, schools can strengthen areas of weakness by targeting, monitoring, and implementing necessary means of intervention (Snider, 2008). As STEAM relates to a systematic effort to seamlessly intertwine all academic arenas for outcome achievement, the review focuses on similar trends. While the study will evaluate arts participation, mathematics, and science achievement as they are taught in isolation, the literature will focus on integrative approaches to merge science and arts. It is important to survey the coupling of two distinctly different courses when formulating potential impact. The review of literature discusses evidenced results from previous studies, stakeholder perceptions, and other cultural effects.

Scope/Limitations

This study informs school leaders and policymakers on the potential impact of arts and creativity in most educational settings, including STEM academies. Examples of schools and classes using STEAM driven agendas will be outlined to model effectiveness and document experiences. However, this study does not analyze specific operational concerns of implementing STEAM such as teacher background, training, school budget or facilities, and/or many specific student accommodations experienced at the site-based level. Although, the evaluation will account for student demographics to better understand the correlation between arts involvement and science/mathematics performance among various student sub-groups. Results are intended to lay the framework of arts in STEM by determining if students participating in the arts demonstrate higher levels of achievement in math and science. The findings will illustrate any correlation between arts instruction and STEM based knowledge as they are taught in isolation.

Discussion of program specifics such as cost and training were intentionally omitted in order for more attention to focus research on STEAM initiatives and scientific research concerning the arts. Collecting evidence to support art-integrated schools will better assist educational leaders and supervisors in deciding if cost and training are worth the spending needed to satisfy areas of deficiency.

Another exemption of the literature was curriculum guides, maps, and adoptions. This study did not deliberate specific curriculum guidelines or standards as it is assumed most principles of art-based research support universal applications. It is believed the effects of arts integration on any curriculum will transcend cultural, socio-economic, and content boundaries. STEM frameworks were used in this study to represent the extreme dichotomy of arts and science merging as STEAM. Currently, in the United States there is a shift to a national curriculum, Common Core. However, most STEM academies follow a separate curriculum or one that will incorporate standards. Regardless, the research supports art's enhancement of learning at various stages of development and in most educational settings. The literature will spend more time discussing the general impact and implications of arts on many levels. Time spent examining the utilization of arts in Common Core Standards would almost be another study entirely. Therefore, this research will examine arts as it relates to more technical disciplines and the creation of STEAM. If success can incur between technical and non-technical disciplines in the case of STEAM, an argument can be made for arts integration across most content areas.

Library Research Plan

A number of web-based sources, articles, and books were explored to obtain literature concerning arts and STEM. Claremont Graduate University publishes a STEAM Journal and several editorials and articles of notable scholars were reviewed. Numerous studies were explored through electronic versions of Journal for Learning through the Arts. A number of consortium reports from state educational institutions and philanthropic organizations were also explored. Academic databases including Educational Resources Information Center (ERIC), Google Scholar, and LOUIS (The Louisiana Library Network) offered at the university level granted further access and assisted in finding studies. The review contains sources both quantitative and qualitative in nature. The studies were reviewed through a lens concerning effects of arts on student learning, the value of creativity in learning and development, STEM initiatives and backgrounds, and examples of STEM programs implementing arts-driven planning and instruction.

Summary

The workers produced by current STEM initiatives are not up to the standards desired by employers and demands of global markets. Proponents of STEAM believe that arts may better prepare the workforce for future economic competition and innovation. Why the arts are deemed as a possible vehicle to deliver desired results is a question worth pursuing.

Those in favor of STEAM contend that arts integration can have a substantial impact on teaching and learning. It is their belief that an exposure to arts-based curriculum may increase student confidence, motivation, teacher collaboration, student cooperation, and creativity. Also, they claim that reuniting humanities to technical studies may have the added benefit of closing the disparities between minority and non-minority groups entering into STEM. Opponents of arts-based reform argue the subjective nature of creativity and view the arts as extracurricular to traditional core subjects. While many conservative politicians are not opposed to the arts, they often resent the use of public monies to support such endeavors. Examining the relationship between exposure to the arts and performance in STEM subjects can provide insight into the potential impact of arts on STEM learning and educational practices of the twenty-first century.

Chapter 2: Review of Literature

Seemingly, more scholars and professionals are advocating for the acceptance of arts into science rather than the exclusion of it. Why is it important that inclusion of arts into STEM programs be considered? Scholars argue:

> In the long run, America's true competitive edge is not its technical prowess but its creativity, its imagination, its inventiveness, its people's capacity to devise new solutions, to innovate, to invest new organizational as well as technological forms, and to eke productivity gains out of what others see as static situations. (Finn & Ravitch, p. 7, 2007)

Theoretical Perspective

The ideals of integrating curriculum are in alignment with the works of Piaget, Dewey, Bruner, and other notable scholars who stand for a progressive education fulfilled through a deeper and holistic understanding of concepts (Lake, 1994). The same correlation can be said for Gardner's theory of multiple intelligences about the arts. Multifaceted intelligence models have had a major impact on current educational reform and practices (Wilson & Conyers, 2013). In short, scholars agree multifaceted approaches to intelligence constitute a constructivist dynamic in learning. One is not restricted to genetic inheritance, but can build knowledge through experiences, openness to adapt, and through formal and informal interactions in a variety of settings (Pea, 1993; Sternberg, 1999; Sternberg, 2003; Wilson & Conyers, 2013).

In 1983, Howard Gardner proposed that certain traits reside in the inherited abilities of individuals extending beyond the traditional mental intelligence that is often assessed (Kornhaber & Gardner, 1993). Multiple intelligences reflect the idea that individuals are capable of resolving issues or producing solutions that are valued in certain organizational systems. Very rarely are these intelligences used in remote sequences. As Kornhaber and Gardner (1993) state: “for normal individuals to function in and across cultural domains, several intelligences or competencies must be coordinated” (p. 17). Be it “language, logical-mathematical analysis, spatial representation, musical thinking, the use of the body to solve problems or to make things, an understanding of other individuals, and an understanding of ourselves,” everyone varies in their abilities across these seven intelligences (Gardner, 2011, p. 12). In what Gardner identified as “profile of intelligences,” individuals apply one or several combinations of intelligences to complete tasks, conceptualize or problem solve, and explore understanding across domains (Gardner, 2011). Concepts embedded in arts integration and creativity are referenced as a method for students to explore deeper understanding by accessing various intelligences (Russel-Bowie, 2009). The theory of multiple intelligences is important to this study because it challenges the traditional notion that “everyone can learn the same materials in the same way and that a uniform, universal measures suffices to test student learning” (Gardner, p. 12, 2011).

Accompanying Gardner, Sternberg has contributed significant research on multifaceted intelligences (Wilson & Conyers, 2013). Along with his triarchic model, Sternberg identified what he called “successful intelligences” (1999). The theory of successful intelligence regards intellect as “the ability to achieve success in life, given one’s personal standards within one’s sociocultural context” (p. 293). This approach is multifaceted. It relates to one’s cultural environment, strengths, weaknesses, and ability to accommodate various settings. Regarding education, Sternberg (1999; 2003) argues equilibrium must exist between students’ “analytical,” “creative,” and “practical abilities.”

Students need to understand the problem in environmental terms, appreciate one's inherent abilities, accommodate shortcomings, and apply intelligence in innovative ways (Sternberg, 1999; Wilson and Conyers, 2013).

The final intelligence theory of note is Pea's "Distributed Intelligence" (Pea, 1993, p. 47). Distributed intelligence is theory in which people obtain knowledge through engagements of various activities and socio-cultural situations. Pea (1993) posits, "intelligence is accomplished rather than possessed" (p. 50). Pea describes distributed intelligence in forms of affordances and desires. Affordances relate to what is available in the exploration of knowledge. This may include resources, tools, strategies, or environmental factors that offer a way to problem solve or learn. Desires relates to the overall intentions of a learner. People often react or produce as a result of necessity or desired change. As one interprets a scenario in terms of desires, intelligence may innately be distributed. Distributed intelligence suggests students may find knowledge in a math problem structured in class or at recess outside in a casual exchange. These findings further elaborate on intricacies of intelligence theory and the need for educational institutions to align practices with intelligence research (Pea).

In addition to multifaceted intelligences is an abundance of brain-based research to accommodate the principles involved with teaching through multiple disciplines (Lake, 1994). Many researchers have studied the scientific links between cognitive abilities and neurological processes. The brain welcomes variety, pattern, and holistic learning. Lake suggests "the brain may resist learning fragmented facts that are presented in isolation" (p. 6). These brain-based assessments echo interdisciplinary learning, calling teachers to understand the importance of differentiated instruction in an attempt to educate the whole student (Lake). The arts are advantageous for brain development, cognition, interpersonal abilities, and instructional practices, therefore, investigation of arts must continue, focusing on STEM applications, and revealing the potential for STEAM (Sousa & Pilecki). See Appendix for an overview of the conceptual framework.

Historical Foundations

While the partnership between science and art may seem odd, they are intrinsically linked throughout human history. Dating back to the sixteenth century, the Italian Renaissance was a retreat from blind complacency and medieval customs, leading to a rise in discovery, exploration, and technological advancements (Stokstad, 2005). Artists of the time were defined by holistic academic backgrounds, portraying various aptitudes and talents. Leonardo da Vinci and Michelangelo, key Renaissance artists, had an astute understanding of science, math, architecture, music, and language arts. Artists of the time would create precise linear perspectives through a labyrinth of geometric measurements and grid patterns before painting (Stokstad).

Albrecht Durer, for example, published scholarly works emphasizing the geometry and science within art. In the 1960s, Bauhaus, a school in Germany founded by artist Walter Gropius, was conceived on the notion that art and industry could become synonymous with one another (Stokstad, 2005). Historically, when science and art interact, the implications can be far-reaching. Such influences cause scholars such as Dail (2013) to comment, "together, art (intuition) and science (intellect) can create an experience that is more powerful than their autonomous endeavors" (p. 3). However, since the 1980s, public funded arts exhibitions and governmental leagues have exhibited controversial material, causing political and economic debates between liberal and conservative spokespersons (Annis, 2013). During his administration, President Reagan, a former actor, cut the arts budget in half. Despite cuts and financial slashing, governmental agencies dedicated to improving culture by artistic means, such as the NEA, have continued to advocate for arts in education (Annis, 2013).

The STEM movement has its own history. While STEM education can be defined in a number of ways, most agree the current STEM movement was birthed as a counter movement to "the publication of the report *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future"* (Barakos et al, 2012). In this report, America lagging behind other industrial countries in highly technical fields was deemed a threat to economic prosperity. Because a broad range of content is included in this initiative, it has become very difficult to clarify STEM standards. Albeit, experts agree the predominant focus of STEM is to "prepare students for the twenty-first century workforce" (p. 4). Taking place in numerous educational institutes around the world, STEM academies generally allow students to apply technical learning across all disciplines. Various interpretations of STEM curriculum have some schools teaching subjects in isolation while others are fully content integrated (Barakos et al.). Nonetheless, there is a severe shortage of highly qualified STEM workers (Sousa & Pilecki, 2013).

In the decades following World War II, the United States dominated the global market in science and engineering fields (Augustine, 2007). However, other international powers have restructured technical training and financed research to compete in a global economy. Many nations have emulated the post World War United States to restructure their STEM policies. These foreign powers have promoted public support and finance for research in universities while expanding investment opportunities and venture capital to propel new and innovative businesses. For countries such as China, research and development has become a major priority and "national spending in the past few years for all R&D activities rose 500%" (p. 72). The gap in scientific publications and research has narrowed between the United States and foreign competitors. European and Asian countries are now offering multilingual classes to attract international students. The United States also educates a large portion of international students in science and technology doctorate programs. However, countries such as India and China have taken the initiative to offer substantial incentives and training opportunities for post-graduate candidates. For these reasons, coupled with strong investment capital dedicated to STEM enterprises, many international students attending school in the United States choose to return to their native country. In a sense, international competitors have begun "sending students away to gain skills and providing jobs to draw them back" (Augustine, p. 82, 2007).

With global and domestic economies increasing reliance on a STEM based workforce, student achievement in math and science has become a growing concern. In 2011, the National Center for Educational Statistics (NCES) correlated math and science performance of students in the United States versus international peers from more than 50 countries (Provasnik, Katsnerg, Ferraro, Lemanski, Roey, & Jenkins, 2012). The Trends in International Mathematics and Science Study (TIMSS) allows the public to compare performance of fourth and eighth grade students from the United States on a global scale. For fourth grade Mathematics, the United States' average score was in the eleventh ranked position. By the eighth grade, the United States average was ninth ranked. In Science, for fourth grade, the United States held the seventh ranked position and dropped to 10th place by eighth grade. Compared with 2007, the 2011 fourth Grade mathematics performance was the only significant gain noted. For eighth grade mathematics, fourth grade science, and eighth grade science there was no significant gain in achievement performance from 2007 to 2011 (Provasnik et al., 2012).

International performance aside, current research implies domestic disparities and inequalities have begun to surface in U.S. STEM training and educational institutions. Many students avoid a STEM education because it is viewed as stiff, regimented, or mechanical with a pre-programmed set of academic solutions (Sonnert & Fox, 2012; Gonzalez & Kuenzi, 2012). In particular, women, minority groups, and poverty stricken students feel disconnected to the content. In their work for the U.S. Department of Commerce, Beede, Julian, Langdon, McKittrick, Khan, and Doms (2011) referenced this disparity amongst women. Women constitute fifty percent of the entire workforce in the United States, yet acquire less than a quarter of STEM employment. This trend has been developing for well over a decade and women are more likely to work in health care or education related careers (Beede et al., 2011). Farinde (2012) researched larger discrepancies prevalent among African American females. It was found that despite academically outperforming gender and ethnic counterparts, African American females were a vastly underrepresented subgroup in STEM fields (Farinde, 2012).

In mathematics, the achievement levels are disproportionate between other ethnic groups. According to Flores (2007), there exists a significant achievement gap in Mathematics between African American and Latino students versus that of white and Asian students. Flores (2007) also posits that impoverished students fall significantly behind those students from a high socio-economic status. Factors such as a lack of motivation, engagement, and supportive environments are cited as causes for minority students and women exiting STEM academies (ASHE, 2011). Other challenges to current STEM education include undergraduate recruitment, ill prepared graduates, and high attrition rates (Augustine, 2007).

In contrast, art-based education programs have seen dramatic results among various demographic groups (Barakos, Lujan, & Strang, 2012). However as a result of international competition there is no shortage of financing for STEM and STEM related businesses (Augustine, 2007). STEM programs continue to get a surge of public capital, far more than the arts. Annis (2013) argues that science and math achievement is quantifiable, while the arts are unprofitable and may only contribute socially or emotionally.

The classic examples of the marriage of arts and science mentioned previously along with the struggles of STEM are behind contemporary efforts to create STEAM. For example, John Maeda, president of Rhode Island School of Design (RISD), is attempting to reinvigorate STEM by reuniting scientific truth with aesthetic beauty. RISD has implemented programs and initiatives that include visualizing oceanic case studies, conducting Nature Labs, and interning students between medical and artistic professions (Maeda, 2013). The New Schools Project in North Carolina is introducing design as a key component in its STEM agenda (Barakos et al., 2012). Obviously inspired by similar programs, STEAM initiatives are more common on the national and international stage (Maeda).

Art is gaining momentum and acceptance in the scientific community. The instructional methods of yesterday, utilizing lecture and busy work, are no longer effective in today's classroom; the requirements of today's learners are changing and evolving more than ever before (Finn & Ravitch, 2007). Disciplines such as science, technology, math, and engineering are realizing a gap in technical thinking and abstract construction, creativity and application (Sousa & Pilecki, 2013). STEM practitioners are embracing principles of the art world to invigorate innovation in the educational paradigm. Seemingly, scientific and art arenas are working in unison. Several conferences were recently held by the National Science Foundation (NSF) and National Endowment for the Arts (NEA) in attempt to bridge the two disciplines (Eger, 2013). The NSF alone has spent $2.6 million dollars to implement educational programs across the U.S., taking a creative approach to STEM that includes drawing, visual graphics, fictional writing, improvising, technical gaming, and narration to produce outcomes (Eger).

Arts

Cognition, arts, and brain-based research. Before tracing the direct influence of the arts on STEM, it is important to outline scientific evidence to support arts related to cognitive capabilities. As Annis (2013) and Brooks (2001) have outlined, a popular perspective of art in education often concludes that it is non-essential. It is their contention that the argument over arts is a political battleground. Some view art as an extra subject with no real merit or educational value, while others believe it is paramount to educating the whole child (Brooks, 2001). Howard (2001) contends many critics of arts-based reform fail to see the necessity of including art when other content areas need to be covered.

Wooten (2008) believes that involvement with or implementation of the arts can provide joy, excitement, and happiness in learning. Development of a love for learning can have a profound effect on a student's education (2008). Music, painting, plays, and dancing are all instrumental in developing a child's passion for education (Bergonzi & Smith, 1996).

The belief that an arts-embedded curriculum can improve academic achievement lies behind the idea that arts should be integrated into STEM, creating STEAM. The following review highlights the important attributes of arts in education and cites several studies to illustrate the stimulus arts provide to cognitive, social, and physical development. In 2008, the Dana Arts and Cognition Consortium reported findings from neuroscientific research inquiring into the "possible causal relationships between arts training and the ability of the brain to learn in other cognitive domains" (Gazziniga, 2008, p. v). The Consortium published empirical data, based on research conducted by several U.S. universities, that links arts to motivational factors, cognitive manipulation, computational abilities, sequential learning, memory, and personal attitudes (Asbury & Rich, 2008).

Congruent with these findings, Betts (2006) monitored learning in an extensive examination of multimedia arts, a bridge of technology to arts for the digital age. Several consistencies were established between arts and learning including increased pupil self-efficacy and attitudes. Betts (2006) concluded that arts led to student confidence increasing the likelihood of those students to take educational risks. Also, students' attitudes toward work itself improved, "working hard at arts related projects and being successful as a result of this hard work affected student thinking regarding the relationship between hard work and success" (Betts, p. 14, 2006). Characteristics such as self-motivation are especially important when looking at the concerns of modern economist relating to global competition (Friedman & Mandelbaum, 2011). As Friedman and Mandelbaum (2011) conclude, lifelong learning is paramount when technologies are constantly updating. Tomorrow's workers must eagerly crave knowledge in an effort to not be outmoded (2013). Research on the effect of cross-curriculum strategies and arts on student learning can better prepare a classroom of lifelong learners by increasing their organizational management, technological use, and ability to make the globalized connections needed to better understand a rapidly approaching modern age (Meagher, 2006).

Posner, Rothbart, Sheese, and Kieras (2008) formulated a hypothesis expressing beliefs that brain functions vary when diversity in aesthetics exist. Specifically, natural curiosities prevail with arts. As a result of curiosity, interest is more likely to develop and concludes with higher student motivation. An increase in motivation will improve student attention and eventual cognition of tasks. In order to test the hypothesis, Posner et al. (2008) developed a mixed-methods approach to studying each component of their theory. Questionnaires, experimental testing, field-testing, clinical testing, and interviews were utilized to determine the impact of aesthetics on cognition. Interestingly, when the researchers simulated focused attention produced by the arts, the portion of the brain associated with conflict resolution became increasingly active (Posner et al.). Interpersonal skills and communicating with others is often a desired byproduct of working with the arts and has been identified as a twenty-first century skill for student success (Wilson & Conyers, 2013).

In another study, Jonides (2008) sought to determine the difference in a musician's verbal memory versus that of non-musicians. By surveying "functional resonance imaging (fMRI) to visualize brain activity," the author concluded that musicians displayed a better understanding of verbal context than non-musicians (p. 11). Also, it appears that the practice and rehearsal usually dedicated to learning music was instinctually applied to verbal memorization (Jonides). Such phenomenon are helpful in understanding the success of students who hear, sing, and play with children's rhymes to better phonemic awareness (Wilson & Conyers, 2013). As noted by Wilson and Conyers (2013) when children learn through such abnormal task the brain undergoes structural development.

Relating to science and math, Spelke (2008) investigated the ability of music instruction to enhance the following mathematical concepts in adolescents and children: precise quantity identification, large approximations, and geometric understandings. Six mathematical tests were administered to children ages five through 18 years. Music participants, non-music participants, athletes, and other art form participants were all included in the study. A one-way analysis of variance established significant findings for all assessments. While results for precise quantity identification were inconclusive, a significant correlation between spatial understanding and geometric reasoning in students with music training was exhibited. The author clarifies, "our experiments provide evidence for an association between music and geometry only when training in music is intensive and prolonged" (p. 47). Furthermore, the study suggests that various art forms may have specific influences over different mathematical computations. For example, students with a strong visual arts background outperformed musicians on the geometry portions but underperformed on problems requiring more precise calculations (Spelke). Wilson and Conyers (2013) also determined brain activity was lessened during math lessons involving simple memorization or repeated procedural practice. Pathways of neural transmitters were increased when untraditional and complex problems allowed students to explore solutions (Wilson & Conyers). Arts may contribute learning moments such as the ones previously described by offering metacognitive processes allowing students to create and experiment to become experts in STEM fields (Wallace, Vuksanovich, & Carlile, 2010).

Teaching creativity. In essence, one of the strongest impacts of the introduction of arts into STEM programs is the concurrent introduction of creativity to learning (Platz, 2007). Critics, such as the National Heritage Foundation, are concerned with the application and instruction of such an abstract concept (Jarvik, 1997). Major concerns of critics lie in the highly subjective nature of the arts. Who is to say what is or is not creative, aesthetically pleasing, or innovative? For years, conservatives have cautioned against the liberal agenda being pushed or masqueraded as artistic expression (Jarvik, 1997; Annis, 2013).

Despite these arguments, there exists a plethora of information regarding the use of creativity for educational purposes. Scholars further believe "creativity is essential to economic competiveness" (Sharp & le Metais, 2000, p. 3). Due to technological and fast pace innovation, teaching creativity has become a major focus of governments (Sharp & le Metais, 2000). Sousa and Pilecki (2013) outlined similar research, referencing findings from recent neuroscientific studies. The general consensus was that more original thoughts and creative processes result when counterparts of the brain interact. In simple terms, "the best way to be creative is to be creative" (Chapter 1, Arts Promotes Creativity section, para. 5). By shutting down the part of brain activity that is normally associated with remote tasks one can become more uninhibited in their studies (Sousa & Pilecki). Gardner also believes in a deeper more authentic education of students. He describes students who first enter educational institutions as unschooled, who are eager to express themselves and engage with the natural world. Nonetheless, children are believed to think a certain way and judge with a preconceived standard. Gardner calls for schools to allow students to stay in an explorative state of mind longer and train teachers to cultivate such curiosities in all disciplines to an assortment of learning styles (Gardner, 2011).

As declared by Friedman and Mandelbaum (2011), there are two types of individuals, creators and servers. Regardless of which category one may fall, in no way can they become routine in their service or task. Employers are looking for creative, passionate types cognizant of their roles. Both authors believe that creativity is teachable. Perhaps no better medium exists to teach creativity than art (Sharp & le Metais, 2000). In a sense, art teaches students more about themselves offering an intrinsic understanding or appreciation of their contributions (Dail, 2013).

Sternberg (2003) has exhaustively researched the power of creativity in learning. Sternberg's theory of successful intelligences outlined basic components from which all problems are processed and solved (Stemler, Sternberg, Grigorenko, Jarvin, & Sharpes, 2009). Sternberg (2003) feels that regardless of the problem complexity or context, all resolutions are made through an application of one or more kinds of thought. Creative, practical, or analytical thinking can be used individually or in combination depending on the task or skill required to problem solve (Stemler et al.). These assumptions have led Sternberg and his team to assess alternate test formats as opposed to the standardized norms currently in schools. This research demonstrated compelling evidence arguing the efficacy of creativity's contribution to enhancing student ability in problem-finding and solving (Stemler et al., 2009). Welle-Strand and Tjeldvoll (2003) expressed these sentiments in another way. When describing the traits of creativity, one can note the application of original solutions to problems, collaboration, and dedication to future knowledge (Welle-Strand and Tjeldvoll).

In a prior study, Sternberg (2003) evaluated student intelligence on the basis of his triarchic model. Through an assortment of questioning formats, types, and styles, students were exposed to a battery of examinations requiring creative, analytic, and practical processing. The results indicated that students considered successful regarding creative and practical reasoning represented more diverse backgrounds than students with strong analytical aptitudes. Furthermore, all types of tests were strong indicators of school performance. Therefore, students who are not introduced to creative-arts based practicum do not have the same advantages as students naturally inclined to apply analytic skills. In addition, those students taught to apply and reason with a triarchic of skills outperformed students instructed in a traditional manner (Sternberg, 2003).

These findings confirm the importance of creative research and arts education for instructional purposes. As detailed by Moga, et al. (2000), the study of arts has lead students to challenge themselves for more detailed, complex solutions to typical problems. Sternberg (2003) advocates, "in teaching students to process information creatively, we encourage them to create, invent, discover, explore, imagine, and suppose" (p. 333). Also, attitudes established by students with a strong creative knowledge can lead to considerably beneficial personality traits, greater social understanding, and may have educational implications (Murdock, 2003).

The relationships between intelligence and skills required to solve complex problems can be distinguished (Kaufmann, 2003). According to the novelty-creativity taxonomy, there is a recognizable difference between problems requiring higher novelty based creative solutions representative of tasks intelligent in nature and those that do not. Those apparently simple, routine tasks require little creativity, offer little novelty, and require minimal thought to be resolved (Kaufmann, 2003). It is the connection between intelligence and creativity causing movements in educational reform that have developed a new vision; one inspired by the ideals, humanism, talents, and intuitive thought process resulting from creating, manufacturing or producing (Eisner, 2003).

Instructional applications and implications. Seemingly more traditional paradigms are looking to the arts as a way to improve qualitative abilities of students. In a study conducted by Harris (2007), test results from 200 early elementary students (ages three to five) were utilized to determine effects of a music-enhanced curriculum. The experiment was conducted in a Montessori setting. These learning environments are known for student-centered approaches in which teachers allow exploration and choice to obtain objectives. The author argues that Montessori education statistically outperforms more traditional forms of schooling. However, this study was dedicated to demonstrating possibilities when "the arts become a central part of the learning experience" (p. 4).

As part of the study, a music teacher assisted in bridging connections between musical concepts (rhythm) with those in math (counting). Harris concluded that students receiving arts enriched lessons outperformed traditional learners on math benchmark testing. A standardized pre and post-assessment of the Test of Early Mathematics Ability 3 (TEMA-3) were given to two groups of students across various age levels. A factorial analysis of variance determined that for the three, four, and five year old students receiving music-integrated instruction, a higher proficiency on the TEMA-3 was documented. Interestingly, three year olds receiving music instruction was the highest performing group. Therefore, one can scaffold more success from music and arts in math once implemented at earlier stages of development. Harris (2007) posits, "the findings are significant, because, a grasp of proportional mathematics and fractions is a prerequisite to mathematics at higher levels, and children who do not master these areas of mathematics cannot understand more advances mathematics" (p. 33).

In a similar study, Minneapolis public schools partnered math with the arts to improve achievement. Ingram and Riedel (2003) reported findings for "Arts for Academic Achievement (AAA)", an organization dedicated to showing the power of arts on standard core subjects (p. 1). Including 45 schools, grades three through five, and lasting almost four years, the AAA produced considerable gains. Most notably, the authors reported the biggest strides were those garnered by disadvantaged children. For every grade analyzed, a linear relationship between frequency of arts inclusion and higher achievement was presented. Findings revealed "arts integration is significantly related to mathematics achievement for third grade students…the more their math teacher integrates arts into mathematics lessons, the more students gain on the mathematics test" (p. 29). This program impacted all students regardless of socioeconomic status, community, parental involvement, or previous education; no student suffered from an arts integrated curriculum (Ingram and Riedel).

The results of this study coincide with recent research aligning student engagement with the arts to better overall academic performance (Bergonzi & Smith, 1996). A direct correlation was noted between arts instruction and arts education and transference of general knowledge (Bergonzi & Smith, 1996). Mandated arts programs are a pivotal part of education around the world. From the Netherlands to Hungary and certain universities in England, educational departments have required implementation and instruction of the arts (Gullatt, 2008). Through instruction of the arts, teachers have enabled students to redesign, problem-solve, generate support for one's ideas, and achieve higher levels of learning (Sternberg, 2003). As Eisner (2003) states, the importance of creative intelligence is its ability to improve all facets of student life, not just academics.

In his testament to arts in education, Eisner (2004) explained the historical and contemporary perspective of aesthetics in our society. Historically, education has supported science over the arts because the latter is more abstract, considerably too subjective, and not quantifiably measurable. Arts were often regarded as superfluous, whereas science was seen as integral. In regards to budget and financial prowess, art cannot compete with the large governmental funded Science and Math programs (Sousa & Pilecki, 2013). However, current paradigms call for the arts in modern classrooms (Eisner, 2004). In order to pay tribute one may reference the skilled by calling them an artist at their craft. Education can learn from what art teaches individuals. The result of aesthetic experiences may be transferrable to all disciplines. Eisner identifies six major advantages of artistic rationalization. Trust in one's self to make intuitive judgments, visualization, understanding and expressing in an alternative construct, resourcefulness, satisfaction in engagement, and bridging concepts are important principles education can learn from the arts (Eisner).

A major attribute of introducing aesthetics into education is student susceptibility to creative processing (Rosier, Locker, & Naufel, 2013). Rosier et al. found that interaction with visual arts assisted with memory. More importantly, arts may engage students in a creative task increasing the likelihood those experiences will be committed to memory. In essence, "by engaging in a highly creative act, individuals may be able to process information on a deeper level, and then generalize to another task" (p. 274). These aspects of learning are important and relative to all subjects. In science, one may observe, interact and experience certain topics of study. Rosier et al. (2013) utilized several prompts to investigate the power of visual arts on memory. The study consisted of analyzing memory skills of students receiving visual arts stimuli versus those not. Initially, researchers generalized that memory was improved because students were able to draw, thus the kinesthetic aspect of moving may have increased memory recall. However, in a follow-up experiment accounting for motor sensory activity in both groups, the visual arts group continued to demonstrate superior memorization. The authors contributed this to two factors. First, the act of creating, not simply moving, accounts for the visual arts group's superior performance. Second, the results from personality measures indicated a more positive reaction from those students involved with the arts. In essence, arts may bridge creativity to "physiological arousal" increasing memory capabilities for students (Rosier et al., p. 275).

Wallace, Vuksanovich, and Carlile (2010) identify two projects similar to those implemented at RISD. In Ohio, a large portion of funding has been expended for a non-traditional K-12 curriculum focused on strengthening skills necessary for collegiate STEM studies. However, the instruction "will emphasize experiential and inquiry-based learning to help students problem-solving, collaboration, critical thinking and research skills" (p. 3E-4). The arts will be introduced for students to have kinesthetic learning opportunities and increased dialogue for collaboration. It is believed that the arts assist in developing cognition and interpersonal skills (Wallace et al.).

Cross Curriculum Arts Integration

Overview and empirical defense. Research on the effect of cross-curriculum strategies and assessments on student learning can better prepare a classroom of lifelong learners by increasing their organizational management, technological use, and ability to make the globalized connections needed to better understand a rapidly approaching modern age (Meagher, 2006). Despite the advocacy for interdisciplinary instruction, merging any subjects, especially those drastically different as science and art comes with challenges. In his analysis, Jones (2010) isolated hindrances to cross- curriculum instruction. For example, professionals with a vast amount of knowledge in a particular field assume their content is superior. As a result, both members of faculty may presume dominance for their subjects as opposed to emergent interdisciplinary concepts. This situation if not properly structured may result in conflict rather than compromise (Jones, 2010). Results of a survey conducted by Finn and Ravitch (2007) indicated that less instructional time was spent with art and music than other content areas.

Despite logistical and systemic concerns, holistic education has been a persuasive factor in the debate for effectiveness in arts integration (Gullat, 2008). Sousa and Pilecki decree the purpose of STEAM academies is better preparation of students for life after school (2013). As teachers become more competent in crossing curriculums, they will be more involved with strategies such as project-based learning and inquiry driven instruction to implement arts during other content (Kilinc, 2010). Arts-based education has the potential to expose teachers to more innovative instructional activities. Project-based and twenty-first century learning allow students to remain product-focused, creating solutions to challenging problems that require students to design, analyze, create, and present findings while reflecting on their own self-discovery (Kilinc, 2010). Inquiry-driven instruction utilizes students' preexisting interests and knowledge challenging their own understanding through opportunities of explanation and examination (Panasan & Nuangchalerm, 2010). Betts (2006) advocated for arts implementation across curriculum, based on the belief that arts allow creation from understanding and deepened engagement with a topic. Integration can include core subjects of math, science, language arts, and social studies in addition to various elective courses. An arts integrated experience can lead students to freely express themselves, enjoying new aesthetic experiences, and positive behavior changes (Betts, 2006; Russel-Bowie, 2009).

Multidisciplinary inclusion is a staple of current educational reform (Meagher, 2006). Advocates for cross-curriculum instruction argue that teacher morale and student achievement can be improved by planning across disciplines. However, many teachers misunderstand the true benefits and practices involved (Meagher, 2006). Teachers are often secluded from one another, physically and departmentally, making it more difficult to coordinate high functioning interdisciplinary lessons (Combs & White, 2000). Educational leaders are beginning to realize the importance of an integrative curriculum by restructuring school systems to accommodate teacher collaboration and planning, shifting the "emphasis from helping individual teachers improve instruction to helping teams of teachers ensure that students achieve the intended outcomes" (DuFour, 2002, p. 13). For STEAM, incorporating aesthetic practices can be both creative and functional (Catterall, 2013). Hardened, rigorous STEM content areas can become more enjoyable and approachable (Catterall, 2013).

Empirical evidence strongly supports the use of arts to strengthen understanding across disciplines. Regarding Math and Geometry, Walker, Winner, Hetland, Simmons, and Goldsmith (2011) concluded visual thinking among art students is advantageous to geometric rationalization. Thinking in terms of spatial relativity is a trait shared by most STEM students. Visualizing a solution to complex geometric algorithms requires a constructed mental image to be formulated and translated into multidimensional, symbolic notations. These types of complex visual exercises are more common in art classes. Therefore, a study to determine the relationship between spatial conception and geometric reasoning was conducted to determine any advantage of visual arts in geometry. Walker et al. (2011)

analyzed the results of studio art and psychology majors on a "27 item geometric visualization/reasoning inventory" (p. 23). The assessment was concentrated on geometric performance utilizing visual thinking skills. Participants were not allowed to draw and all visualization had to be done mentally. Many of the items required two- and three-dimensional concepts. The authors concluded that "training in the arts was a significant predictor of geometry performance" and generalized those trained in arts have increased visualization skills and spatial understanding (Walker et al.).

STEAM Applications

Sousa and Pilecki (2013) believe art and science have the same mission- discovery and creation. Despite an absence of research on systemic STEAM applications, there is a plethora of information concerning the impact of arts integrated instruction and examples of its premise in practice. Arts integrated instruction has been linked to cognition and improved instruction and is considered influential on various demographic achievement levels. As a result, many technical colleges and secondary institutions have begun to introduce arts into their curriculum and required coursework (Driver, 2001).

There are a number of educational institutions across the country and some in Europe that have embraced the STEAM concept and mission (Wallace et al., 2010). Institutions incorporating arts systemically (i.e. STEAM) increase opportunities for deeper, authentic learning and higher-level thinking (Russel-Bowie, 2009). As previously mentioned, minority groups are grossly unrepresented in STEM academies (Ashby, 2006). Yet, strong correlations exist between arts involvement and performance of students labeled at-risk (Catteral, Dumais, & Hapmden-Thompson, 2012). The work conducted by Catteral et al. (2012) found at-risk youth participating in integrated and/or extracurricular arts programs outperformed their counterparts in mathematics. These students were five times more likely to participate in other school activities, such as athletics or journalism, and arts involved students were eager to engage in civic responsibilities. For example, students took "an interest in current affairs, as evidenced by comparatively high levels of volunteering, voting, and engagement with local or school politics" (p. 18). More impressing, arts involvement enables at risk students to outperform students of a high socioeconomic status (SES) (Catteral et al., 2012). Integrating arts in STEM can assist in narrowing the gap of disproportionate dropout rates between at-risk and high SES peers (Sousa & Pilecki, 2013). While these results were not deemed causal, it is fathomable that arts provided the positive encouragement and motivation for students to succeed beyond expectations (Sousa & Pilecki, 2013).

Engineering. Regarding engineering, social researchers at Georgia Tech transformed extensive, qualitative research linking arts and engineering methods into an arts-integrated Engineering course (Fantauzzacoffin, Rogers, and Bolter, 2012). Professors at Georgia Institute of Technology, designed a course proposed to give "students skills to participate in the creative innovative economy" (p. 1). After thoroughly examining artists and engineers at work in numerous case studies many similarities were shared by the two groups. Both groups instinctually would "imagine, conceptualize, design, and build;" however, the authors identified two underlying concepts (Fantauzzacoffin et al.).

In processing the work, engineers displayed a backwards design approach, labeled "teleological" (Fantauzzacoffin et al., 2012, p. 2). Artists approached scholarly tasks with an open-ended path, guided by experiment and impulse called "stochastic" (p. 2). Engineers worked with the end in mind, charted a stable route to completion, and relied on predictable outcomes. Artists tended to indulge a creative process, yielding emergent results, and remained adaptable in uncertainty (Fantazzacoffin).

The engineering course created as a byproduct of the research aimed toward having artist and engineers work together on projects (Fantauzzacoffin et al., 2012). Course designers aspired for engineers to develop an adventurous spirit and more ambitious ideas, take risks, adjust to failure, use individual interest, and develop creative solutions or artifacts. The majority of class assignments revolve around a project-based learning approach (Fantauzzacoffin et al.). Project-based learning (PBL) has become a preeminent answer to the challenges of educating the twenty-first century learner (Fillippatou & Kaldi, 2010). PBL teaching methods combine student choice, variety, product focus, time management, exploration, pre-existing student curiosities, and self-directed learning to develop student's skill set toward learning objectives (Fillippatou & Kaldi). Advocates for PBL declare creative problem-solving empowers students to explore knowledge by a personal means aligned to their needs, interests, and aptitudes (Fantauzzacoffin et al., 2012).

Physics. In a study conducted by Jatila van der Veen (2012), art and aesthetic education was utilized to teach science and math based courses. Van der Veen's (2012) study was driven by ambition to "promoting at least a more equitable gender balance in the physics community in future generations" (p. 359). The task was finding a medium that could improve instruction and bridge gender gaps. Van der Veen (2012) decided to integrate "Maxine Greene's Aesthetic Education" to "humanize the teaching and learning of physics" (p. 359). The author aimed to instill imagination and innovation into abstract topics of study while not forgoing heightened academic computations. The study consisted of collecting and recording work, experiences, student samples, and reflections while teaching a physics course within the aesthetic education framework.

Throughout the duration of the experiment Van der Veen noted several advantages to merging arts and science. First, "incorporating arts-based learning strategies of Aesthetic Education can help reduce barriers presented by language" (p. 363). The author clarifies that physics and the formal language involved can become a social barrier to minority groups of certain cultures. Science is a language that can remain unilaterally interpreted, but introducing art for reflection and response can aid in translating cultural barriers. Therefore, "the language of the arts can provide a means of helping students visualize the relationships in the physical world that are described by mathematics" (p. 364).

Second, visualization equates to a depth of understanding. Van der Veen (2012) claims learning is defining phenomenon never experienced or creating representation for abstract concepts. The author conducts several exercises as a class instructor to illustrate his point. For example, to explore "Einstein's (1936/2003) essay 'Physics and Reality,'" Van der Veen had students draw, create, or produce a response to the article (p. 371). Ranging from abstract gestures that needed explanation, to literal representations or visual charts, students have extensive choice in their pursuit of understanding. "Drawing is a means by which a learner (artist) can get in touch with and express her or his own inner language, and is thus a way to connect students' internal translations of external experiences through symbolic representations" (p. 365). Van der Veen (2012) linked these practices to a similar study conducted to determine the importance of visualization and illustration to promote elementary students' cognitive ability from "naïve thinking" to "scientific thinking" (p. 366)

Math. Similar results were also found in Duatepe-Paksu and Ubuz's (2009) investigation of the effects of performance art based instruction techniques on geometry. One-hundred and two middle-class Turkish students, ages 12-13, were tested assessing their understanding of basic geometric shapes and measurements. The test was administered four months after instruction to assess material retention. The study was quantitative and qualitative, with both scores and reflections of student learning being recorded by the researcher. The experimental group utilized unusual seating formats, student led, teacher facilitated instruction, and group work requiring acting, pretending, and imagination for lesson goals. The control group was seated in a traditional classroom setting with teacher instruction throughout lecture, individual student work, and note taking. The results of the quantitative study portrayed significantly higher scores for the students in the experimental group. The qualitative results showed students of the experimental group to have considerable more enjoyment and social interaction during their lessons. These findings confirmed the impact of drama based teaching techniques on student learning, motivation, and retention. The methods involved with this study portrayed the enthusiasm students can obtain from arts integrated instruction and the longevity of information gained through such methods (Duatepe-Paksu & Ubuz).

Collaboration. Laius and Rainikmae (2011) examined students' scientific literacy and performance in creative, socio-scientific reasoning with teachers who collaborate and had been trained on integrative approaches versus those teachers with little training or have not collaborated with other teachers. The results declared that student performance on socio-scientific literacy exercises were significantly stronger when led by a teacher who works collaboratively with others as opposed to a teacher working in seclusion. Teachers that experienced collaboration amongst coworkers were believed to be highly motivated, encouraged, and self-directed consequently improving student reasoning and educational enthusiasm (Laius & Rainikmae, 2011).

Another STEAM venture is being conducted at Youngstown State University. Called CoLab, students from the STEM Academy and those from the College of Fine and Performing Arts coordinate academic exercises (Wallace et al., 2010). Resources, space, and expertise are universally shared amongst the students. It was found that through “creating an environment in which students must work with colleagues who come from other, very different disciplines, the students are forced to make design compromises that consider factors beyond their own area of expertise” (p. 3E-5). These tough conversations lend to unconventional solutions that otherwise may not have been reached. The objective is for engineering students to ensnare the creative spirit and vision of artists. For artists, they look to gain an in depth knowledge of more technical aspects of academia. Together they will learn to discuss and share their expertise with a layperson, demonstrating an acute understanding of subject matter. According to Wallace et al. these are the same “communication skills that will make them considerably valuable in the workplace” (p. 3E-5).

Technology. Critics of STEAM, argue that arts take time away from necessary scientific exploration. However, it is Platz’s (2007) assessment that students who participate in creative and performing arts are more likely to gain skills needed for future societal needs and job requirements. Congruent with these sentiments, the National Educational Technology Standards (NETS) have identified criteria desired for employees in the twenty-first century workforce (ISTE, 2007). Many of the noted criteria are those gained by arts participation including creativity, innovation, communication, collaboration, and citizenship. Integrating arts into standard education paradigms better prepares students for the creativity demanded in today's competitive society and business world (Dail, 2013).

Relating to technology, several advances in multimedia and software programming have incorporated arts into the discipline (Betts, 2006). These applications allow students, artists and non-artists to fabricate designs and create digital products. Revered as a "new literacy," multimedia arts provide students a rich, interactive format to communicate, explore, and relay information (p. 3). Multimedia arts operate on the reliance of various sensory-motor systems in a context students are comfortable working. As cited by Betts (2006), Freedman and Mitchell suggest an arts integrated curriculum accompanied by technology provides an important design element, personalizes learning, and "reflect the visual culture" students routinely explore (p. 6). Betts explores the Multimedia Arts Education Program (MAEP) to better understand the relationship between arts and technology. With MAEP, students had access to computer applications, labs, word processing, sound/video editors, graphic manipulators, and digital animation programs aligned with curricula. An extensive evaluation of surveys, interviews, journals, and artifacts led Betts to deem programs such as MAEP a success. Hong Kong has implemented similar projects in order to promote creativity and multimedia development (Sharp & le Metais, 2000). Students became confident in new literacies and increased confidence by developing skills for presentations and reflection (Betts, 2006).

Students are believed to benefit from the integration of arts related teaching strategies (Gullatt, 2008). Recent surveys have shown a renewed interest in student creativity, individualized thinking, and improved social skills (Miller & Hopper, 2008). Gullatt (2008) posits:

> If research and best practice identify benefits to the academic curriculum provided by the arts which can enhance academic gain, then why are the arts so often blatantly overlooked as a medium of assistance for teaching and learning in schools across America? (p. 1)

John Tarnoff, a studio executive and media specialist who has worked with DreamWorks and MGM expressed his belief in the rationale for arts in STEM with the Huffington Post. Tarnoff (2010) stresses the importance of finding employees (technologists) who are able to effectively communicate in groups, retain genuine and meaningful discussions, sell their ideas and themselves, assess and identify shortcomings, reflect on and embrace criticisms, and become problem solvers. Tarnoff further states, “I don't find these kids sitting alone at a lab table or buried in an algorithm” (para. 9). Current STEM facilities have students working in isolation resolute in finding rote solutions to arbitrary problems. Integrating art and sciences provides the expressive components many technicians are lacking in today’s market. It is the marriage of competition and creativity that will lead to innovation (Tarnoff).

STEAM concepts are in practice. Universities and STEM academies around the world have embraced the arts. Despite financial restriction and political opposition, arts-based education reforms are a reality. Therefore, it is only logical for STEM administrators to view the arts as a potential way to increase the quantity and quality of its graduates. Also, it is appropriate to further investigate any impact the arts may have in STEM.

Challenges. Introducing arts into standard subject matter can pose additional problems and challenges. Several of the studies cited above have indicated training, professional development, adequate planning time, qualified personnel, and meaningful collaboration as hurdles to arts-based reform (Catteral, et al., 2012; Fantauzzacoffin et al., 2012; Laius & Rainikmae, 2011; van der Veen, 2012). In their research Wallace et al. (2010) noted the biggest obstacle faced when implementing arts across curricula was the preexisting faculty and student mentality that engineering and arts should not interplay. In turn, initial hesitance among those representing arts and engineering made it difficult to share a common workspace. In her research Murdock (2003) explained that many members of the staff did not feel comfortable working to build creativity and questioned the feasibility of teaching an abstract concept. Likewise, Palak and Walls (2009) concluded that unless implemented reforms remained entirely on student-centered instruction the program was more likely to fall short of its goal. However, despite the logistical obstacles, none of the studies reviewed reported negative correlations with arts integration. In contrast, all studies discussed evidenced neutral or positive findings between arts integration and its respective domain of focus.

Summary and Conclusions

STEM programs have long been viewed as the solution to educational and economic woes of the country. However, after years of declining graduation rates, ill representation of minority groups, and a lack of career readiness skills STEM academies have looked to reform their practices. A major player in educational reform, arts-based instruction has been introduced to STEM curricula. Despite growing criticism from political factions and criteria for implementation that is undefined, notable scholars and STEM leaders are embracing the arts as a viable alternative to traditional STEM learning. Empirical results and theoretical foundations have linked arts to cognition, student confidence, risk-taking, increased creativity, deeper learning, and cultural empathy. As a result, STEM programs have already introduced faculty and students to an arts integrated environment. While STEAM remains a relatively new concept, its premise of arts-based reform is anchored in educational research. Proponents of STEAM believe they have found the missing link to bridge technical understanding and conceptual discovery or innovation. If arts-based reform is found to have a positive impact on STEM learning or instruction, the implications would be far-reaching.

Chapter 3: Methodology

The purpose of this study was to investigate the following question: Do students participating in the arts demonstrate higher academic achievement in STEM knowledge versus those students not participating in the arts?

Results yielded by the research question may provide empirical support for or against adding arts into STEM. The research question suggests the following null hypotheses:

1) There is no difference in scientific achievement scores between students participating in arts instruction and students not participating in arts instruction.

2) There is no difference in mathematic achievement scores of students participating in arts instruction and students not participating arts instruction.

Research Design

A quantitative, nonexperimental approach with a causal comparative analysis was utilized to research the hypothesis. Student results from national assessments were acquired from a central database to determine if participation in the arts has an effect on average achievement scores in science and math. In this section a brief introduction into the database is provided along with a discussion of the variables.

Data source. To operationalize this design and investigate the research question, data from the National Assessment of Educational Process (NAEP) Data Explorer was analyzed. The High School Transcript Study (HSTS), in conjunction with NAEP assessments, allowed student achievement scores to be coupled with high school course-taking habits.

NAEP has administered national assessments since 1969 and began offering state assessments in 1990 (NAEP, 2012). NAEP "is the largest nationally continuing assessment of what America's students know and can do" (NAEP, 2014, para. 1). NAEP was not designed to offer individual scores of students or schools; instead "it offers results for populations of students… and groups within those populations" (What NAEP does section, para 1). NAEP offers assessments in various content areas. The NAEP database is governed by the National Center for Education Statistics in order to track and monitor academic progress across subjects, states, and various student populations. NAEP field staff members administer questionnaires, surveys, and assessment exercises from chosen samples (2014).

HSTS "analyzes transcripts collected from a nationally-representative sample of twelfth-graders in public and private schools" ("Welcome to the NAEP Data Explorer", n.d., HSTS NDE section, para. 1). Trained personnel enter information concerning graduates' transcripts including GPA, class rank, credits earned, courses taken, and standardized scores into a computer data system. The most recent study was conducted in 2009 and will be utilized in this research. More than 37,000 transcripts were collected and "740 schools participated in the HSTS 2009 survey…for HSTS 2009, the 2009 NAEP scale scores for mathematics and science were provided" (U.S. Department of Education, 2011, p. 3). Having NAEP achievement results and HSTS data in one place allowed information to be cross-tabulated for further evaluation.

Study Variables

Dependent variable. As previously mentioned, the research was causal-comparative in nature and investigated to determine if achievement scores were impacted by participation in the arts. In this study, the dependent variable was the average 12th grade student's Science and Mathematics achievement score. Results from the National 2009 NAEP assessments in mathematics and science were available to weigh student progress in STEM fields. Both assessments are reviewed and administered periodically, with input from "subject area experts, school administrators, policymakers, teachers, parents" and are given in a uniform manner by certified staff (NAEP 2012b; NAEP 2012c).

NAEP Science Achievement Score. The NAEP science scale score ranges from 0 to 300; for the purposes of this study, an average of scores was evaluated. The NAEP Science assessment measures student knowledge across three broad areas including Physical Science, Life Science, Earth and Space Sciences. Conceptual understanding is the primary focus of the test; other assessment items include "paper- and –pencil questions, hands on performance tasks, and interactive computer tasks" (NAEP, 2012c, Comparison Frameworks section).

NAEP Mathematics Achievement Score. The overall NAEP mathematics scale score ranges from 0 to 300. Four major content areas are tested for twelfth grade students: number properties and operations, measurement/geometry, data analysis/statistics/probability, and algebra. The testing format consists primarily of multiple-choice and constructed response questions. Students had the option of using a graphing or scientific calculator. The independent variable effect on both mathematics and science scale scores were investigated (NAEP, 2012b).

Independent Variable.

Fine Arts Credit Earned. This study is dedicated to better understanding the arguments for incorporating the arts into science and other technical fields. Advocates for STEAM call for a full integration of arts into scientific/mathematic learning. As such, accepting or rejecting the null hypotheses of this study will assist in determining if there is any relationship between participation in arts and scientific or mathematic achievement. The independent variable is credits earned in fine arts courses based on transcript information of twelfth graders in 2009. The research included results of students based on the amount of fine arts credits earned (0-0.5 credits, 0.6-1.5 credits, 1.5-3.0 credits, and 3.0 credits or above). Accounting for the presence or absence of credits in art simulated current STEM practices and STEAM propositions.

As previously discussed, transcript information of over 37,000 graduating twelfth graders was taken from public and private students across the nation. Fine arts course code is defined as follows:

> A group of instructional programs that describe the organization of materials and media for two-or three-dimensional visual affects that communicate ideas and express emotion and are considered primarily in relation to aesthetic criteria of judgments of beauty or meaningfulness. (“HST”, n.d., subcategory 07)

Fine arts classes may include- visual arts, crafts, music, drama, dance, art history, or music appreciation (U.S. Department of Education, 2011).

Control Variables. The literature review detailed several ongoing difficulties of current STEM programs, specifically a misrepresentation of minority and female students and those of a low socio-economic status (SES) (ASHE, 2011). Countering this decline in STEM, advocates for STEAM cited studies in which the arts have helped bridge the achievement gap of these same students (Ingram & Riedel, 2003). Therefore, demographic variables were isolated and controlled to create subgroups for comparison. Determination will be made if an increased participation in fine arts better serves these students for STEM learning. The following control variables will be featured in this study: gender, race, and National School Lunch Program eligibility.

The strong sampling of NAEP participants across physical and social demography will aid with generalizing findings:

> In an average state, 2,500 students in approximately 100 public schools are assessed per grade, for each subject assessed. The selection process for schools uses stratified random sampling within categories of schools with similar characteristics… A national sample will have sufficient schools and students to yield data for public schools, each of the four NAEP regions of the country, as well as sex, race, degree of urbanization of school location, parent education, and participation in the National School Lunch Program (NSLP). (NAEP, 2011)

Along with these demographic variables, participation in STEM classes was another factor analyzed in this research. In order to simulate the STEAM experience, a student's participation in STEM classes was cross-tabulated with fine arts instruction to determine if a relationship exists. Accounting for STEM courses taken and fine arts exposure will better represent STEAM ideology. Cross-tabulations grant the researcher an ability to combine variables. For example, female students earning credits in art can be cross-tabulated to male students earning credits in art (See Table 1 for an overview of variables).

Table 1

Variables, Definitions, and Measures

Variable	Measure Identification	Definition	Scale of Measurement
Dependent			
NAEP Science Achievement	SciScore	Average scale score of twelfth grade students on 2009 NAEP Science Assessment	0-300
NAEP Mathematics Achievement	MaScore	Average scale score of twelfth grade students on 2009 NAEP Science Assessment	0-300
Independent			
Credits Earned in Fine Arts	Arts	Fine Arts Credits earned in 2009 by twelfth grade students	0.5, .6-1.5, 1.5-3.0, Over 3.0
Controlled			
Gender	Sex	Identification of gender for twelfth grade students participating in the 2009 NAEP assessments by gender	Male, Female
Race	Race	Identification of race for twelfth grade students by participating in the 2009 NAEP assessments by gender	White, Black, Hispanic
National School Lunch Program	SES	Identification of lunch eligibility for twelfth grade students participating in the 2009 NAEP assessments by gender	Eligible, Not Eligible

Note. Criteria, measures, jurisdiction, and variable information from NAEP Data Explorer (2011). *See* http://nces.ed.gov/nationsreportcard/hstsdata/

Data Analysis Methods

Several statistical measures can be analyzed to draw inferences when comparing the average scaled scores between groups. First, NAEP Data Explorer allows researchers to test the statistical significance between populations of interest by means of a *t* test for independent groups (NAEP, 2008). A *t* test for independent samples determines a statistical difference in the two groups under examination. Groups representing a statistical difference at alpha level .05 or below are characterized as statistically significant. Groups with a statistical difference at an alpha level above .05 are not characterized as statistically significant.

Second, the NAEP Data Explorer reports a standard error for the mean scale scores of selected populations ("Standard Error", n.d.). Accounting for "the standard error of measurement allows you to determine the probable range within which the individuals true score falls" (Gall, Gall, & Borg, 2003, p. 199). In accordance with proper distribution, accounting for a "plus or minus two standard errors of measurement" allows a researcher to predict the mean range with 95 percent accuracy (2003). The standard error of measurement accompanies mean scale scores of student populations.

Another option for statistical analysis in NAEP data explorer is confidence intervals. Confidence intervals are important in surmising results and discussing the implications indicated by a sample on the whole population. Confidence intervals enable researchers to establish parameters of the population in an effort to better generalize sample results (Gall, Gall, & Borg, 2003). Applying the same "plus or minus two standard errors approximates a 95 percent confidence interval for the corresponding population quantity" ("Confidence intervals", n.d., para. 2). In other words, the confidence parameters of the sample evaluated lends itself to an accurate picture of the true population.

Finally, if a null hypothesis is rejected and a significant relationship is found, effect sizes will be calculated to discuss the impact of findings. The effect size quantifies the impact of the independent variable. As cited by Salkind (2011), Cohen's ranges of effect are referenced as the baseline in labeling variance between groups. Specifically, "a small effect size ranges from 0.0 to .20…a medium effect size ranges from .20 to .50…a large effect size is any value above .50" (Salkind, 2011, p.198).

Chapter 4: Data Analysis And Discussion

Data retrieved from the High School Transcript Study (HSTS) and the National Assessment for Educational Progress (NAEP) are presented to determine if students participating in the arts demonstrated higher academic achievement on scientific and mathematic assessments. Student performance in science and math are discussed and displayed in relation to the number of credits earned in fine arts courses. The analyses are arranged by hypothesis. Tables house data relevant to particular hypotheses and display average scores by groups of students. Also, standard error (SE) of indicated performances are noted in the tables. In text, effect sizes and confidence intervals further illustrate any relevant findings.

Null Hypothesis One

The first null hypothesis read: there is no difference in scientific achievement scores between students participating in arts instruction and students not participating in arts instruction. Data obtained from the 2009 NAEP and HSTS for credits earned in fine arts and composite science score of 12^{th} grade students was used to determine if there was a statistical difference between students earning over three credits of arts and those with little or no credits in arts. Is there a relationship between the arts and scientific achievement? Table 2 shows a significant difference in scientific achievement scores of students who earned over three fine arts credits and students who earned 0.5 credits or less ($p<.001$). Table 2 shows no significant difference between scientific achievement scores of students who earned between 0.6 and 3.0 fine arts credits ($p>.05$). In 2009, the group of students who earned over 3.0 fine arts credits had an increased average science achievement score of 12.9 points. Taking into account the Standard error (SE), students with the most exposure to arts instructions outperformed students with little or no exposure to arts instruction. The first null hypothesis is rejected.

Comparing confidence intervals and standard deviation of groups of students with over three credits of arts and those with 0.5 credits or less further illustrates differences between these groups regarding science. For the group of students with 0.5 fine arts credit or less, the mean was 150.5, 95% CI [147.4, 153.5]. For the group of students with over three credits of fine arts, the mean was 163.4, CI [160.9,165.9]. Taking into account the standard deviation and average performance of both groups, calculations yield an effect size of 0.20 and Cohen's d is 0.40. A medium effect size means that students who participated in over three credits of fine arts gained an average eight percentile points in scientific achievement over students with little or no arts participation.

Table 2

Average Composite Science Score, Grade 12 by Credits Earned in Fine Arts

Year	Fine Arts: Credits Earned							
2009	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
	150.5	1.5	147.7	1.4	151.0	1.3	163.4	.8

Null Hypothesis Two

The second hypothesis read: there is no difference in mathematic achievement scores of students participating in arts instruction and students not participating in arts instruction. Is there a relationship between the arts and mathematic achievement? Table 3 shows a significant difference in mathematic achievement scores of students who earned over three fine arts credits and all other groups of students ($p<.001$). Table 3 shows no significant difference between mathematic achievement scores of students who earned between 0.6 and 3.0 fine arts credits with students of .05 credits or less ($p=>.05$). In 2009, the group of students who earned over 3.0 fine arts credits outperformed all other groups of students with less fine arts experience. The group of students with the most arts exposure (above 3.0) had an average math score 8.6 points higher than students with the least amount of arts credits (0-0.5). Taking into account the Standard error (SE), students with the most exposure to arts instruction outperformed students with little or no arts exposure on mathematics achievement tests. The second null hypothesis is rejected.

Comparing confidence intervals and standard deviation of groups of students with over three credits of arts and those with 0.5 credits or less further illustrated differences between these groups regarding math. For the group of students with 0.5 fine arts credit or less, the mean was 154.7, 95% CI [152.0, 157.4]. For the group of students with over three credits of fine arts, the mean was 163.3, CI [161.4,165.1]. Taking into account the standard deviation and average performance of all groups, calculations yield an effect size of at least 0.13 over students earning little or no credits. A medium effect size means that students participating in over three credits of fine arts gained an average five to six percentile points in mathematics achievement over students in any other group with less arts exposure.

Table 3

Average Composite Mathematics Score, Grade 12 by Credits Earned in Fine Arts

Year	Fine Arts: Credits Earned							
2009	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
	154.7	1.3	153.7	.9	153.5	1.1	163.3	.9

Controlled Variables

When controlling for demographic variables, is there a correlation between the arts and math and science achievement? The following analysis was a result of controlling for various demographic factors (gender, race, and socio-economic status) to determine if exposure to the arts improved scientific and math performance. As previously discussed, there has been a decline in STEM enrollment while achievement gaps between males and females, white and non-white ethnicities, and students from high and low poverty households have widened (ASHE, 2011; Ashby, 2006).

Gender. A major concern of current STEM practices is the growing disparity in achievement and graduate rates amongst male and female students (Beede et al., 2011). According to recent trends, women constitute less than a quarter of the STEM workforce (Beede et al.). Much research looks toward art as an instrument to close the achievement gap between males and females in STEM (Ingram & Riedel, 2003). Tables 4 and 5 traces science and math performance of males and females by number of credits earned in fine arts. Drawing upon such data can assist in determining the impact of arts on gender in relation to science and math achievement.

According to NAEP results for both math and science assessments, female students performed significantly lower than males ($p<.05$). However, science and math scores of females with over three fine arts credits were significantly higher than male students enrolled in 0 to 3.0 credits. Based on science and math achievement, female students outperformed males with less arts exposure in all groups excluding male students with over three credits earned. Table 4 and Table 5 show males with over three credits of fine arts outperformed all male and female groups in science and math assessments.

For this study, the science achievement average of male students with the most arts exposure outperformed male students with minimal to no arts by 12.8 points. The science achievement average for female students with the most arts outperformed the group of females with little or no arts by 18.2 points. The group of female students earning over three credits in fine arts demonstrated a high effect size for science achievement at 0.29 over female students with little or no fine arts credits. Similarly, there exists a medium effect size for science achievement among male students completing over three credits of fine arts at 0.20 over male students with little or no participation in the arts. Relating to science achievement, this translates into an average 11 percentile gain for female students exposed to over three credits of fine arts and an average eight percentile gain for male students earning more than three credits of fine arts.

For this study, the mathematics achievement average for the group of male students with the most arts exposure outperformed the group of male students with minimal to no arts by 10.6 points. The mathematics achievement average for female students with the most arts outperformed the group of females with little or no arts by 9.7 points. The group of female students earning over three credits in fine arts demonstrated a medium effect size for mathematics achievement at 0.21 over female students with little or no fine arts credits. Similarly, there exists a medium effect size for mathematics achievement among male students completing over three credits of fine arts at 0.16 over male students with little or no participation in the arts. Regarding mathematics achievement, this translates into an average eight percentile gain for female students earning over three credits of fine arts and an average six percentile gain for male students earning more than three credits of fine arts.

Table 4

Average Composite Science Score, Grade 12 by Credits Earned in Fine Arts and Gender

Sex	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
Male	155.6	1.8	149.9	2.0	154.9	2.1	168.4	1.8
Female	142.4	2.4	145.1	1.8	148.1	1.5	160.6	1.5

Table 5

Average Composite Mathematics Score, Grade 12 by Credits Earned in Fine Arts and Gender

Sex	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
Male	156.6	1.6	155.6	1.1	155.9	1.3	167.2	1.4
Female	151.3	1.5	151.6	1.0	151.6	1.2	161.0	1.0

Race. As with gender, there are noted gaps in achievement amongst white students and non-white students for STEM related fields (Barakos, Lujan, & Strang, 2012). Counter to these findings, research identified arts-based reform as a way to bolster STEM achievement for minority groups (Van der Veen, 2012; ASHE, 2011). Controlling for three separate ethnic groups (White, Black, and Hispanic) allowed further evaluation to determine the impact an increased exposure to the arts has on scientific and mathematic achievement. Table 6 and Table 7 contain information specific to ethnic groups in relation to math and science performance based on credits earned in fine arts.

Overall, with regards to math and science achievement, white students outperformed other races ($p<.001$). Hispanics outperformed black students on math and science assessments ($p<.001$). Among white students, those in the group earning more than three credit hours demonstrated a higher performance over white students with less than three hours of arts in both math and science. As a group, white students earning more than three credits of fine arts scored 10.8 points higher on the science test and 6.4 points higher on the math test than white students with little or no fine arts credits. Hispanic students with the most exposure to arts (above 3.0) outperformed all other Hispanic groups on science and math achievement tests. The group of Hispanic students earning the most credits in fine arts had an average score 13.1 points higher in science and 8.4 points in math than Hispanic students with little to no arts participation. Among black students, those in the group with the most fine arts credits outperformed students in groups with 1.5 credits or less on the science test. Regarding math, the black students with more than three credit hours performed better than any other black student groups. Black students in the group earning more than three fine arts credits outperformed the other groups by a maximum of 11.9 points in science and 7.7 points in math.

For white students, black students and Hispanic students with increased exposure to the arts there was an effect size of 0.10, 0.14, and 0.15, respectively, in science achievement. For science achievement, white students with increased exposure to the arts stood to gain four percentile points over white students with minimal arts background. Black students earning fine arts credits stood to gain six percentile points on science test over black students with little or no arts participation. Similar results indicate Hispanics participating in the arts can expect a six percentile point gain over Hispanic students with little or no experience in the arts.

For white students, black students and Hispanic students with increased exposure to the arts there was an effect size of 0.18, 0.17, and 0.22, respectively, in mathematic achievement. For mathematics achievement, white students with an increased exposure to the arts stand to gain seven percentile points over white students with a minimal arts background. Black students earning fine arts credits stand to gain seven percentile points in math achievement over black students with little or no arts participation. Similar results indicate Hispanics participating in the arts can expect a nine percentile point gain over Hispanic students with little or no experience in the arts.

Table 6

Average Composite Science Score, Grade 12 by Credits Earned in Fine Arts and Race/Ethnicity

Race	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
White	157.3	1.7	154.7	2.0	158.4	1.3	168.1	1.3
Black	125.7	2.7	123.6	2.3	130.8	2.7	135.5	3.0
Hispanic	139.8	2.5	139.0	1.6	133.8	2.1	152.9	4.5

Table 7

Average Composite Mathematics Score, Grade 12 by Credits Earned in Fine Arts and Race/Ethnicity

Race	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
White	161.1	1.6	160.8	0.8	159.7	0.9	167.5	0.9
Black	131.9	1.4	132.9	1.4	132.7	1.6	139.6	1.4
Hispanic	138.8	1.7	141.5	1.1	140.4	1.3	147.2	1.8

Socio-Economic Status. Finally, to determine if the arts can impact students from various economic backgrounds, performance of students qualifying for the National School Lunch Program (NSLP) was compared to students not eligible. As stated previously in the literature, student factors derived from the arts have been linked to success among students labeled at-risk and from a low socio-economic status (Catteral et al., 2012; Sousa & Pilecki, 2013). Table 8 and Table 9 display student performance results on scientific and mathematic achievement tests by eligibility for NSLP.

Overall, students not eligible for the NSLP score significantly higher than eligible students on math and science achievement tests ($p<.001$). As shown in Table 8, students eligible for the NSLP earning more than three hours of fine arts performed better in science than all other eligible groups (0-0.5, 0.6-1.5, and 1.5-3.0). Eligible NSLP students with the greatest exposure to the arts (above 3.0) had an average score 15.7 points higher than eligible students with minimal fine arts (0-0.5). Non-eligible students with over three credits of fine arts had the highest science achievement score of all groups. Non-eligible students receiving over three credits of fine arts had an average 11.4 points higher than students not earning fine arts credits in science achievement. With an effect size of 0.18, Non-eligible students stand to gain seven percentile points on science achievement tests by increasing participation in the arts. For science, arts participation had a larger effect on eligible students than non-eligible students. With an effect size of 0.25, eligible students stand to gain 10 percentile points on national science assessments by increasing participation in the arts.

As shown in Table 9, students eligible for the NSLP earning more than three hours of fine arts performed better in mathematics than all other eligible groups (0-0.5, 0.6-1.5, and 1.5-3.0). Eligible NSLP students with the greatest exposure to the arts (above 3.0) had an average score 10.5 points higher than eligible students with little or no fine arts credits. Non-eligible students with over three credits of fine arts had the highest mathematics achievement score of all groups. Non-eligible students earning over three credits of fine arts had a math average 6.5 points higher than other non-eligible students with little or no credits in fine arts. For math, arts participation had a larger effect on eligible students than non-eligible students. With an effect size of 0.18, eligible students stand to gain seven percentile points on mathematics achievement tests by increasing participation in the arts. At a 0.10 effect size, non-eligible students stand to gain four percentile points on mathematics achievement tests by increasing participation in the arts.

Table 8

Average Composite Science Score, Grade 12 by Credits Earned in Fine Arts and National School Lunch Eligibility

SES	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
Eligible	133.1	2.0	131.9	2.2	136.9	1.9	148.8	2.8
Non-Eligible	156.2	1.9	155.2	1.4	157.0	1.5	167.6	1.4

Table 9

Average Composite Mathematics Score, Grade 12 by Credits Earned in Fine Arts and National School Lunch Eligibility

SES	Fine Arts: Credits Earned							
	0-0.5	*SE*	0.6-1.5	*SE*	1.5-3.0	*SE*	Above 3.0	*SE*
Eligible	136.7	1.2	140.0	1.2	138.8	1.4	147.2	1.3
Non-Eligible	160.5	1.5	159.6	1.0	159.8	1.2	167.0	0.9

The findings from this study suggest a correlation between increased involvement in the arts and higher mathematic and science achievement scores. Accounting for various demographic factors, the arts were found to have a positive relationship with math and science performance. The results of this national study are congruent with similar, smaller studies and multifaceted theories of learning.

Chapter 5: Conclusions

This study answered one essential question. Is there a relationship between an increased exposure to the arts and performance in Science, Technology, Engineering, and Math (STEM) subjects? Results from the National Assessment of Educational Progress (NAEP) dataset indicated a correlation between the amount of arts credits and increased achievement scores in science and math. The same correlation was found when controlling for demographic factors such as gender, race, and socio-economic status (SES). Among all groups, students who earned the greatest amount of fine arts credits had the highest science and math scores.

Summary and Findings

Science, technology, engineering, and math (STEM) initiatives and programs have received national attention as a result of international competition in these same fields. However, over the past decade, declining enrollment rates, a lull in mathematics and science achievement scores, and disproportionate representation of demographic groups has led many critics to scrutinize current STEM initiatives. As a result, educators and researchers have introduced arts into STEM to create STEAM. Art has been empirically linked to creativity, open-ended problem solving, higher student motivation, increased interpersonal socialization, and intrapersonal skills. Neurological research and multifaceted theories supports a merger of arts and science to enhance learning and close achievement gaps between students of various gender, race, and poverty levels. This study suggests a correlation between participation in the arts and higher scientific and mathematic performance.

For this research, two null hypotheses were developed. First, there is no difference in scientific achievement scores between students participating in arts and students not participating in arts. Second, there is no difference in mathematic achievement scores between students participating in arts and students not participating in arts. Upon examination of the 2009 NAEP assessments, both null hypotheses were rejected.

Based on analysis of national science and mathematics achievement scores, findings included:

1) In observance of science scores, students earning the most credits in fine arts outperformed students with little or no credit in fine arts.
2) In observance of mathematics scores, students earning the most credits in fine arts outperformed students with little or no credit in fine arts.
3) In observance of science and math scores with relation to gender, males earning the most credits in fine arts outperformed males with little or no credit in fine arts.
4) In observance of science and math scores with relation to gender, females earning the most credits in fine arts outperformed females with little or no credit in fine arts.
5) In observance of science and math scores with relation to race, white students earning the most credits in fine arts outperformed white students with little or no credit in fine arts.
6) In observance of science and math scores with relation to race, black students earning the most credits in fine arts outperformed black students with little or no credit in fine arts.

7) In observance of science and math scores with relation to race, Hispanic students earning the most credits in fine arts outperformed Hispanic students with little or no credit in fine arts.
8) In observance of science and math scores with relation to poverty level, low SES students earning the most credits in fine arts outperformed low SES students with little or no credit in fine arts.
9) In observance of science and math scores with relation to poverty level, high SES students earning the most credits of fine arts outperformed high SES students with little or no credits in fine arts.

Interpretations

Results of this study support the argument for arts in STEM learning, or STEAM. Similar outcomes were found in prior research and studies. Overall, the arts greatest impact was on students identified as "at-risk" or underrepresented in STEM fields. Controlling for these variable groups, one can note the quantifiable differences in scores. As it stands, STEM programs do not produce a sufficient amount of female STEM workers (Beede, et al., 2011). STEM fields are "marked by notable gender disparities in participation, performance, and rewards" (Sonnert & Fox, 2012, p. 73). Findings were synonymous with current STEM trends when no arts were earned. While the impact of arts was positive for both male and females, the effect on female student performance was larger.

Pertaining to race, scholars have argued that current STEM programs require positive, engaging, or interactive environmental factors to increase student interest (ASHE, 2011). Evidence from this study demonstrated that Hispanic students experienced the largest increase in math and science scores when arts credits were earned. Past research has linked an increase in arts instruction to increased self-efficacy and positive attitudes among low SES students (Betts, 2006). These findings support this claim. While low SES students did not outperform their high SES peers, the achievement gap in science and math was narrowed with the addition of arts.

With over 36,000 12th grade participants contributing to this national study, the results are largely generalizable for the whole population. An increased participation in the arts was correlated to higher performance in STEM fields. Arts participation was shown to correlate with higher achievement levels in math and science for all groups. The effect of arts on female, Hispanic, and low SES students was particularly large. Research has noted achievement gaps among these same groups in STEM. Art may provide additional opportunities or skills these minority and at-risk students lack in traditional STEM programs.

Implications

The acceptance of arts into STEM fields can impact instructional practices, theory, and program and policy development. Arts participants demonstrating higher science and math knowledge support theories of multifaceted intelligence (Pea, 1993; Sternberg, 1999; Sternberg, 2003). As students experienced more arts, they encountered a variety of settings, projects, and instructional practices to which they may not have been exposed without arts. As a result, these students learned new skills and applied abilities in a variety of ways. It is believed these intelligences were transferred to science and math learning, as evidenced by better content understanding.

Connecting arts to STEM can also inform instructional practices, including interdisciplinary teaching. As students learn to unlock multiple intelligences teachers can use an arts integrative approach for instruction. Educators can apply creative, varied, and project-based techniques for students to explore knowledge. As previously stated, the brain welcomes variety, pattern, and holistic learning (Lake, 1994). Students learn more deeply when knowledge is passed through abnormal tasks (Wilson & Conyers, 2013)

The vast research of cross-curriculum instruction coupled with recent evidence supporting arts exposure, builds a strong argument for STEAM. Integrating arts into STEM instruction may better serve all students regardless of learning style, gender, race, or SES. The findings of this study imply that the students least served in current STEM programs have the most to gain from STEAM initiatives. Those students with the lowest performance scores experienced the greatest impact of arts experience. If STEM institutions experienced more success among low SES, minority, and female students, enrollment rates and the workforce may become more balanced.

Finally, in reference to economic and educational policies, introducing the arts into STEM fields may further innovation and national prosperity. John Meada (2013) stated:

> With global competition rising, America is at a critical juncture in defining its economic future. I believe that art and design are poised to transform our economy in the twenty-first century like science and technology did in the last century, and the STEAM movement is an opportunity for America to sustain its role as innovator of the world. (p. 2)

Art teaches creativity, enabling students to think of new ideas and solutions with resources that would have been otherwise unavailable. Yet, art is one of the most consistently under budgeted or understaffed departments in education (Annis, 2013). STEM workers exposed to more arts may be better qualified for twenty-first century jobs. Art may no longer be extra but essential to schooling and a viable workforce. In establishing a connection between arts participation and STEM achievement, policy makers can look to art as a potential factor when making educational or economic decisions.

Conclusions

An empirical analysis of the achievement scores in Math and Science cross-tabulated with earned credits in fine arts demonstrated a relationship between participation in arts and performance in STEM fields. Students earning more credits in arts possessed higher achievement scores on math and science assessments. Demographic variables such as gender, race, and SES were controlled for this study to determine any impact of arts involvement on various student subgroups. In all groups, those earning more arts credits outperformed students with little or no arts instruction.

Limitations

The 2009 NAEP dataset is appropriate for examining national educational trends. However, research is limited to investigation that is within the confines of the available survey questions, transcript information, measures, and years. As a result, fine arts credit earned was used as the independent variable to represent arts participation. This was the only fine arts variable available for the study to represent arts participation. Also, 12th graders were the only students with information related to both arts credits and math/science achievement. Eighth grade scores were also available in math and science but not in the High School Transcript Study (HTST) allowing for the use of fine arts credits as a variable. 2009 was the most recent year the national assessments were administered.

Recommendations

Data obtained from NAEP and HSTS lends valuable information related to arts experience and achievement in STEM fields. Specifically, findings related to demographic groups and STEM performance when arts participation was increased was particularly interesting. Further investigation into interdisciplinary teaching utilizing arts integration techniques is recommended to determine the impact of arts on STEM learning. This study determined an initial relationship between arts, science and math. Future studies may seek to determine the effect of arts-based instruction on STEM learning. In this study, the instruction of arts and the instruction of science and math took place independently. Examining arts instruction in the context of STEM programs may provide a better simulation of STEAM principles. Extensive studies on arts integration have been conducted (Ingram & Riedel, 2003). While specific universities and STEM institutes are enacting principles of STEAM, there is little more than anecdotal evidence and qualitative records to evidence results. A larger study with an extensive timeline may better suite the need to understand the influence of merging arts and STEM. Especially, as STEAM relates to the demographic subgroups mentioned in this study.

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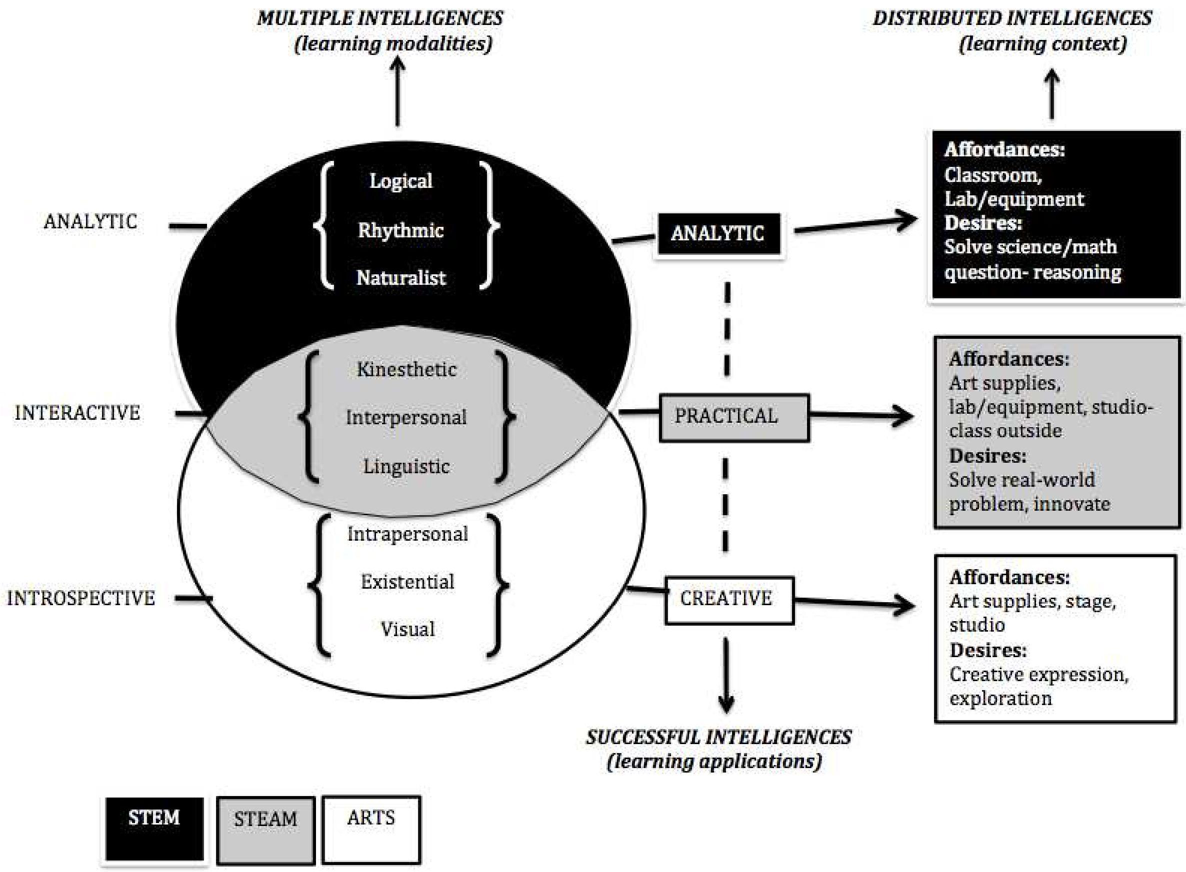
Appendix

Conceptual Framework



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Dissertation Director: Dr. Robert Slater
Pages in Dissertation: 88; Words in Abstract: 239

ABSTRACT

The purpose of this study is to examine the relationship between exposure to the arts and performance in Science, Technology, Engineering, and Math (STEM) subjects. STEAM, an integration of arts-based instruction into science and math related fields, is viewed as an alternative to traditional STEM academies. The literature briefly examines the current state of STEM programs and the deficiencies in graduate quality and quantity and the call from employers for a more innovative workforce. Advocates for STEAM argue for arts as a means to improve creativity, collaboration, risk-taking and exploration. Arguments against arts in STEM are grounded in political opinions concerning arts funding and logistical complications of implementing STEAM. However, some schools and STEM programs have embraced the STEAM premise and have begun to integrate arts into the traditional curriculum. The 2009 National Assessment of Educational Progress (NAEP) dataset was utilized to determine a correlation between the number of arts credits earned and mathematics/science achievement. Results from the NAEP dataset indicated a correlation between the amount of arts credits and increased achievement scores in science and math. The same correlation was found when controlling for demographic factors such as gender, race, and socio-economic status (SES). Overall, the arts' greatest impact was on students identified as "at-risk" or underrepresented in STEM fields. Controlling for these variable

groups, one can note the quantifiable differences in scores. Overall, findings of the study provide empirical support for the addition of arts in STEM.

Biographical Sketch

Mark E. Rabalais was born to Eddie and Sherry Rabalais on February 20, 1984 in Avoyelles Parish, Louisiana. He was raised in Pineville, Louisiana, and earned his Bachelor of Arts, Master of Arts, and Master of Education at Northwestern State University in Natchitoches, Louisiana. Mark is a National Board Certified Teacher and is currently working as an administrator with the Lafayette Parish School System.