Spring 2023

Prospects for Professional Art and STEM Collaborations to Create STEAM Programs and Projects

Darius K. Hines

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Darius K. Hines

Claremont Graduate University

2023

Approval of the Review Committee

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Darius K. Hines as fulfilling the scope and quality requirements for meriting the degree of Doctor of Philosophy.

Dr. David Drew, Chair
Claremont Graduate University
Professor of Education

Dr. Andrew Vosko, Member
Claremont Graduate University
Professor of Transdisciplinary Studies

Dr. Thomas Luschei, Member
Claremont Graduate University
Professor of Education

ABSTRACT

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Would STEAM project and program resources be better utilized through collaboration between STEM and Arts professionals or from creating STEAM from within the Arts and STEM disciplines organically? Four hundred nineteen STEM and Arts professionals from academia and industry were surveyed for their thoughts and opinions regarding STEAM, creating a unique data set. The data was analyzed using descriptive statistics and the inferential methods T-test, Chi-Squared and Multivariate Regression.

Respondents reported a very small number of STEM (11%) and Arts (18.9%) professionals they know studied both STEM and Arts perform both equally in their careers. The majority of the STEM and Arts professionals they know either mostly or completely specialize within their respective career paths. Arts (92.3%) and STEM (82.6%) professionals reported they are receptive to collaborating for STEAM if approached, but approximately 66% of STEM and 59% of Arts respondents didn't reach out. STEM and Arts professionals agree on many of the factors that make a collaboration successful. Selection of members with certain characteristics was reported as highly important to a successful collaboration. The number one reason for collaborating is because they wanted to. The number one reason for not collaborating was not being asked. The implication is collaboration is better than organic development of STEAM within a discipline. A successful STEAM Collaboration will be guided by a transdisciplinary convener who can initiate and facilitate important activities, such as vetting potential members, and cultivate over time the development of a transdisciplinary STEAM collaboration.

Keywords: art, collaboration, collaboration theory, specialization, STEAM, STEM, transdisciplinary.

Dedication

To my Family who always believed in me.

To my Friends who always supported me.

To Rita, my source of peace, calm and comfort.

Acknowledgement

To my Dissertation Committee members, many thanks for the continuous insights and support you have provided me. The discussions we have are always full of inspiration and are enjoyed greatly.

To my colleagues at work, thank you for helping me with my survey development and review.

To my colleagues at Claremont, thank you for critical feedback on my ideas, thoughts and opinions. They all helped me grow and advance.

Table of Contents

List of Tables

List of Figures

CHAPTER 1

Introduction

The concept of STEAM, the interconnected application of five technical disciplines (science, technology, engineering, art, and mathematics) is ubiquitous. Regardless of whether you envision the solitary artists toiling away at their craft or the lone, obsessed scientists hidden away in their lab, the reality is the existence of strong international support to combine the disciplines. Both private and public educational institutions support STEAM programs. There are university degree programs that lead to a diploma in STEAM. The STEAM concept and STEAM programs are fast becoming an incorporated part of the established academic and industrial worlds.

Background of the Study

The concept of combining arts with STEM to create STEAM has been variously articulated to address three problems, the need for innovation, to increase the number of people entering the STEM fields and to increase support for arts programs. John Maeda is credited with championing the term STEAM (Gunn, 2017). John Maeda (2012) argues that STEM is insufficient for maintaining American global economic competitiveness. He argues that convergent thinkers, characterized as STEM professionals, must unite with divergent thinkers (characterized as arts professionals) to produce innovation (Maeda, 2013). He argues this innovation is necessary to maintain U.S. global leadership as an innovative nation.

Lisa Caterall (2017) traces the problem of not enough people in STEM back to poor scores on The Program of International Student Assessment (PISA), an international regimen that reported Americans are in the middle of the pack with respect to test performance. She traces the foundations of STEAM back to the work of her father as a means for explaining to lawmakers the importance of the arts in school. She indicates there are two schools thought related to the benefits of STEAM; the first is economic and the second is creative. This leads to the argument related to the shortage of STEM professionals who are prepared to supply the soon to be ever increasing demand for competent employees. The idea that people will be creating new and desired products is essentially a financial boon for capitalists. Despite the information regarding the number of STEM jobs available, STEM related jobs are still projected to be the fastest growing field going forward. STEM is projected to grow 9 million jobs between 2012 and 2022 (Bureau of Labor Statistics, 2014). In 2017 the Bureau of Labor Statistics projected mathematical science occupations to grow by 28.2%, compared to 6.5% for all other occupations between 2014 to 2024. Between the period of 2009 to 2015 the bureau reports that STEM occupations grew at a rate of 10.5% compared to 5.2% for non-STEM occupations. Going forward, STEM disciplines will impact society in ways that are yet fully understood. The more STEM ready our society, the better prepared it will be to face these future challenges. Caterall (2017) calls having a population in possession of STEAM related skills a "cash cow".

The second path to benefits Caterall (2017) describes is towards creativity, self-expression and the inner peace and happiness that brings. Egley (2014) writes that STEAM may provide the motivation for white women and non-whites to explore the creativity that will keep them in STEM. She reports that employers are looking for creativity in their employees and have found it lacking. She also implies that STEAM could improve math and reading skills. Feldman (2015) advocates for the inclusion of the arts in STEM education. She indicates that STEAM will move STEM professionals towards a more people specific as opposed to a subject specific orientation. She articulates the focus is to increase the sense and awareness of creativity in the STEM students. She points to the possibilities of using STEAM to engage the non-STEM students by listing a few examples of arts students using 3D printers and other technology to create. STEAM has been presented as a means for increasing the diversity of the STEM professions (Jolly, 2014, Gunn, 2017).

Georgette Yakman is generally credited with formalizing the idea of STEAM. Her goals were twofold; to create a classification structure to organize the individual disciplines and an academic structure that permitted teaching the interconnectedness of the disciplines in an academic setting (Yakman, 2008). Her motivation was to create a framework where all the disciplines are given equal appreciation and how to link the STEM disciplines with the arts. Based on her research and studies, she developed a meaning for STEAM; 'Science and Technology, interpreted through Engineering and the Arts, all based in a language of Mathematics.'

There is an argument made for not combining the Arts with STEM. There are arguments from both STEM and Arts professionals against STEAM. In one summary of objections STEM professionals are characterized as feeling that the arts are naturally a component of STEM, such as writing to communicate ideas or creating design solutions (Jolly, 2014). The summary also includes arguments made by artists against STEAM; while STEM can assist artists in their endeavors, but the use of art in STEM would devalue the art and defeat the purpose of art. The author ends by observing the best idea is to incorporate art in STEM where it naturally fits, which seems like the idea of developing art from within STEM. Gunn (2017) echoed these sentiments by indicating that STEM is designed to merely focus on areas of academic need, not to exclude other subjects The author then related the concerns of those who argue that the STEM focus has led to both a dearth of funding and a marginalization of the arts. While not being averse to STEM students studying arts in the least, Gary May (2015) makes two points against

STEAM. The first is that we are just now integrating the four components of STEM, and therefore too much arts content would dilute the process. His next argument is that there is a major need for STEM professionals in the future, and STEM is so foundational to so many careers that arts shouldn't be a component. His last argument, however, has many detractors.

A lot has been written about the shortage of STEM professionals. There are those who believe there isn't a shortage of STEM professionals (Xue, et al., 2015, AFL-CIO (DPE), 2016). One author implied that promulgating the myth of a STEM shortage increases the available pool of labor, thereby reducing the need for generous compensation and benefits packages (Charette, 2013). Steve Lohr (2017) presents combined data from the Bureau of Labor Statistics and the National Center for Education Statistics to convey the projected number of degrees versus the number of jobs in STEM. For the period 2014 to 2024, graduate numbers outstripped available jobs for all but computer programming. The difference is projected to be only 1000 more jobs than graduates. Ed Lazowska (2011), wrote that 85% of all STEM jobs between 2010 and 2020 will be in computer science and engineering, with only a small percentage of growth in physical, life and social sciences.

If STEAM were to be universally adopted, it would go a long way to address another issue society must address, scientific literacy. One of the most important duties of educators is to prepare students to be effective, successful, productive, well-adjusted members of society (Rothstein, 2004). To that end, scientific and technological literacy are vital to be effective members of society. We live in a designed world. People must have facility with science and technology to make wise decisions across a varied array of options and pitfalls. Career choices such as doctor, engineer, teacher, banking, finance, economics, involve STEM skill sets. While these are obvious reasons for promoting STEM education, there are other reasons as well.

Scientific and technological literacy will make individuals more analytical in their thinking. This in turn will make them more intelligent consumers and participants in society. Many choices in an individual's world have some basis in science and technology. What basis should I use to choose a phone or computer? What are the benefits and detriments between organic, genetically modified, and standard fruits and vegetables? What are the alternatives to unquestioningly trusting experts like my doctor and dentist (ITEA, 2007)? At the societal level, technical literacy will better inform discussion of the ethical questions that surround issues like global warming, the creation of genetically modified new species and the control of information.

Statement of the Problem

The problem addressed by this research is essentially one of resource investment. Allocated resources back commitments to STEAM at the local, regional, and national levels. These allocations of resources in STEAM programs can be substantial. In 2015 twenty-seven Pennsylvania school districts received over one-half million dollars for STEAM programs (Gough, 2015). In that same year the U.S. Department of Education allocated funds for STEM Innovation Networks ($110 million), the National STEM Master Teacher Corps ($20 million), the STEM Teacher Pathways ($40 million) and the Effective Teaching and Learning: STEM ($150 million) programs (U.S. Department of Education, 2014). There were no indications of allocations for arts education. This trend has continued. The U.S. government 2020 fiscal budget calls for $1.3B for Career and Technical Education (CTE) support at the state level with an additional $20M for national CTE with a specific focus on STEM. This same budget proposed a cut in Arts in Education Funding of $29M

Purpose of the Study

To address the problem articulated above, we must consider questions surrounding the idea of combining science, technology, engineering and math (STEM) with the arts to promote a new paradigm with the acronym STEAM. The existence of two options for doing this, seeking collaborations between the arts and STEM disciplines or to develop STEAM organically within the STEM framework is at the heart of this investigation. What are the historic and contemporary contexts for evaluating the feasibility of these two approaches? Would one choice be more effective than the other, or should the approaches be pursued simultaneously? How do artists feel about this initiative?

The purpose is to collect data on the thoughts and opinions of STEM and Arts professionals to determine what their interest levels are with regards to creating STEAM programs and projects. Specifically, which professionals are interested in engaging in STEAM programs and projects, which professionals prefer to collaborate to create these programs and which professionals pair most and least favorably with each other with respect to collaboration.

Significance of the Study

The question to resolve is whether it is more effective to pursue STEAM through collaboration between STEM and Arts professions, or by way of cultivating the arts organically from within a STEM environment. One benefit derived from the answer to this question will be the ability to insightfully impact resource allocation ranging from local to national educational policy implementations. Assessing the reasons why Sciences and the arts separated from a historical perspective appears to be an avenue unpursued by current research. Understanding the separation of Arts and Sciences from a historical perspective could inform policy regarding the implementation of STEAM programs. The benefit of this research will be to assist in the creation of data driven, decision-making policy with respect to resource allocation within STEAM programs.

Research Questions

After reviewing historical examples of STEM and Art disciplines being unified and then bifurcated, the question I seek to address is if it is better to create STEAM projects and programs from collaboration as opposed to organically developing it within STEM. In other words, should STEM and Arts professionals develop collaborations to create STEAM programs and projects, or should two versions of STEAM be developed, one out of the STEM disciplines and one out of the Arts disciplines. This question arose from my anecdotal observations that it seemed that STEM professionals routinely reached out to Arts professionals to create STEAM projects but rarely was the reverse observed.

To develop evidence to be used to address my fundamental question, I investigated the following questions:

1. *How similar or different are the opinions of STEM and Arts professionals about the factors that affect the success of a collaboration?*
2. *Is specialization a force that may prevent STEM and Arts professionals from incorporating Arts and STEM skills respectively?*

Methods

The primary method of data collection were via an electronic survey sent to STEM and Arts professionals in both academia and industry. The academics represented K-12, community college and four-year universities. Industry professionals were outreached via associations and events. Additionally, some qualitative data was collected via open-ended questions and from email correspondence.

Organization of Dissertation

This opening chapter describes the importance of this research to the promotion of STEAM programs and projects. Chapter two starts with a review of the circumstances in existence during the time when Art and Science were unified and practiced together. Next, factors that cause the split between Art and the emerging group of STEM disciplines are reviewed. Themes in STEAM are explored based on contemporary programs and projects. Finally, the conceptual framework for this investigation is presented. Chapter three describes the methods to be used to collect and analyze data for this investigation. Chapter four lays out the analysis of the data collected. This analysis includes both descriptive and inferential statistical findings. This chapter also includes a narrative discussion of qualitative data collected. Chapter five offers a conclusion and discussion of the findings and their relevance to answering the research questions. The discussion includes a reflection on the implications of these findings for STEAM policy for the future. Lastly, the final pages include the appendices, references and reproductions of the surveys, interview questions and consent forms.

CHAPTER 2

Focus of Literature Review

There are a great many individuals, organizations and institutions interested in combining the Science, Technology, Engineering and Math (STEM) disciplines with the Arts to form the group of STEAM disciplines. Taken separately, STEM has a great many proponents who have argued the importance of STEM education. The preparation of youth, especially in underrepresented groups such as white women and non-white people, is seen as critical to both maintaining American competitiveness internationally and a vehicle for remedying social inequalities domestically. Likewise, the Arts have been described as a means by which creative thinking and problem solving can be practiced and mastered. The use of the design process in the Arts has been promulgated as a means to juxtapose the creative process between artists and engineers.

Across the nation, one can, from a cursory search, find all manner of STEAM programs and professional development activity currently in place. The question becomes; are all the resources and personnel being well utilized? Moreover, in many cases, careful review of the project reveals the STEAM project is initiated by STEM professionals or Arts professionals with a STEM background. Where are the pure artists who reach out to the STEM professional? Are they inhibited by the math background that is a staple of the STEM disciplines? Is collaboration between the Arts and the STEM disciplines the most natural and efficient means of obtaining the objective of producing students with 21st-century transferable skills? Is there perhaps a better way?

The question I seek to answer is whether it is more natural for STEM disciplines to cultivate arts and humanities from within the various STEM disciplines, or to continue to pursue collaboration with artists in the form of reaching out to the arts communities. On the one hand, it seems that arts and humanities cultivated from within STEM will be more organic and less forced; the manifestation of the arts and humanities will be from the inquiry and discovery that are at the foundation of the STEM disciplines. Instead of chemists explaining the reactions that produce the paint artists use, the chemist can be trained to see and express the aesthetic and rhythm of the reaction itself, in addition to greater variety of methods to explain the reactions to others. This expression will naturally extend beyond the equation that explains the reaction; it will be a sharing of the natural process of color with the rest of humanity. This also could encourage a sense of social and economic justice that may lead to a greater appreciation of the natural world that provided the resources that led to the chemical reaction. On the other hand, one could seek out the arts community to encourage artists to 1) incorporate the thinking and practices of a member of a STEM discipline in their art projects, 2) participate in science investigations and 3) inform the thinking of STEM professionals. Having artists involved from the beginning of the science investigation or design process of a project will increase respect for the artist's contribution and move the project in a different direction. While many have discussed the format and rationale for the combination of STEM and the arts, it doesn't seem that anyone has either developed a blueprint for a sustainable program for STEAM that is guided by a historical perspective or looked at the feasibility of the concept STEAM from such a perspective. This is the gap I seek to fill; what policy should be in place and what would it look like.

Search Methodology

The search process was conducted using two databases and one search engine. The first database used was the Education Resources Information Clearinghouse (ERIC) and the second database was the Art Full Text. The search engine used was Google Scholar. Both databases were accessed via the Claremont Graduate University library. ERIC was accessed through the Education heading and Art Full Text was accessed through the Art and Art History heading. Keywords used in ERIC were "STEAM," "STEM," "arts" and "collaboration." Keywords used in Art Full Text were "art," "science," "division" and "separation." For both databases, the discipline-based keywords were searched individually. The descriptive terms such as "division," "collaboration" and "separation were searched in multiple combinations with the discipline-based keywords and by using Boolean operators 'and' and 'or.' Results from the ERIC searches were either accepted or rejected based on the abstract's description of a program or study that explained how a STEAM collaboration was created, implemented, or evaluated. Results that did not meet this criterion were rejected. Results from the Art Full Text searches where either accepted or rejected based on the abstract's description of a program or study that discussed how the division of art and science came to pass. Results that did not meet this criterion were rejected.

Critical Review

The first part of this literature review will look at historical examples of ideas and conditions that united the arts and sciences. The goal will be to identify the factors that held them together. The areas that I will survey are philosophy, artisan and craftsmanship, astronomy, medicine, and architecture. My attempt will be to review the way different cultures have unified arts and science through those areas. While this is not an exhaustive description of several millennia of science and arts interactions, it should provide a solid basis for developing the concepts.

The Unification of Arts and Science

Form and function. In many cultures around the world, the unity of form and function was at the heart of unified Arts and Sciences. In summary, whether it was religious practices wedded to ideology, household objects made able to also represent abstract concepts or philosophical concepts that unify (wo)man with the workings of the natural world, form and function were co-equal companions. The expression of form and function was carried by individuals who practiced art and science. This can be inferred from the following examples.

Artisans and craftsmen. The inclusion of geometric features was part of Chinese art extending back to the Shang Dynasty (Shih, H., 1972). Examples of symmetry, curvilinear patterns in addition to zoomorphic and theriomorphic designs are evident (Shih, H., 1972).

Aesthetics evolved out activities related to totemic rites and magic (Zehou, 1997). Aesthetics and artistic creation began when primitives started to infuse social value and content into symbols and signs (Zehou, 1997). Song and dance evolved from spiritual expression into poetry, music, myth, legend and eventually art and literature (Zehou, 1997). Zehou (1997) argues in favor of the theory that geometric representation of organisms has its origin in the effort of primitive people to represent actual physical objects like the coiling or wriggling snakes (Zehou, 1997). Over time, the imagery became more geometric and more abstracted; it evolved into symbolism that is described as a critical point in the awareness of art and aesthetics (Zehou, 1997). Originally, objects were not decorative on purpose. Decoration on objects were representations of the living organisms in the observable, natural world that identified clan or community (Zehou, 1997). These objects acquired the property of beauty once they were able to inspire specific feelings and emotions in the observer based on the social and cultural content defined by the form of the object (Zehou, 1997). For example, pottery evolved from functional objects to artistic functional objects as their creations included an awareness of and manipulation of elements that elicited non-typical emotions such as color and line; key elements of visual arts (Zehou, 1997). Artisans combined the sciences of materials and metallurgy with the evolving sense of art and aesthetics to create useful objects that had meaning.

There is very little available evidence that artisans were much respected in most pre-Islamic Arabian culture (Ettinghausen & Grabar, 1987). Influences on Islamic art come from essentially three Arabic cultures that had received significant influence from non-Arabic sources. These non-Arabic cultures were 1) the Lakhmids, a Christian dynasty found in Iraq during the 5th and 6th centuries, 2) Yemen, a trading hub between Egypt and Ethiopia in Africa and the Mediterranean and 3) Christian Ghassanids in Syria and Jordan, the latter to influencing up to about the 6th century (Ettinghausen & Grabar, 1987). The Lakhmids were located between the Persians and the Byzantines, receiving influence from both. It has been debated that at this time the Persians had provided the basis for common written Arabic (Ettinghausen & Grabar, 1987).

The Abbasid Dynasty for the most part simply continued the method of adoption and adaptation of existing artistic practices. However, they were responsible for two ceramic innovations as well (Ettinghausen & Grabar, 1987). The first was the combination of a cobalt blue glaze used to paint vegetal, geometric, calligraphic or a combination of these on an opaque white glazed vessel and then firing the object (Ettinghausen & Grabar, 1987). The second technique was to use metal oxides of silver or copper, mixed with a medium, and painted on an already fired opaque-glazed surface (Ettinghausen & Grabar, 1987). The subsequent chemical reaction released the oxygen and left the metal, which then exhibited refractory and lustrous properties. This practice was unique to Basra during this time (Ettinghausen & Grabar, 1987).

Examples of innovation in Islam occurred around the end of the first millennium and the beginning of the second millennium (Ettinghausen & Grabar, 1987). Artisans would overlay a given glass blank (e.g., an ewer) with a given viscous and ductile material (a ‘gather’ in glass-blowing terminology), in his example the author indicates turquoise-blue glass. A wheel was used to subtract the overlay such that the image would emerge in relief. Called relief-cut by the author, he indicates the origin of this technical innovation evolved from the methods of stonework with precious minerals such as turquoise or emerald (Ettinghausen & Grabar, 1987). In the first half of the 13th century artistic patronage was provided by groups in the Turkic dynasty such Artuqids (Ettinghausen & Grabar, 1987). Craftsmen specialized in copper, but other metals were worked as well. The objects created were of a wide variety, all being very functional yet artistically created (Ettinghausen & Grabar, 1987). Belts, lamps, mirrors, and ewers were made of copper, gold, and silver, with various combinations by way of inlays, mostly silver. The inlays were about calligraphic script of scriptures and images of the daily lives of royalty (Ettinghausen & Grabar, 1987). Techniques such as repousse and open space designs were also used. These craftsmen demonstrated the blending of art, science and technology and design all by one person.

Hoffman (1996) notes that as late as the Renaissance Period the sciences, arts and humanities were still unified as evident in the work of individuals such as Leonardo da Vinci. During the time of the Renaissance, the professionals did both artistic and STEM related activity in addition to collaborating (Zilsel, E., 2000). Zilsel (2000) identifies several professionals he describes as artist-engineers, such as Brunelleschi (1377-1446), Ghiberti (1377-1466), Leone Batista Alberti (4401-1472), Leonardo Da Vinci (1492-1519) and Vanoccio Bringucci (d. 1538). These professionals created art as well as structures and instruments. This was possible due to the lack of a division of labor during the time around the fifteenth century. Virtually none of them had any form of advanced scholarly training.

In Europe, surgeons collaborated with artists due to their common interest in anatomical knowledge. Instrument performers work with instrument makers. Science originated when scholars united with experimentalist artisans and craftsmen. Prior to the coming together of the literati and the advanced craftsmen, the proto-scientists and engineers created and invented due to the necessities of their own professional work (Zilsel, E., 2000). They represented the experimentalists while the scholars represented theoreticians. The two groups remained separated because of the lack of respect the liberal artists (scholars) had for the manual artists (artisans and craftsmen). By about 1550, economic and military forces drove the liberal artists to begin to adopt the methods of superior craftsmen and artisans (Zilsel, E., 2000). The application of scholarly training to the methods of mechanical artists resulted in the birth of the scientific approach. “The rise of manual workers to the ranks of the academically trained scholar at the end of the 16th century is the decisive event in the genesis of science” (Zilsel, E., 2000). In Europe, in order of decreasing development, the sciences were mathematics, biology and the least developed, physical science. Technology was limited to war machines and entertainment devices (Zilsel, E., 2000). Artists such as sculptors and painters were grouped with artisans and craftsmen because they made a living with their hands. However, they were elevated to a higher class over time. Working for a living was considered lower class and not respected because manual work was associated with slavery (Zilsel, E., 2000).

Artisans and craftsmen prior to the advent of capitalism combined art and science because they created everyday items with aesthetic quality. Body scarification and other cultural characteristics provide the context for the aesthetic (Dewey, 1934) and guide how the artisan uses science to create artistic items. Textiles, utensils, bowls, and other items were created by artisans and craftsmen who were meeting the needs of the population in a way that combined artistry with scientific expertise. Today, they are hoarded as exquisite works of art, but in their day, they were simply tools and artifacts of everyday life. While their artistic merits made them worthy of museum curation today, they were created to be part of everyday experience (Dewey, 1934).

Astronomy. The connection between art and astronomy has a long history. Astronomy provided religious inspiration which allowed it to have a special place in society. Additionally, it had a secular value in the fields of navigation and time measurement. This dual utility allowed it a special place among the sciences and the arts (Zilsel, E., 2000).

The study of cultural astronomy in Africa reveals much of this connection. The earliest evidence of sky gazing in Egypt is on the Nabta Playa (Malville, 2008). On this location have been found a gnomon, calendar circles and burial sites that date back to 9000 BC. Cow herders used the motion of the sun to determine the arrival of winter solstice rains. The gnomon was also used to determine the direction of true north. Malville (2008) believes that the symmetry of the movement of shadows and their celestial indications of the poles, equinoxes and solstices were an inspiration for the creation of rock and ceramic art and decorations in addition to basket weaving patterns (Malville, 2008). The author relates the work of Berosus in 340 BCE (Malville, 2008). Berosus placed a gnomon in a hollow hemisphere. Not only could it tell seasons of the year it could also tell hours in a day. The author points to the symbolism of the hemisphere reflecting the connection between the celestial and the terrestrial as it was viewed by the movement of the gnomon's shadow in the hemisphere. Art and science are evident at Nabta Playa, just north of the southern border between Egypt and Sudan. A calendar circle of megaliths aligns with both the cardinal direction north and the summer solstice. (Malville, Schild, Wendorf & Brenmer. 2008). Other megalith groupings are carved in various shapes, some anthropomorphic and some like animals (Malville, et al, 2008). The authors confirm that the megaliths point to the stars Arcturus, Sirius, Alpha Centari and Alnilam where they would have been six to seven thousand years ago (Malville, et al, 2008, p. 138). More evidence of the art and astronomy connection is in the form of artwork on rocks and the erection of megaliths. The author believes that religious influences predominate over the astronomical or astrological considerations (Chami, 2008). Based on ethnographic research, Chami (2008) believes that groups such as the Musi of Ethiopia used astronomical knowledge to create calendars that marked major religious events (Chami, 2008). Chami (2008) acknowledges that while there are those with alternate explanations that the artworks are either spawned from archetypes of universal concepts or simple doodling; he rejects these ideas based on the idea that a belief in a universal sun-god existed in sub-Saharan Africa. Celestial bodies were used to symbolize this sun-god (Chami, Felix A. 2008). The author points to megalith sites which are aligned in such a way as to calculate annual time. These megaliths are aligned to highlight celestial objects with shadows or passages (Chami, 2008). The author also points to drawings and engravings that represent rays from the sun and moon. The author feels that some of these drawings represent not only celestial objects, but script as well.

The height of Islamic science occurred between 808 AD to 1308 AD. The authors indicate that until recently, stars dominated human life with respect to time, seasons, navigation and spirituality (Medupe et al., 2008 and Snedegar, 2000). Religion was the driving force for astronomy in the Islamic world (Medupe et al., 2008). The first reason is directional; to both pray facing towards; and to erect their mosques facing towards Mecca. The second reason is temporal; to mark the times for their daily prayers at sunrise, noon, afternoon, sunset and evening. Islamic astronomers also improved the astrolabe, a device used to predict the positions of stars and planets.

Medupe et al., (2008) cite a translated Arabic historical manuscript from Timbuktu, Mali that indicates that the uses of astronomy, among other things, is for "decorating the sky." This, and the uses of charting direction, creating calendars and marking times, especially for prayer were taught from manuscripts in 1723. Astronomy initially provided information on time and direction and then combined artistic interpretation and expression.

Architecture. In Chinese architecture, art and engineering were blended from the beginning of the building of the home (Ruitenbeek, 1986). The carpenter cut and selected the wood, drew up the plans for the home and shaped the wood members for construction (Ruitenbeek, 1986). In keeping with the Chinese idea of unity of physical and spiritual principles, the carpenter had to take care not to offend or attract evil portents. The same Chinese text that serves as the seminal document on construction of homes for ordinary people, the Lu Ban jing, also includes chapters on making furniture and utensils (Ruitenbeek, 1986). This book has also become a significant source document for art historians interested in furniture construction as well (Ruitenbeek, 1986). The Lu Ban jing dates to the 15th century (Ruitenbeek, 1986).

In the African sensibility, the idea of architecture is the combination of concrete and philosophic spaces (Prussin, 1974). The concrete space includes the use of local materials, processed in such a way that they adapt and accommodate the specific conditions of the environment. This can include humidity, air flow patterns and sun intensity (Prussin, 1974). Consideration of the properties of the available materials played a role in determining the architectural design implemented. Manipulation of lines, textures and curves in the construction was done to create a more favorable habitation (Prussin, 1974). Materials such as river shells, fishbones and earth were combined to create building materials that where hard and strong yet able to be decorated (Prussin, 1974). Moreover, the local environment also played a role in determining which types of structures were useful. For example, while granaries would be useful in the savannah environment, they would be useless in the rainforest (Prussin, 1974). In terms of philosophic expression, artistic inclusion can be found in the carving of wooden support poles and patterns woven into the fabrics use to comprise the architecture of the nomadic peoples of sub-Saharan Africa (Prussin, 1974). The African residence is seen as a physical extension of the family structure within (Prussin, 1974). To that extent, the architecture communicates a great deal of information about the beliefs of the resident and the community. In the African culture, the impermanence of the structures is not a sign of instability. Rather, it reflects the ever changing and growing life of the community and the people in it (Prussin, 1974). The architecture tells the story of the family and community, the divisions of labor and the relationships between the members of the group. For example, the architecture reflects the relationship between man and woman in that while the man is responsible for the construction, the woman is responsible for the decorative elements. Interpersonal relationships define the union of art, science, and engineering. Over time, while the construction methods changed very slowly, the exogamous nature of marriage led to an ever changing and wide variety of decorative expression (Prussin, 1974).

Yemen, the purported home of the Queen of Sheba, had a rich history of art and architecture for centuries prior to Islam (Ettinghausen & Grabar, 1987). Influence for the Ghassanids was Byzantine in origin. Art and architecture in Islam are essentially based on pre-Islamic external influences on Arabic culture (Ettinghausen & Grabar, 1987). The teachings of Islam provide no direct instruction on art and architecture. The Prophet never ruled or addressed problems that directly related to art and architecture (Ettinghausen & Grabar, 1987). While the Qur'an doesn't explicitly have any commentary regarding art or architecture; many verses have been used at various dates to impact them (Ettinghausen & Grabar, 1987). During the Abbasid, from the middle to the 8th century to the beginning of the 10th century, infused science, philosophy, and mathematics with the translations acquired from Greek, Syriac, Old Persian, and Sanskrit texts (Ettinghausen & Grabar, 1987).

The author identifies three types of monuments attributable to the Umayyad and Abbasid Dynasties. The three functional groups are the 1) unique Dome of The Rock, 2) the congregational and other mosques and 3) secular buildings, primarily palaces (Ettinghausen & Grabar, 1987). Each building has its own architectural decorations.

Congregational mosques were patterned after the home of the Prophet Muhammed in Madina (Ettinghausen & Grabar, 1987). The simple plan was that of a squarish structure (Ettinghausen & Grabar, 1987). While most initial mosques followed this plan, as time progressed the shape was modified to a rectangular shape; the function evolved from home and place of worship to a community center that included, place of worship, governor's palace, and community treasury (Ettinghausen & Grabar, 1987). Additionally, two features of obscure origin are the maqsura, an enclosure used by the princes when in the qubla to pray, and the minaret (Ettinghausen & Grabar, 1987). The maqsura is believed to be a protection from assassination and the minaret functioned to be a place to call for prayer, providing visibility for both Muslims and non-Muslims and to acknowledge something holy for all Muslims (Ettinghausen & Grabar, 1987). The architectural traditions of Syria provided construction elements for both the congregational mosques as well as the Dome of The Rock (Ettinghausen & Grabar, 1987). A recurrent theme in Abbasid architecture was the subordination of decorative elements to architectural ones; the decorations were used to highlight architectural elements (Ettinghausen & Grabar, 1987), (Ettinghausen & Grabar, 1987).

The Abbasid Dynasty employed astronomers to determine the date for ground-breaking on the construction of Bagdad in 762 AD (Ettinghausen & Grabar, 1987). Engineers and laborers from all over the empire were called upon to complete construction. The palaces of Samarra, founded in 862 AD used geometric shapes in two of the three main classes of stucco carvings (Ettinghausen & Grabar, 1987). The third class mostly abandons geometric motifs for linear and curvilinear lines, spirals and interaction between lines, notches, and planes (Ettinghausen &

Grabar, 1987). Additionally, the design was molded, not carved. A great many mural paintings demonstrate techniques reminiscent of styles across the empire. Comparable examples are found in Central Asia and Chinese Turkestan (Ettinghausen & Grabar, 1987).

The Umayyad Dynasty took many of its artistic and architectural forms from the lands they conquered (Ettinghausen & Grabar, 1987). Areas previously under control of Greco-Roman cultures provided geometric design elements (Ettinghausen & Grabar, 1987). This was evidenced in repousséd metalwork by artisans working on the Dome of The Rock, Roman influenced unglazed pottery (Ettinghausen & Grabar, 1987), metalwork (Ettinghausen & Grabar, 1987) and textiles (Ettinghausen & Grabar, 1987) influenced by Sasanian artistry.

Medicine. African alchemy incorporated the use of sculped images, paintings and masks with chemical elements and compounds. The idea of 'functional art' can be extended to everyday objects. Traditional African medicine included an understanding of the person as well as the disease. Clay sculpted figurines play just as important a role in healing a person as the herbs used for treatment due to the spiritual aspect of medical treatment; understanding the person (Kankpeyeng et al., 2011). In some cases, the figurines can represent a place to transfer the malevolent spirits or forces from the patient. Unnatural (i.e., not found in nature) or stylistic creations can arise from this practice (Kankpeyeng et al., 2011).

Nigerian proverbs were used to convey medicinal practices for the Yoruba people. The proverbs describe the two types of doctors: one related to divinity and psychotherapy and the other the herbalist (Ojoade, 1992). They describe the levels of prestige and describe the standards of behavior. They describe issues related to fees, types of treatment, ingredients, and patients (Ojoade, 1992). They address types of health, illnesses, and prevention (Ojoade, 1992). They relate to incurable conditions like madness and leprosy (Ojoade, 1992). Other issues such as divination and sacrifice are also components of the proverbs that describe the health of an individual (Ojoade, 1992). The proverbs tell stories about how the health of an individual is cared for and maintained by the medical professional of the community. The author concludes that there must be some efficacy, otherwise a given treatment would be discarded if it wasn't effective (Ojoade, 1992). In fact, the efficacy was such that some treatments were not abandoned after western practices were introduced. Sculpted artifacts and storytelling in the oral tradition were used in conjunction with knowledge of chemistry and botany.

In looking at all these examples of art and science integration, it seems safe to state that in the ancient world the union of form and function was the basis of this integration. The path of progression and development seems that form followed function and expression followed form. The expression was the culturally based communication of thoughts, feelings, and emotions. The union of art and science resulted in culturally relevant solutions to practical problems in such a way that the solution also communicated meaning. It also seems reasonable that the idea of problem solving in a way that conveys cultural meaning could be the foundation behind a historically based conceptualization of STEAM.

The Bifurcation of Arts and Sciences

The second part of this literature review will look at the ideas and conditions that led to the separation of the arts and sciences. The factors that led to the separation of art and science are very important to understand to determine if a reunion of arts and science is something that could be sustainable or not.

Specialization. Specialization in both the evolution of society as well as in the evolution of science has contributed to the focus on one set of skills abilities at the expense of another. In the below section the role of specialization in society in separating art and science will be presented. Specialization due to the evolution of science will be treated separately in the following section.

Blacksmiths in 19th Zamfara (northern Nigeria) were involved in all aspects of ironwork from finding iron ore (Abubaker, 1992) to making and running the furnace (Abubaker, 1992) to making tools like hoes, gates and weapons (Abubaker, 1992). Besides iron, other metals were worked. These metals were used to create adornments. Working with metals other than iron is typically done by whitesmiths. Whitesmithing was evident in Zamfara c. 1762 (Abubaker, 1992). Originally, whitesmithing was done by blacksmiths who were experimenting with various other metals. Due to demand, specialization arose in smithing. It was done by either blacksmiths who transitioned to whitesmithing exclusively or professional whitesmiths who were brought in from other lands (Abubaker, 1992, p. 70). The jewelry created by these smiths were earrings, armlets, anklets, rings for hands and feet and necklaces. They worked in gold, silver, copper, brass and bronze (Abubaker, 1992, p. 69). By the 18th century the whitesmiths had become members of the blacksmith guilds.

Demand caused the art and science of glassmaking to separate in Nupeland, Nigeria. The glass was created out of raw materials. It was then passed to other glass makers who created the finished product (Thomas-Emeagwali & Idrees, 1992). The original skill of glassmaking was passed to Nupeland from Egypt; acknowledged as virtually the worldwide origin of the skill (Thomas-Emeagwali & Idrees, 1992). In creating the glass from raw materials, the proper materials were acquired and processed for use in the glass furnace. This semi-processed glass was called ‘bikini’ by residents in the city of Bida in Nupeland (Thomas-Emeagwali & Idrees, 1992). The bikini was then sent to workshops where the creation of the glass products was performed. The glass was used for glaze and faience (Thomas-Emeagwali & Idrees) as well as made into beads that adorned items such as armlets and head-dresses (Thomas-Emeagwali & Idrees, 1992). The specialization of the process of making glass and the process of working glass meant that the chemistry was primarily separated from the artistry. While there was chemistry evident in the form of manipulating physical properties associated with the artistry of glasswork, the manipulation of the chemical properties that produced the glass were separated from the artistry.

Societal Pressures. In Islam between the second and eighth centuries, knowledge was not compartmentalized, Muslim religious scientists also conducted empirical scientific research and experimentation (Chapra, 2008). Ettinghausen & Grabar (1987) have identified that artforms such as architecture and calligraphy were integral components of Islamic life.

The primary caused for the separation of science and art within Islamic religion was the instillation of resentment and animosity in the population by the rationalists who were the proponents of science and philosophy (Chapra, 2008). The rationalist had engaged in a deep debate with the conservatives, who were religious scholars. The debate centered around the nature and attributes of God. The rationalists felt that logic and reason were necessary to understand God while the conservatives felt that the Qur'an provided all the information necessary.

During this time, the rationalists were supported in large part by the ‘Abbasid dynasty (750-1240 AD). As they were the patrons of the rich and powerful, they were able to use force to make people adhere to their perspectives (Chapra, 2008). Beheadings and death by torture awaited those who didn't conform. The torture and brutality employed made the people cautious of the rationalists and drove them to the conservatives (Chapra, 2008). The rationalist inquisition had concluded by 849 AD (Chapra, 2008). By about 943 AD the conservatives began to ascend in their debate with the rationalists. In 1095 a conservative scholar, Al-Ghazali, authored a book which virtually destroyed the positions of the more extreme rationalists, who were at the forefront of the violence inflicted (Chapra, 2008). While he did not reject out of hand the principles of physical science, his work permitted the extreme conservatives to further weaken the ideas of rationalism and scientific inquiry.

The last great effort to revive the ideas of the rationalists occurred in 1180 AD (Chapra, 2008). The author, Ibn Rushd, attempted to use logic and reason to reconcile the rationalist and conservative perspectives by arguing, among other things, that cause and effect were still legitimate concepts in that God was the ultimate cause of everything (Chapra, 2008). Nevertheless, the conservative movement, in the form of the Ash'arite, became the dominant perspective and has remained so into the 21st century (Chapra, 2008). This has translated into greater rigidity in the conservative perspective, the reduction in tolerance for debate of alternate perspectives (Chapra, 2008) and the exclusion of philosophy and physical sciences from the instruction in religious schools. Science education didn't return to the Muslim world in a meaningful way until after colonization (Chapra, 2008). Thus, while art and architecture flourished, science was repressed.

Hoffman (1996) identifies the schism between art and science in Europe as having its origin during the Age of Reason (1685 – 1815). During this time science became ascendant and was used as the basis for making decisions that the author considered as 'real' or 'hard.' Mortier (1994) describes the year 1760 as the date when there was a shift in attitudes with respect to art and science. Prior to 1760 art was seen as a mechanism for exulting nobility, royalty, and the church. After 1760, the perspective of science gained ascendancy. Nature was no longer an object of emulation for its value of scenery or setting (Mortier (1994). It was seen as a resource that could be exploited for the benefit of improving human quality of life and efficiency of labor. The change in social perspective was promulgated by the thinking of utilitarian philosophers and the ascendance of empiricism. The year 1760 connects the Age of Reason, the Industrial revolution (1760-1840) and the separation of art and science.

Karen De Bruin (2015) also discussed the separation of arts and science in developing her argument for the importance of the arts and humanities as cultural guideposts. De Bruin's premise is that the definition of progress relies too much on ideas that are related to business and economic security. They in turn are related to advances and advantages proffered by STEM disciplines. To explain why this schism between the arts and sciences occurred and why it is bad for society, she begins with the forces that drove arts and sciences apart. Like Hoffman (1996), she traces the beginning to the European Enlightenment (aka the Age of Reason). As her foundation for building and expanding her argument, she uses the writings of French Philosopher Germaine de Staël (1765-1817). It is worthwhile to note her life spanned a large part of the Industrial Revolution. As a reference point, De Bruin (2015) uses the Jesuit middle schools. Between the early seventeenth century and the beginning of the eighteenth-century, teaching shifted from emulating the ancients of all disciplines for the purpose of learning their values to a focus on scientific inquiry and empirical knowledge. Values related to personal morals and contributions to the public good were supplanted by public utility. Focus shifted from improvement of self to improvement of the system. This shift, in part, was due to new ideas around the progress of society and humanity. De Bruin (2015) describes three camps of philosophy related to the idea of progress and perfecting the human condition. The first two camps posited that knowledge and inquiry were the keys to perfecting the human condition and that reason would be the governing force that civilized passions. Their only difference is in the assumption of whether nature (and therefore humanity) will always naturally tend towards good or whether society needed reason to guide it constantly towards good. The third camp felt that cultivation of the consciousness and the acquisition of knowledge were more important aspirations than the perfection of humanity. They felt that without cultivation of consciousness "progress...leads inevitably to materialism, and increased greed, selfishness, vanity, and deception..." The schism then becomes the result of advocacy, or the lack thereof. Proponents of science, knowledge and reason vigorously promoted the first two philosophies. Yet, the third camp was not as vigorously promoted. De Bruin (2015) returns to the work of Germaine de Staël, who resided in the third camp, as a guide. De Br Bruin (2015) represents de Staël as seeing cultivation of consciousness as the province of arts and literature. De Bruin (2015) writes "Over the centuries, according to de Staël, the philosophical education provided by literature, and by extension the arts, influence public opinion and political thinking, thereby progressively pushing public morality..." The point is that cultivation of consciousness involves issues of morality and justice which were not seen as central to empirical knowledge and scientific inquiry. Yet De Bruin (2015) indicated she interprets de Staël to state "Rather than progress at pace with the physical and political sciences...Enlightenment art and literature reverted back to classical models of morality..." Thus, science ascended while arts and humanities stagnated.

Class Issues. Zilsel (2000) describes three classes of intellectuals: those in the universities, the humanists, and the laborers. While he describes the rationality of the three groups, he argues that the form of rationality of the laborers is more suited to both capitalism and science than the other two. He states the scholars and educators possess a rationale that is suited to the processes of classification and distinction (Zilsel, E., 2000). The group he classifies as laborers; tradesmen, craftsmen and engineers, are concerned with the rationale of calculating, estimating, causation and physical laws (Zilsel, E., 2000).

While these distinctions were in effect during the European Renaissance, the classification of the artists was evolving. Initially part of the mechanical arts, they fought to be included in the upper-class liberal artists. In the 14th century artists were in the category of craftsman (Zilsel, E., 2000). This transition was accomplished in Italy by the end of the sixteenth century (Zilsel, E., 2000).

Zilsel (2000) describes the “fathers of humanism” as the officials who carried out the affairs of state for the medieval princes and the pope. As time progressed these humanists, especially in Italy, lost their political or official roles and became the literati. Their livelihood depended on the princes, nobles, and bankers as patrons. They would become writers and teachers of the elites. They prided themselves on memory and learning. The way they achieved fame was through their writings and through making their patrons look good (Zilsel, E., 2000). The rationale of the humanists was related to literature and classical scholarship (Zilsel, E., 2000). Zilsel (2000) breaks the classes into two groups: the liberal artists and the mechanical artists. The humanists and the scholars were the liberal artists (literati) and those who made a living with their hands were the mechanical artists (Zilsel, E., 2000). “Both, therefore, adopted the ancient distinction between liberal and mechanical arts: only professions which do not require a manual work were considered by them, their patrons, and the public to be worthy of well-bred men” (Zilsel, E., 2000).

Capitalism. Capitalism produced many, long term effects within Western civilization and around the world. Three important impacts were a repressive effect on arts, a buoying, but restricting effect on sciences and the introduction of systemic injustice. Fueled by the Industrial

Revolution, capitalism favored unscientific yet profitable endeavors and normalized human rights violations. However, since science requires manual labor and working with devices, there is an argument that capitalism's association with slave labor inhibited the growth of science. Specifically, slave labor was considered cheaper than investing in, and creating machines plus the slaves were felt to be incapable and untrustworthy to use machines (Zilsel, 2000).

Capitalism was born in the towns where the people were, not with the nobles and clergymen. This and the opinion that science is 'worldly and not military' is given as the reason that capitalism and science developed together among the townspeople (Zilsel, 2000). Capitalism lent itself to the individual and entrepreneurial spirit that encouraged innovation and scientific thinking (Zilsel, 2000). The ability to be critical is key to scientific thinking and Zilsel (2000) argues that being critical cannot exist in a society bereft of the existence of economic competition. Zilsel (1942) credits the growth of quantitative methods, at the heart of empiricism, with the advent of capitalism and the concomitant need to quantify and evaluate. Porter (2009) goes further to relate there are those who believe capitalism would not be possible without the appropriation of scientific and other technical expertise.

Poetry and philosophy were the stock and trade of the literati. Yet, as capitalism demanded more innovation, the empiricists became more advanced, and the literati became less able to comment knowledgably on technical work. This was causally related to the fact that sciences such as physics demanded a level of mathematical skill that existed in a dwindling few of the literati (Eichner, 1994). The capitalists found STEM disciplines were more profitable. Bookkeeping and mathematics, considered manual arts, were part of the capitalists' toolkit (Zilsel, 2000). Authors such as Rousseau reframed ideas concerning the acceptability of manual labor (Mortier, 1994). Engineers and architects were promoted (Mortier, 1994). Natural resources were acquired and consumed at vigorous pace (Dawson and Lightman, 2011). Engineers and architects built bridges, tunnels, railway systems and machines. The unearthing of fossils and the like sparked greater interest in science.

Visual arts were useful for the capitalist to visualize his businesses. Artists were commissioned to recreate images of the workshops and factories owned by capitalists to document their enterprises. Visual art in capitalism was limited to drawings and diagrams. Moreover, the images also acted as propaganda to hide the true horrors of capitalism behind the façade of clean, efficient workplaces where work was done by happy, smiling faces (Mortier, 1994). Visual artists were also employed in creating high quality portraits of various scientists. During the 1700's artists were creating scientifically accurate high-quality images for important figures such as Diderot (Mortier, 1994). As capitalism grew and evolved, visual art became more of a servant to sciences in the employ of capitalism. Artists who understood science were able to have success as designers of devices used to teach science. In 1750's France, sciences were taught to upper class members, more often women than men. The devices used were of high quality and served as more than instructional aids; they were imbued with beauty (Mortier 1994).

Dewey (1934) indicates that capitalism had a negative effect on art in other ways. Endogenous art was collected by capitalists, typically the nouveau riche. The aim was to hoard and display art for the purpose of personal aggrandizement. The effect was to separate the art from its functional role in society as a vibrant part of the lived experience of the masses. Moreover, the spending of money by these capitalists for philanthropic and tax purposes created artificial demand for art that was not part of the society because it was not evolved out of the society; it was funded and directed for the purpose of personal interest and advantage (Dewey, 1934). Thus, bereft of its functional capability, the artifact no longer combined art and science.

The negative impact of capitalism cannot be overstated. African slavery was at the heart of this capitalist expansion. The poets and philosophers of the time provided the intellectual justifications for the slave trade. Philosophy and poetry were not clearly defined as different from empiricism (the term scientist did not arrive until 1833). Enlightenment writers like Kant and Blumenbach advanced a pseudo-scientific rationale that classified Africans as inferior to Europeans (Bouie, 2018). Racism emerged as a methodology, the embodiment of the ideals and precepts of white supremacy. John Locke not only was an early advocate of racism and a profiteer from the slave trade, but also wrote legislation that ended the practice of granting freedom to slaves who converted to Christianity, thus making slavery a permanent state of existence (Bouie, 2018). In Africa, the slave trade drastically curtailed the pursuit of arts and science. In the colonies, African art and science was aggressively prohibited, especially learning to read, write or perform mathematics, which was punishable by death. To this day, there is no tradition of African drums, arts, or sciences in the United States. In coastal West Africa, kidnap, invasions, and war precluded much attention to advancing art and science. In the colonies, practices akin to genocide prevented focus on little else but survival. According to Zilsel (1942), the development of science was delayed because the capitalists were focused on maintaining the slave trade, which disincentivized the development of science. Slavery was more profitable than using a STEM related solution.

In Europe, while some arts such as music and drama were little impacted other than perhaps an increase of bourgeois patrons, things were different for the literati and the visual artists. Capitalism created a patron system that treated artists like they were any other expendable worker. Visual arts found low demand for what we would call editorial work. They were essentially commissioned to perform in the service of the sciences that helped fuel capitalism.

For the literati, capitalism was even more impactful. The literati struggled to define a role for science in their philosophies and writings well into the Victorian era (Dawson and Lightman, 2011). Some argue there was a bit of envy of the clearly defined methods, standards of evidence and precision displayed by the empiricists (Eichner, 1994). Losing the patronage of the evaporating feudal class, they had little to offer the ascending capitalists, who already had their record keepers and mathematicians (Zilsel, 1942). They had to seek a living in new ways, such as university appointments.

Foreign Invasion. Eighteenth century theft of African artifacts by the Europeans created an artificial separation of arts and science. As groups like the French stole from Africa everything that wasn't nailed down (and some things that were), they couldn't take examples of vernacular architecture. Therefore, they would remove architectural components from buildings and structures. They would then reclassify those pilfered items as sculptures (Prussin, L., 1974). This removed all aspects of its functional purpose.

Invasion was another reason for the separation of art and science. Dewey (1934) stated it resulted in the sequestering of art into museums and galleries by European powers. He notes that most art in European capitals is either art that was stolen during wars of conquest or endogenous art nationalized by the rulers of the nation state. These museums and galleries were places where the rulers could showcase their artistic heritage and military prowess through the spoils of their thievery. However, this activity also separated the artworks from the societies that produced them. This meant that the functional role they played in society was divorced from the artistic role.

The evolution of science. Zilsel (2000) argues that the emergence of fully developed science occurred only in modern western civilization (Zilsel, E., 2000). The emergence of modern science is concurrent with the initial appearance of capitalism (Zilsel, E., 2000). It is therefore predictable that the evolution of science, like capitalism, played a significant role in the cleaving apart the union of art and science in western civilization.

Emotional content. As science became established and evolved, the role of emotion in science became distinct from the role of emotion in the arts. During the period overlapping the end of the Age of Enlightenment and the beginning of the Victorian Era science was not clearly distinct from literature (Dawson & Lightman, 2011). However, by the end of the Victorian Era some differences had become evident.

One distinction is with respect to the role of emotion in the processes of art and science. Processes in science can be so bereft of emotion they can, and typically are, represented by an algorithm. On the other hand, emotional content is indispensable to the artistic process (Goodwin, 1998). Anything created by an artist will have emotional content, and you don't need specialized knowledge to pick up on emotional content. Someone who walks into an artist's studio and looks at a painting, or a sculpture, or listens to a couple bars of music can appreciate the beauty because the method of exchange and communication is on an emotional level. This is because the sensation of pleasure received from art is felt, not just observed, or acknowledged. This physiological pleasure is what has been argued to be a form of emotional content that is not shared with science (Goodwin, 1998). As science evolved, factors such as quantification, expertise, and objectivity all worked to suppress the emotional content that is critical to artistic modes of communication. Factors that reduced the emotional content of science make it more and more difficult for arts and science to speak the same language.

Quantification. The development and expansion of technology during the end of the Dark Ages not only supported the emergence of mechanics and chemistry, but also led to more causal thinking (Zilsel, E., 2000). Zilsel (2000) identifies feudalism as governed by custom and tradition while capitalism is governed by rationality. This rationality led to the use of machines, mathematics in bookkeeping, quantitative methods, and rationality in the form of the scientific method. The author states that during the fifteenth and sixteenth centuries, mathematical writing was foremost concerned about economic applications and secondarily about military, construction, and artistic applications (Zilsel, E., 2000). As science evolved, adherents to quantitative thinking indicated the ideas of impersonality, communicability, and impartiality, all of which led to a reduction of emotional content, as benefits to be inculcated, despite impersonality and impartiality not necessarily being part of quantification (Daston, 1995). Quantification also has the effect of congealing consensus (Daston, 1995); we all agree that one plus one equals two. This further increased the ability of scientists to communicate in one language.

Technical Specialization. As science increasingly specialized, it became less and less accessible to the general public, including the artists. The use of mathematics to explain science has been identified as a primary reason for sciences becoming both specialized and remote from the general population since the Age of Enlightenment.

In science, technicality and expertise are directly related in that as one develops more and more expertise, their technical repertoire becomes more specialized. To be technical means to rely on a set of concepts and vocabulary only a subset of the population understands and utilizes (Porter, 2009). Naturally, this separation will divide artists and STEM professionals. Theodore Porter (2009) points out that the necessity of scientific literacy, mathematical proficiency and competency in scientific skills have resulted in making science the specialized technical profession it has evolved into. Although not mandated, the increase in expertise reduces the audience of science from the laity to peers, not only scientific peers, but often exclusively to peers from within the same area of expertise. The reduction and redefinition of the audience was driven by the proliferation of technical terms and concepts that were utilized in the STEM fields. Some have argued that part of the reason for this increase in technical aspects of STEM disciplines was to restrict the access to knowledge, as was the case in guilds and the legal and medical professions (Porter, 2009). Indeed, many experts like Laplace, whose methods are typically studied in modern courses on solving differential equations, were identified as wanting to maintain the exclusivity of mathematical understanding (Porter, 2009). But there were others who felt technical knowledge should be seen as valuable to the public. Porter (2009) notes that there several individuals who felt science shouldn't automatically be reserved for the specialists. In engineering, for example, there were those who sought to be more open and make the knowledge more accessible (Porter, 2009). Nevertheless, the use of technical terms, practices and concepts required students of these fields to acquire specialized knowledge that the general public and artists in particular, often found dispensable.

In addition to the adoption of specialized skills, concepts and vocabulary, specialization arose from the division of labor. Daston (1992) notes that as science grew in scope and skill, the pool of competent labor was not deep enough. Therefore, skill sets were divided into smaller and smaller groupings of laborers. This assisted in guaranteeing even lowly trained workers could report accurate and reliable observations. Although Daston (1995) that the more experimental design was carried out by the scientist, even the laborer whose job it was to carry out the experiments and document the results obtained specialized the roles, even within the scientific investigation itself.

The forces that drive specialization in science seem not to abate, but to intensify in the soon and distance future. Coccia (2020) uses four terms that describe what he believes drive specialization in science; (a) *scientific fission*, the splitting of an existing discipline into two or more disciplines; (b) *ambidextrous drivers of science,* the creation of new scientific disciplines due to either new scientific discoveries or the creation of new technology; (c) *higher growth rates of the scientific production*, newer areas of research generate more new information than older areas; (d) *average duration of the growth phase of scientific production,* on average a new phase of scientific production begins every 80 years. Taken together, these forces will continue to produce new areas of study and specialization for the foreseeable future.

Objectivity. The concept of objectivity in science greatly assisted in the separation of art and science because objectively typically implied a constraint or suppression of emotional content. The practice of objectivity was manifested from different directions to pursue a plausible common goal; to achieve consistency in the communication and transfer of scientific knowledge. Yet the removal of emotional content became a casualty in scientific evolution.

Two types of objectivity rise in relevance above all others, mechanical and aperspectival objectivity. Mechanical objectivity is an objectivity borne of scientific instruments being used to make observations. Using a scale removes the differences in skill regarding the ability to estimate weight. Instruments did not have agendas or predilections; they simply reported the observation in a quantifiable manner understood by all. Mechanical objectivity removes the human element in the observation of the phenomena (Daston, 1995). Specifically, Daston (1995, 21) notes that mechanical objectivity does away with the desire to aestheticize, among other human tendencies. This also removes the scientist from commonality with artist, whose stock and trade is guided by aesthetics.

Aperspectival objectivity seeks to remove influences in the observations of phenomena that are particular to the person conducting the scientific investigation. Think of the 60's song *Secret Agent Man* made famous by Johnny Rivers, specifically the line "they've given you a number, and taken away your name." Aperspectival objectivity seeks to provide a standardized, unadulterated report of observations that can be had regardless of individual skill or abilities (Daston,1995). This attitude places artists, who are very personally invested in their work, at a diametrically opposite position to the aperspectival scientist, some of whom felt that there should be no indication of the individual scientist conducting the investigation. In fact, some scientists, like Claude Bernard contrasted the artists and scientists by implying the artists were all about "I" while the scientists were all about "Us" (Daston, 1995). This attitude is still evident today, with students in science classes being taught to write reports in a passive voice, never referring to themselves but only stating what was done, and what had happened.

Philosophical Differences. Ramachandran and Hirstein (1999) stated that the purpose of art is not to simply show the world and the phenomena in it as they exist. They argue that the purpose of art is to distort reality to gain new perspectives. This is at odds with the belief in the passionless, emotionless objective representation of reality found in science. An instance of this debate between artists and scientists in the project described by Arcadias and Corbet (2015) focused on how far they should stray from an accurate portrayal of stellar images when creating artistic representations.

Generational Gaps. Chandrashekar (1987) contrasted the creativity of scientists versus the creativity of artists. He used as his examples Beethoven, Shakespeare and to the lesser extend Shelly. When discussing the creativity of scientists, he talked about Isaac Newton Albert Einstein and James Maxwell. One thing that he noticed, was that artist tend to enjoy their greatest creativity, producing their masterful works at the later part of their age while scientist tend to have their flashes of genius during their early years, specifically between their 20s and 30s. He noted that while a scientist's greatest contributions tend to be associated with the ideas and work and this work tends to be his best efforts when young; for artists, their work is divided into early, middle, and late periods.

Aesthetic Appreciation. One key to understanding the difference between the artist and scientist is connected to how the audience can share in the given discipline's understanding of their aesthetic. As science evolved, its aesthetic became more abstract. The layman in the audience does not need special understanding to appreciate the beauty of the artist as opposed to the beauty of the scientist. Chandrasekhar (1987) notes that Kepler compared the beauty of the revolution of the planets to the beauty discovered by Pythagoras in the harmonious vibration of strings under equal tension and with their lengths in simple numerical ratios of each other. The beauty discovered by Kepler is much more abstract, to be aware of the symmetry and harmony one would need specific specialized knowledge of mathematics and the ability to visualize the motion of all the planets in their orbits. On the other hand, a layman would not require knowledge of harmonics, tension, and frequency to appreciate the unity of tonality found in the vibrating strings that Pythagoras investigated. While specialized knowledge and understanding would expand or highlight or increase the appreciation of beauty in both the case of Kepler and Pythagoras, that specialized knowledge is necessary to see the beauty of Kepler whereas it is not necessary to appreciate the beauty articulated by Pythagoras. I feel this is one of the great differences between beauty in science and beauty in art. Chandrasekhar (1987) relates Boltzmann's description of the beauty he found within Maxwell's equations on electromagnetics, yet, without knowledge of either electromagnetics and differential or integral calculus it is difficult to share appreciation of the aesthetic. Without question, the role of the audience is of vital importance in the expression of artistic endeavor. The need for specialized knowledge in science to appreciate the scientific aesthetic is arguably one of the reasons why science does not often translate its beauty into the general audience.

While it is obvious there was no 'one' reason for the separation of art and science, specialization, capitalism and the evolution of science seem the most relevant. Of the three specialization seems the most significant obstacle. Capitalism will be the dominant socio-economic structure for the foreseeable future. Yet it can change if change is profitable or forced. In fact, the forces to create STEAM could be seen as capitalism's adjustment to address the need for innovation, and the tens of millions of dollars spent on STEAM is the evidence of that change. The STEM disciplines will always grow and evolve, splintering into more and more specialized pathways, each manifesting its own aesthetic. I feel one of the key reasons the evolution of science led to the separation of art and science is because as science developed, it created its own aesthetic. If science is to be taken as a social construct, then it makes sense that it would create an aesthetic outside of the general social construct that holds society together. If you are not indoctrinated into the scientific social construct, it will be difficult for you to appreciate the aesthetic.

Themes in the implementation of STEAM

The third section will look at contemporary examples of collaboration between STEM and the arts. It will be useful to organize projects in order to identify characteristics common to STEAM projects. This information will be helpful in informing potential policy recommendations with respect to establishing STEAM programs. Identifiable trends will assist in developing and establishing variables with which to conduct research. Finally, I seek to understand the ways that arts and science are combined to assist in the overall evaluation of their prospects for sustainability.

Aesthetics. Turkka, et al. (2017) point out that emotion, critical in art experience and appreciation is also a bridge between art and science integration. They assert their commonality lies in the study of aesthetics. Furthermore, Bullot et al. (2017) introduce the role that philosophical theory has had on artistic and scientific innovation. They discuss how aesthetic ideas influenced the beliefs of scientists as they investigated natural phenomena. They specifically note ideas of simplicity, symmetry, proportion, and coherence as having an impact on decisions made by scientists. Chandrashekar (1987) notes that several scientists, upon trying to decide about the direction an investigation should proceed, chose beauty over truth as a guide. Aesthetics are an important consideration because if STEAM is to organically develop from STEM, then a foundation for that development must be established within STEM. It stands to reason that a STEM aesthetic should be the foundation for artistic expression in STEM. If STEAM is to be created through the collaboration of art and science, then such a STEAM foundation in STEM would be helpful but perhaps not necessary. After all, it seems safe to assume that the artists who are part of the collaboration will, in most cases, provide a wealth of information regarding art and aesthetics.

A first question to ask if we plan to cultivate STEAM from within STEM is what is the artistic or aesthetic basis in STEM for STEAM? Girod (2007) identifies four aesthetic themes in science that, taken together, could establish a foundation for such a cultivation. The four themes are (1) Intellectual beauty: beauty in ideas and their form, (2) Beauty in wonder and awe: beauty in the sublime, (3) Beauty as truth: beauty as God’s design revealed and (4) Beauty in experience: beauty in seeing and being anew. Girod (2007) combines the philosophical understanding of beauty with the expressions of scientists regarding the beauty they found in their work. For example, he quotes Ernest Rutherford describing the theories of Maxwell and Einstein as works of art to exemplify intellectual beauty. He then organized these understandings and expressions into themes. While adopting these themes as the pillars of organic STEAM it must be clearly acknowledged, as Girod (2007) notes, there is no denying there could be other formulations.

As opposed to the analysis of the things made or created by science such as tools and artifacts, Girod (2007) relies on the 18th century aesthetic theory of Francis Hutcheson to elaborate on the idea of intellectual beauty. As is applied by Girod (2007), intellectual beauty is comprised of three levels of abstraction. The first level is that of recognizing the beauty of objects studied in the natural world. The beauty of items like images of the stars require no special scientific skills to appreciate. The next level of abstraction requires a level of scientific knowledge. One must understand and analyze scientific concepts and apply them to natural phenomena. To appreciate the beauty in the motion of the stars or how changes in the Earth's crust provide us beautiful vistas, we need specific knowledge and developed skills. The third level is the most abstract and encompasses appreciation of the beauty and elegance found in both scientific theories and mathematical expressions. One should be able to synthesize and evaluate information on natural phenomena to create new understandings, insights and appreciations that allow for prediction of future outcomes. Taken together, they describe a scientific basis for an intellectual appreciation of beauty. Implicit in this understanding is the existence of a relationship between the object and observer. According to Girod (2007), Hutchinson states this is the intersection that creates beauty, the object, the aesthetic and cognitive perceptions of those properties in the object. While the artistic aesthetic retained the emotional content, scientific aesthetic relies on intellectual understanding as opposed to sensation and impression to provide emotional engagement (Goodwin and Briggs, 1998). Chandrasekhar (1987) echoes this sentiment and used several examples of scientists describing their emotional engagement with the scientific aesthetic to further the point. In his examples, intellectual comprehension preceded emotional expression (which was often done poetically). Both the artist and the scientist pursue truth and beauty, but the scientist pursues it from intellectual perspective and can appreciate beauty in an abstract sense without emotional content. The emotional content is there if the scientist has the specialized knowledge to appreciate abstract beauty. While not stating this directly, quoting Einstein stating that the magic of the general theory of relativity is obvious to anyone who comprehends the theory implies the need for that comprehension to have the aesthetic appreciation (Chandrasekhar, 1987).

The second theme in aesthetics in science is described as the beauty of the sublime; the beauty found in the incredibly large, in the incredibly small and in the incomprehensible. The quality that is consistent in this aesthetic is the ability to astonish. The author borrows from German philosopher Immanual Kant’s categories of the sublime to focus this theme. Girod (2007) reports them as: 1) the mathematical sublime and 2) the dynamical sublime. The mathematical sublime encompasses the vastly large and the vastly small. This aesthetic is reflected in awe and wonder experienced by investigators who work to comprehend events in both the microscopic and macroscopic ranges. The dynamical sublime refers to the humbling experience of coming face to face with the overwhelming power of natural phenomena. In assessing why Einstein’s general theory of relativity exhibits an aesthetic from a scientific perspective, Chandrasekhar (1987) applies a criterion for beauty that parallels Girod’s (2007) beauty of the sublime. His criterion was presented in two parts. The first was influenced by

Francis Bacon, a beauty that possesses the ability to demonstrate an exceptionality that incites amazement. This compares very well with the dynamical sublime articulated by Girod (2007). The general theory of relativity demonstrates this beauty in several ways. (Chandrasekhar, 1987). First, it combines space and time, which were previously viewed as independent concepts. This achievement created a far-reaching change in the thinking of physicists worldwide. Another aspect that was overwhelming was the precision obtained by Einstein, accomplished by a combination of insightful conceptual understanding of the involved physics and his exceptional mathematical proficiency (Chandrasekhar, 1987). Einstein developed an exact theory as opposed to a theory that allowed for variations while this is included as a component of the four themes; it is noted to be more peripheral than other themes (Girod, 2007). However, considering Chandrasekhar's (1987) application of this aesthetic, perhaps it need not necessarily be considered peripheral.

The third theme is the idea of the scientist receiving an opportunity to gain insights into the grand workings of the universe as initiated by God, the creator of truth and beauty. Understanding the universe for what it really is represents the revelation of beauty in truth. Girod used the Kepler's laws of planetary motion and the idea of archetypes as espoused by Swiss psychiatrist and psychoanalyst C.G. Jung to describe mathematics as providing the archetypes of celestial motion. The author combines the pursuit of Einstein for a grand unifying theory and his notion epitomized in the well-known phrase "God does not play dice with the universe" to parallel his ideas of space, time, matter, and energy with the archetypical elements of creation, fire, earth, water, and air. Girod (2007) combines these ideas and the reflections of scientists to surmise that the idea of the beauty of God's plan and the revelation of this truth is a guiding force in science and scientific inquiry.

The fourth theme is that of one who has been enlightened and now sees the world differently. Once you have gained scientific insights, you are able to see everyday objects and events from a scientific perspective. This, in turn, changes your outlook with respect to your environment. To develop this theme, the Girod (2007) turns to the perspectives of American philosopher and educator John Dewey. He relates that Dewey connected artwork to the real-world experiences of the observer to create what Dewey called 'an experience,' as opposed to our ordinary, everyday experiences. According to Girod (2007), Dewey distinguished 'an experience' from an ordinary experience by the presence of several qualities which defined the existence of 'an experience.' These qualities specifically included: 1) the fusion or intermingling of thought, emotion, and action; 2) the expansion of one's perception literally creating new ways of seeing the world, and 3) an increased feeling of value for this newfound perspective (Girod, 2007). Phenomena as simple as the burning of wood are viewed from a deeper level of understanding and appreciation once they are seen through the lens of scientific knowledge and inquiry. In response to Girod (2007) asking us to reflect on our own moments of revelation, I think back to one year of calculus. I went home and saw the bowl I had seen my mother use so many times to make cake mixes. I didn't see a bowl; I saw a paraboloid! This theme embodies the transformative power of the aesthetic experience which has scientific ideas as the driving force behind the object or idea produced.

These four themes establish a philosophical conceptual framework for cultivating STEAM from STEM. It encompasses all the components of art and aesthetics as established by well-respected voices in the field. Additionally, it uses the perspectives of scientists in that it is based on how scientists describe their work from an art and aesthetic orientation.

Stepping back, one can ask where do the current efforts in academia and industry leave the idea of STEM to STEAM? Hoffman (1996) curiously poses the question of whether arts and sciences should be reconnected “like trying to force into re-marriage a pair who have been irreconcilably sundered and have been traveling down utterly divergent paths.” He proposed as an alternative the idea of science and art as an integral discipline as practiced by Johann Goethe. As opposed to the purely quantitative work of scientists such as Isaac Newton, the work of Goethe is presented as a holistic approach to understanding natural phenomena. Art and science are combined to produce an understanding that is a sum greater than the parts. The transcendent aspect of the presentation is that there is a philosophical understanding of the union of art and science, of form and function. From this awareness comes a greater appreciation of the natural world. Ultimately, this would lead to an effort by STEM related professionals to ensure their creations exist in harmony with the natural world. This means that for there to be STEAM from within STEM there must be a fundamental change in scientific thought. Fortunately, this change has precedents. When an artist completes a work, up to that point, the artist, much like the scientist, is focused on a product that has integrity and validity. However, with the artist, the audience for the result of their labor is considered as part of the process. The audience does not become privy to the work until the artist is prepared to share it. There are many examples of artists who complete works and locked them in vaults, backrooms, closets, or otherwise never let their work see the light of day. Likewise, the scientist can also objectively focus on works that have integrity and validity and share them with an audience upon completion. The key differences in the new paradigm will be that firstly, the scientist will keep the audience in mind throughout the process as is appropriate and secondly, will expand their audience to include the layperson as well as their colleagues and scientific peers. The addition of cultural relevance and meaning, baked into the results of scientific processes, will be the key to bringing out the beauty within the scientific discoveries. The more culturally relevant the meaning, the more readily the lay audience will connect with science. While this may seem a monumental task for scientists who are typically characterized as being nerds, lacking people skills or downright antisocial, there are many examples of how this can be accomplished, as in the following.

Transdisciplinary Teaching. A hallmark of STEAM programs is the integration of various disciplines. It is informative to explore the ideas behind combining diverse disciplines. Although I call this transdisciplinary, I will also include multidisciplinary and interdisciplinary programs as well. The reason for this is regardless of whether they become transdisciplinary programs, several disciplines combining for knowledge creation is the ideal goal. Constantino (2018) argues for problem-based transdisciplinary curriculum as an impetus for STEAM. She argues that transdisciplinary methods naturally lend themselves to developing multiple perspectives. Katz-Buonincontro (2018) looks to the work of Costantino (2018) for guidance in developing a model for developing STEAM pedagogy. Constantino (2018) advocates for STEAM to be presented in the higher ed environment as opposed to the preK-12 format because it allows for flexibility in developing transdisciplinary curriculum. The preK-12 setting is considered by Constantino (2018) to be too restricted by local, state, and federal mandates to accommodate transdisciplinary instruction. Liao (2016), working with undergraduate elementary education students, discussed the idea of transdisciplinary pedagogy by advocating discipline integration as a natural framework for STEAM. She posits that the arts educators who are proponents of arts-integration see a natural connection with the concept of STEM. She notes that arts educators have a long history of promoting interdisciplinary art education and arts integration (Liao, 2016). Senn, McMurtrie and Coleman (2019) argue that interdisciplinary planning is an effective basis for both STEM and STEAM. They advocate for a format utilizing a minimum of three of the disciplines in the interdisciplinary lessons. They advocate that writing across the curriculum should also be included in each lesson. The three-discipline collaboration format has been utilized by Calvert and Schyfer (2017) as well.

According to Bernarduzzi and Albanesi (2015), the overarching guiding principles were provided by Italy's *National Guidelines for the Curricula of Infant Schools, Primary Schools and Lower Secondary Schools*. These divisions approximately correspond to our primary, middle and high school levels. The guidelines mandated interdisciplinarity. The approach that they used was three-fold. The first was narrative; based on language description and storytelling. The second was creative; based on art and its various fields, in addition to media and other forms of communication. The third was an exploration and investigation of the world through the five senses and the interactions of humans with the natural world. The students would visit a specific museum or laboratory, then return to their schools where they researched ideas. With the help of artists and teachers, the students combined the experience with the ideas to create representations of the science principles and experiments. The Finnish national government also mandates the implementation of a multidisciplinary lessons. This requirement of Finnish school systems greatly facilitates the integration of art and science (Turkka, et al., 2017).

Guyotte, Sochacka, Costantino, Walther, and Kellam (2014) describe a design studio that included graduate and undergraduate students from several disciplines: environmental and civil engineering, landscape architecture and art education. Their goal was to investigate the idea of 'synergistic learning' to develop creative problem-solving skills interdisciplinarity. The guiding principle was directing that disciplines are more than juxtapositioned; they need to be intentionally interconnected to enhance the learning process. Their goal was to elevate the collaboration of the various disciplines to the point where boundaries were removed and the collaboration achieved true transdisciplinary synthesis (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014). It was conveyed in a final reflection by one art student that working with STEM students led her to "...develop a deeper understanding-not only of other disciplines, but also of her own" (Guyotte, et al., 2014). Guyotte et al. (2014) also suggests that creativity, if utilized intentionally, could become a vehicle for creating a dialogue across the disciplines. Bequette and Bequette (2012) advocate interdisciplinary work in the arts and sciences to include both aesthetics and analytical modes of thinking. They see this as a way to enhance both arts and sciences. They see cross-disciplinary student learning viable at the Pre-K – 12 grade levels provided arts are seen as part of the culminating result, and not as a vehicle for STEM activities.

There are some issues raised regarding the problems related to transdisciplinary curriculum. Constantino (2018) identifies logistical issues related to coordinating times and locations for the disciplinary experts to collaborate. She also identifies differences in culture, jargon, and methodology as potential barriers to interdisciplinary instruction. These are reasons she advocates for STEAM at the higher educational level. Nevertheless, there is research that shows the STEM gap between demographic groups begins at the pre K-8 level (Assouline, Ihrig, and Mahatmya, 2017, Olszewski-Kubilius, Steenbergen-Hu, Thomson, and Rosen, 2017, Curran, and Kellogg, 2016, Morgan, Farkas, Hillemeier, and Maczuga, 2016, Quinn, and Cooc, 2015, Wascalus, 2015, Valadez, 2010, Bacharach, Baumeister, and Furr, 2003). If one of the goals of STEAM is to attract underrepresented groups, to achieve that goal STEAM programs should begin in the primary grades. There are several examples of STEAM at the pre-K-12 grade levels in this paper to support this strategy. Conversely, if logistics are a concern as a hinderance to the collaboration of arts and sciences, then logistics would be a justification for the organic development of STEAM from within STEM.

As STEAM is an amalgam of technical disciplines, it is only natural that a transdisciplinary approach would be an attractive option. It seems that while there are STEAM programs based in both arts and STEM, STEAM from an arts perspective is where you find the most mention of interdisciplinary activity. The artists seem to feel that one should be purposeful about being interdisciplinary.

Harmony with the Natural World. Watson (2016) hopes that STEAM education will lead to “empathetic and reflective humans.” Several sources were cited by Guyotte et al., (2014) who promoted the idea of STEAM having a social and ecological justice component borne out of social justice goals pursued by both art and engineering. They suggested that the STEAM approach could nurture within students a more holistic, authentic, and dialogic engagement with social and other real-world issues (Guyotte et al., 2014). This idea seems to draw on those presented by both Hoffman (1997) and De Bruin (2015); qualitative understanding must unite with quantitative knowledge. It is significant to note that the project evaluated by Guyotte et al. (2014) was about environmental sustainability. Not only is landscape architecture a discipline that combines art, design and engineering, but it is also a discipline that was noted by Hoffman (1996) as a means to transcend merely fitting in an environment to actually be in tune with the “genus loci, the 'spirit of the place.'”

An aspect that materialized in the ‘Synthetic Aesthetics’ project studied by Calvert and Schyfter (2017) was the constantly high level at which ethics were introduced into the discussions. Calvert and Schyfter (2017) observed issues of ethics were being brought up between the scientists, engineers, designers, and artists, almost always by the artist and designers. The ethical considerations were raised in the form of addressing the hubris of humans who seek control and domination over lifeforms on the planet and in terms of the direction the developments in the field of synthetic biology are heading. The artists were interested in exploring the ambiguities that arise from the engineering of life forms. They felt these issues should be addressed at the beginning of projects so that alternative pathways for the application of emergent knowledge do not go unconsidered.

The idea of harmony with the natural world is a recurrent theme in the efforts to wed arts and science. This belief translated into artists consistently raising questions related to the place of humans in the natural world. A related focus of the STEAM programs was to create students who are more in tune with the natural world. This is envisioned as being accomplished by cultivating a spirit in students that is “holistic, authentic, reflective and empathetic.” Thus sensitized, the student can then demonstrate a perception of the ‘genus loci’ wherever, whenever and however they interact with the natural world. In terms of goals for STEAM such as economic competitiveness, this connection should translate into innovation governed by a desire create sustainable processes, products, and services.

Neurosciences and Aesthetics. I will focus on two perspectives on the use of science to understand the artistic process and experience. The first is the way science has been used as a model for how to analyze art objectively. This understanding of art through the lens of science becomes relevant when it comes to innovation. The objective of practicing STEAM for innovation to acquire economic competitiveness (Maeda, 2012) boils down to creating products and services for retail and business consumption. Characteristics that will make those products and services superior will include appeals and motivations that an artistic perspective can provide. Born and Barry (2010) reinforce this awareness by noting that innovation starts to flag and lack when there is division between art and science. The second is how does the brain respond to art. The second perspective has two subsections; how does art affect scientific cognition and the reverse, how does science impact artistic cognition. In this case, artistic cognition encompasses both how the artistic experience is processed by the brain and how the artistic process is changed by scientific innovation.

Bullot, Seeley and Davies (2017) advocate the existence of “dependence relations” between art and science. They are in direct opposition to the ideas distilled in CP Snow’s *The Two Cultures*. The perspective presented is that the influence of science on art and art on science is a fluid and continuous state of reciprocity. Often, innovation in art leads to an innovation in science and vice versa. Bullot et al. (2017) assert there are a couple ways to use scientific analysis to study the connection between art and science. One way is to review how art and science have interacted throughout history. The second is to assess the ability of science to help us understand art. Specifically, how cognitive science can help us to address questions about the nature of art.

Ramachandran and Hirstein (1999) proposed eight principles that describe how the brain responds to visual art. In each case, the key is that the brain receives a positive or rewarding activation of the visual areas by the art observed. Of the eight, five (peak shift principle, perceptual grouping, perceptual problem solving, abhorrence of unique vantage points and symmetry) are associated with perceptions of objects. The remaining three (isolating a single cue, extraction of contrast, visual puns or metaphors) are associated with discerning objects from their environment or identifying relationships between objects. Bullot et al. (2017) connect Ramachandran and Hirstein (1999) to Gestalt psychology in terms of how they both propose the use of rules to explain our appreciation of art. Bullot et al. (2017) discussed how these and other cognitive science investigations into the brain's reaction to art have led to the creation of the field of neuroaesthetics. Bullot et al. (2017) describe the field of neuroaesthetics as being based on the belief that human reaction to artworks can provide insights into the neurosciences that govern perception.

To provide the basis for their thesis, Bullot et al. (2017) provide two sections where they develop their evidence. The first section is where they show the influence of artistic innovation and aesthetic skills on scientific cognition. Bullot et al. (2017) discuss examples of where artistic innovation has led to scientific innovation and where aesthetic skills lead to scientific decision making. These exchanges of inspiration occur across a wide array of subject areas. For example, better artistic skills led to better renditions of nature which led to better scientific understanding of observed phenomena. Bullot et al. (2017) reference advances in natural history, anatomy and microbiology as causally related to better detailing of observations.

Secondly, Bullot et al. (2017) develop the idea of dependence of artistic creativity on scientific innovation. They discuss how scientific innovation has led to both aesthetic an artistic innovation and the role that scientific understanding has had in the influence of artistic understanding. For example, dissection and studies of anatomy led artists to develop techniques to better represent the human and animal subjects of their artistry. Bullot et al. (2017) discuss the use of mathematics to investigate musical instruments and acoustics in the Greco-Roman era. They also discuss the use of the golden ratio in painting, sculpture, and architecture as well as the use of Euclidean geometry and algebra in the development of both linear perspective and depth-representation in painting. Bullot et al. (2017) note the use of the technology ubiquitous in the media arts as another example of science propelling artistic innovation.

Bullot et al. (2017) note there are those who have little belief that science can be of use in understanding art. There are researchers that feel neuroscience has no ability to assist in the analysis of an art form like dance or question the validity of the golden ratio as possessing a positive aesthetic character (Bullot et al., 2017). Still others argued that science cannot explain art because neuroscience and neuroaesthetics have a flawed understanding of the nature of art and base their analysis on disqualifying over-simplifications (Bullot et al., 2017). Bullot et al. (2017) lay out three challenging arguments presented by opponents to empirical neurological analysis as to why cognitive science is inadequate in explaining the normative conventions surrounding why we evaluate some things as art and not others. They are: (1) that these normative conventions are not discoverable by the quantifiable perceptual abilities utilized when we engage with artwork, (2) empirical evidence tells us how the normative conventions are applied but this doesn't explain why we call it art, and (3) cognitive science gives us no ability to determine the meaning of an particular artwork as intended by the artist, despite the fact that artists do possess ways to give clues and hints in the form of perceptual and aesthetic techniques. They respond to these challenges by stating that 1) although our perceptual abilities cannot explain the existence of these normative conventions, cognitive science can provide understanding of the cultural creation and evolution of the normative conventions around assessments of what is art, 2) those who feel that empirical data from cognitive scientific investigation can never be of value to understand the nature of art have not sufficiently justified this position, and 3) cognitive sciences, while not able to peer into the mind of the artist, can glean understanding from an analysis of the interaction between artist and their artistic communities. Ramachandran and Hirstein (1997) acknowledge that their formulation is one of many and cannot account for other aspects of art. They note that their application of eight principles or laws are but a small subset of what is the totality of a person's interaction with art, be they artist or audience.

The idea of analyzing art using the methodologies of science is fraught with discord. While there are many adherents there are just as many detractors. Therefore, as a means of uniting arts and science, this may seem to be a less than favorable proposition. Conversely, a greater understanding of how the brain responds to art could lead to artistic expressions that resonate more deeply with the individuals that interact with the art. This in turn could be the genesis of a new cycle of science leading to artistic innovations that pave the way to more scientific innovation. Additionally, utilizing knowledge of how the brain responds to art could inform which types of STEM professionals should be paired with which types of artists.

Engagement with the Audience. It seems that collaborations of Arts and STEM must have as part of their function engagement with an audience at large. When looked at through the lens of social practice, engagement with the community and consideration of the audience become significant characteristics of STEAM (Guyotte et al., 2014). This pulls in another theme of collaboration, the idea of social justice. Because it is believed that STEAM can create more authentic and holistic individuals (Guyotte, et al., 2014), it makes sense that the students of STEAM would infuse their creations with an aesthetic that would convey these qualities to the audience. These audiences, in turn, may be more receptive to issues of social and economic justice.

Moreover, engagement with the audience is supported by application of John Dewey's philosophy; the aesthetic creates the connection between the artist and observer through the object of art. Dewey felt that art does not have an ability to convey meaning without an observer to receive that message, "The work of art is complete only as it works in the experience of others than the one who created it" (Ross, 1994). Dewey (1934) notes even when the artist works alone, the art, the artist, and the observer are present. For the art experience to be complete, the three, the artist, the artwork and the observer must all connect. This means the audience is indispensable to the art and artist. Therefore, if STEM is to truly become STEAM, a role for the audience must be defined.

There is another thing to consider about the importance of the audience in the artistic experience (Peppler and Wohlwend, 2018). In terms of communicating with the audience, the role of artists is different than the STEM professional. The audience for the typical STEM professional presentation is mostly STEM colleagues and peers. Most of the audience for an artist involves a larger number of laypersons than the typical audience for a STEM professional. If STEM professionals were to develop arts from within STEM organically, how would they address the issue of the audience?

One must acknowledge that the art audience expands the STEM audience. This is self-evident because the number of those who connect with art is much higher than those who connect with a STEM discipline. STEM professionals have an audience of similarly trained STEM professionals whereas art will appeal to an individual regardless of their education or training. Bequette and Bequette (2012) state "Understanding art is and always has been a form of mass communication..." They note that museums are always seeking ways to convey complex concepts to the lay public. This understanding and implementation of art has been expressed as far back as when the clans and families used symbols such as family totems, combined with meaning understood by friend and foe alike, to produce what would become art (Zehou, 1994). They also identify museum curators as those who must present science to a general audience in an aesthetically pleasing manner. Bequette and Bequette (2012) noted a museum which incorporated middle and high school students into their community outreach program. Additionally, youth were also the targets of outreach, as they were members of groups that are under-represented in STEM, white girls, Black people, immigrants, and low-income students. This function of museums in STEAM and audience connections revealed itself in the Pavia University's 650th birthday celebration. In honor of this milestone the project "Neverland" was put into place. It included a collaboration between schools in the province of Pavia, Italy and the university's museums and laboratories (Bernarduzzi and Albanesi, 2015). The goal of the project was to remove the line dividing formal and informal science education. Students in the primary, middle and high school levels were paired with various museums and laboratories to create projects that recreated historical experiments by famous Italian scientists and incorporated the work of famous Italian artists. A tribute to Albert Einstein was also included. The results of this project produced multiple opportunities for the participants to engage with various audiences. The general public, other students and online viewers comprised the audience.

During an extended project regarding a STEAM collaboration around environmental impact, one research question given to students was "what can an artist communicate about our impact on the environment." This project would lead to a mosaic to educate the public about Virginia's watershed system (Wynn, and Harris, 2013). A painter interviewed by the authors indicated the importance of the audience being presented with the results of student work, be they administrators, teachers, or other students (Wynn, and Harris, 2013).

Another example of engagement with an audience is a project initiated to encourage girls to pursue STEAM interests. The students had as artifacts computer animated stories and games, which by their nature are designed for engagement with an audience (Liao, Motter, & Patton, 2016).

Arcadias (2015) repeatedly notes that the collaboration between NASA's scientists at The Fermi Gamma-ray Space Telescope and the Maryland Institute College of Arts (MICA) found audience issues were paramount. At one point it is stated, “...while scientific images are directly derived from data, those chosen for public release have often been picked for their inherent visual appeal, and aesthetic choices have been made in the conversion between numerical data and visual appearance.” The challenge was finding the line where the artistic interpretation of a concept agreeably meets with the need for scientific accuracy.

When Constantino (2018) talks about critique and exhibition in STEAM projects, this is another example of engagement with an audience. Critique and exhibition is an opportunity for both formative and summative evaluation. While critique can be used to identify areas of strength and weakness, exhibition is an opportunity to both perform authentic assessment as well as engage with the community (Constantino, 2018). While the concept of critique is in the context of assessment, meaning a small audience, art in general is under constant critique. Everyone will form their opinion regarding the artworks they are exposed to. Every piece of art is at some point, a critique between the individual observer and the artist. In the internet age, feedback can be swift, succinct, and direct. Likewise, Constantino (2018) employs the exhibition as an assessment, but its opportunity to engage with an audience offers multiple options for conveying thoughts, feelings, and emotions.

Although Gyotte et al. (2014) disagrees with the idea that community engagement isn’t part of the art tradition, they nevertheless report on the importance of engagement with the public as an important consideration of the collaboration outcome.

STEAM from STEM. What does STEAM look like in a STEM classroom? This is an important perspective because it directly addresses part of my dissertation question, namely, STEAM from STEM or STEM/Arts collaboration. Examples of how STEAM is implemented in a STEM classroom will inform policy positions regarding the idea of developing STEAM from within STEM organically. Comparison of the results from these programs with the results of programs that focus on collaboration between the Arts and STEM disciplines will serve to highlight similarities and differences inform techniques for evaluating which methodology is more appropriate for policy recommendations.

An important task is to organize the effort to perform STEAM in a STEM classroom. Turkka, Haatainen, and Aksela, (2017) provided a useful framework for assessing this effort. The gap that they sought to fill was the lack of information related to the practices of secondary school science teachers with regards to integrating arts into their curriculum. in developing their theoretical background, they discussed ideas related to knowledge integration and made a distinction between differential integration and commonality integration.

In their study they created categories of art integration established through a coding procedure that looked at open ended responses to questions. This led to two broad categories of integration; art integration based on activity and art integration based on content. Examples of integration based on content included categories where the integration was based on (1) theme, (2) artifact or (3) direct connection between art and science. Examples of integration based on activity led to categories where the focus was (1) more so on science, (2) more so on art, or (3) a focus that was equal in intensity between art and science. The method used by these authors was an e-survey. They had responses from 66 Finnish science teachers. The teachers were all secondary instructors with master's level university degrees. They were experienced in one or two disciplines of science such as physics, chemistry, biology or geography and had the ability to teach math as well. Social media was used to send the questionnaire out in addition to the use of mailing lists. They introduced the idea of exponential learning theory and the conditions under which the transfer of skills becomes effective. Exponential learning theory lays the foundation of concrete experience that an extrapolation of abstract conceptualization can be built upon. One aspect that they introduced was the role of emotion in the science integration process. They rely on the ideas of John Dewey (1938) to describe how the emotional content aligns with the existence of the scientific aesthetic to create what Dewey called "an experience" (1938). It has been argued that this aesthetic experience enhances the understanding of science (Girod, 2007). By comparing and contrasting the role of emotion in science education with that in arts education, one can begin to see which ways art, nature and science align. This understanding will inform how science can be integrated with art.

A method to present the characteristics identified by Turkka, et al. (2017) into a format useful for this study is presented in Figure 1 below.

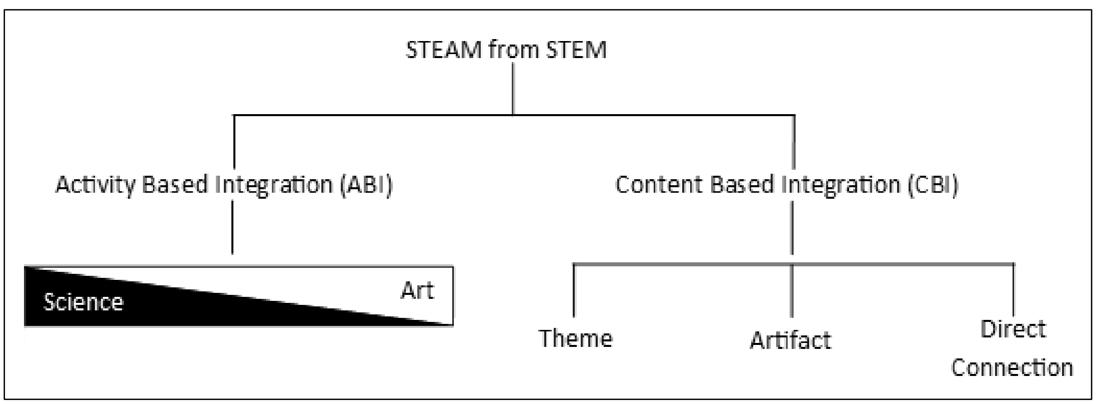

Figure 1. Coding of Results from Turkka, et. al. (2017).

The organization of Turkka, et al. (2017) is very useful because in addition to evaluating current efforts to analyze STEAM in the classroom, it can also be used to pull STEAM orientation out of historical examples of integration of science and math. Concepts such as religion, class and gender relationships are themes that have a place in human society across time and space yet have been represented by works that combine art and science in a variety of ways. The works represent artefacts that conveyed messages and meanings that, while culturally specific, spoke to those themes (Zehou, 1997). The artifacts themselves were created in most cases by items that gained their form and carried out their functions thanks to the science required to create the artifact and the artistic skills that imbued it with the power to communicate a thought, feeling or emotion (Zehou, 1997).

For students participating in the Pavia University celebration, students acted out roles with displays pretending to be historical personalities or replicating historical experiments (Bernarduzzi and Albanesi, 2015). The students created projects that were artistic representations of scientific principles and experiments. The mediums that they used were varied and were connected to the works of artists in a way that showed the relationships between the two.

The goal of Kant, Burckhard, and Meyers (2018) was to see if using Dakota/Lakota values and traditions could encourage female high school students at a Federal Native American boarding school to become interested in STEM fields, specifically engineering. The method behind the work of Kant et al. (2018) in this project was to not teach standards or theoretical concepts. The goal was to increase participatory interest in STEM by showing STEM connections to the lived experiences of the students. The group met monthly from October 2015 to April 2016. The average attendance was 20 girls. Botany and glass making were emphasized because of their role in Native American culture. The students were administered pretests. A focus group was convened at the end of the program to collect qualitative data.

The students participated in a variety of activities to connect the knowledge of the ecosystem to Native American acquisition of that knowledge. These activities included making traditional meals, visits to South Dakota State University to speak with STEAM girls, museum visits, presentations on conservation, planting and identifying various flora and traditional arts and crafts projects. The students modeled glass and bead manufacture with candy making. The students make craft projects using beads and porcupine quills.

An important insight from the collaboration of the Maryland Institute College of Art and NASA Goddard Space Flight Center was that metaphor was an important common language between artists and scientists (Arcadias, 2015). It was articulated that scientists use metaphors when elaborating on concepts. Challenges were resolved between the expressions of artists and scientists when the right metaphor was found that could assist in the exploration of a concept visually.

How STEM incorporates emotion and adjusts the role of objectivity will impact the union of art and science. STEM professionals are willing to incorporate art into their curriculum and observations have led to the discovery of two variables, the ratio of art to the science emphasis (activity) and the type of the product created. Introducing information on the lives of the scientists creates opportunities for art incorporation such as acting and storytelling. Culture is another vector for delivering art into the stem experience. Just as art can be culture specific so can science. The science performed can both be in the service of culture and create artefacts that express that culture. Metaphor has been discovered to be an effective mode of communication between artists and scientists.

STEAM from Arts. As artists grapple with the challenge of developing STEAM programs, questions come to the fore. For example, artists wonder how deep the integration of the disciplines should be with respect to the standards for the individual disciplines. It is felt that if the level of integration is not deep enough then there will be a lack of fundamental change in perspective and understanding with respect to the participant disciplines as far as the student is concerned (Peppler and Wolwend, 2018).

Another question that arises in the arts academia is with respect to the development of STEAM as a discipline. Does it warrant being treated as a new independent discipline or is it still in nascent stages of development? Katz-Buonincontro (2018) conveys a need for a foundation of research and pedagogy in addition to a capacity in terms of professional development that includes training, standards and credentialing to establish STEAM as a standalone discipline. Watson (2016) articulates the need for research to determine the best practices for STEAM education. Constantino (2017) argues that project-based learning (PBL) should be the basis for STEAM pedagogy. Liao (2016) agrees with this perspective and includes the idea of problem-based learning as well. She states that making or producing something is vital for the art teacher to successfully incorporate STEAM into their classroom. Watson (2016) echoes these sentiments by advocating for programs such as project-based learning and design-based learning. Bequette and Bequette (2012) also argue for a fully developed STEAM curriculum, articulating that when arts are not simply used to attract students to STEM disciplines, a better result is produced. Bequette and Bequette (2012) see sustainable interdisciplinary PreK – 12 STEAM curricula possible if arts are targeted as part of the end goal and not a conduit for STEM recruitment. While it seems counter to one of the asserted reasons for STEAM, to recruit underrepresented groups into STEM, upon closer inspection, the two objectives are not mutually exclusive.

A concern that artists have expressed consistently is the fear that when collaborating with STEM professionals, their profession will be devalued (Peppler & Wolwend, 2018, Katz-Buonincontro, 2018, Liao, 2016, Calvert and Schyfter, 2017). Their concern is that they may become servants to STEM and no co-equal partners. In their research project, “Synthetic

Aesthetics" Calvert and Schyfter (2017) noted that artists, and designers often work in the employ of science to introduce new scientific and technological advances to the public. To be treated with equality and to not be peripheral to the process, artists must not be 'self-righteous,' but rather must fully engage and take ownership in the creative processes, materials, technologies and even spaces such having their own lab areas (Calvert and Schyfter, 2017). This implies the acquisition of scientific literacy that goes beyond the operation of technological devices. When artists explore integrating STEM into their work it accomplishes two goals related to one of the stated purposes of STEAM; to elevate the status of the artistic professions. The first goal accomplished is addressing the concern are being devalued as a profession. Certainly, artists will not downplay the artistic component of STEAM if they are in fact the ones creating the STEAM program. The second goal accomplished relates back to one of the articulated reasons for creating STEAM. If artists incorporate STEM skills and scientific literacy into their profession, they will then elevate the value and significance of art.

A theme that appears in artists incorporation of STEAM into their disciplines manifests itself as the use of technology as tools to better express themselves. Peppler and Wohlwend (2018) highlight several programs which they feel are exemplars of STEAM. In these examples the science engineering and mathematical aspects of STEAM are dwarfed by the technological aspect. In fact, there is very little distinction between the utilization of technology versus the creation of technology. While they provide examples or both, they make no distinction between the two, they both represent STEM in arts projects. In a way, this goes back to the question of how deeply the disciplines should be implemented. Do you need to create technology to be a technologist, or is simply using technology sufficient for one to be considered a technologist?

Another theme that appears in arts academia is the distinction between two types of art in the context of fine art and art in the context of craft. Artists appear to identify two types of STEAM. One form is STEAM (with a capital A). STEAM with ‘A’ denotes fine arts, as would be presented in the higher educational setting (Peppler and Wolwend, 2018). What comes to mind is gallery art or ‘art for art’s sake.’ STEaM (with a lowercase A) is described as craft arts, exemplified by traditional female crafts (Peppler and Wolwend, 2018). Peppler and Wolwend, (2018) associate STEAM with programing such as Scratch with visual and performing arts while Katz-Buonincontro (2018) builds on the work of Peppler to describe STEaM crafts such as involving sewing in the service of producing e-textiles. There are some ideas which appear to be at odds with the goal of attracting underrepresented groups to STEM. Katz-Buonincontro (2018) comments on a program that includes sewing in an e-textile STEAM project. In the article sewing is characterized as women's work and this seems to help reinforce gender stereotypes. On top of that, sewing is given the lowercase “A” in STEAM which on the surface certainly appears like it is being belittled, that is not as important or relevant as fine art.

Knochel (2018) seeks to develop STEAM curriculum from the use of the objects available to the individuals who seek to implement STEAM. The aim is to create curriculum with an orientation that allows for the reflective process that artists engage in. This is done by allowing the objects that exist in the academic world and in the world of lived experiences to act as conduits to introduce the living world into the curriculum. And an equally important criterion is that the objects have efficacy in both the STEM setting and the artistic setting. The three classes of objects the author focuses on are called boundary shifters, material objects (materiality) and the thinking that arises out of 3D printing.

Knochel (2018) gives video game controllers and graphics software programs such as Photoshop as examples of boundary shifters. Boundary shifters cross boundaries and in doing so are transformed in such a way that they create transformations in the entities that utilized them. The author describes materiality as the use of physical objects as starting points for a theoretical approach to understand thought and behavior. The author relies on the concept of tomography to build up the idea of 3D thinking through processes that create objects either through additive or subtractive manipulation of material. He pairs this idea with the concept of 'numbering numbers' to maintain quantitative relationships between characteristic values while infusing the qualitative value that comes from the various iterative processes such as prototyping and understanding performances such as dance through motion capture.

There appears to be a justified concern that STEAM may relegate arts into the role of vehicle for the transmission of STEM. However, it seems that a related question is what level the inculcation of STEM into the arts should. Turned around and observed from a STEM perspective, one could ask how much art must be inculcated in to STEM. From a STEM perspective, art may be used to express STEM concepts and knowledge in a vein comparable to how STEM is used by artists to create their artworks. Questions about the level of literacy necessary to internalize STEM concepts do not seem to be settled. This uncertainty appears connected to the desire for STEAM research, standards, and curriculum. In looking over these activities, I readily agree with the question by Peppler and Wholwend (2018) raised regarding the applicability of the different disciplines to the actual experiences of the artists. In other words, do you have to understand or internalize the STEM concepts as an artist to have a truly STEAM related experience? This question seems to animate artists more so than STEM professionals to desire or expect a STEAM curriculum with standards. Perhaps the drive for a standards-based STEAM curriculum is how artists see STEAM elevating the arts disciplines. Related to the questions of standards for proficiency with STEM concepts is whether operation of technological devices is sufficient to claim the existence of a STEAM program or is more necessary?

Process model of STEAM/the design process. Another method of STEAM implementation is to focus on the similarity of the design processes in both art and engineering. Both engineers and (visual) artists use problem solving and multiple solutions by conducting inquiry. The inquiry is aesthetically oriented from the arts and analytically oriented from engineering. The implication being that the participants became more process oriented; neither the discipline nor the materials matter as much as the process, which dictated how the discipline and materials were used to solve the problem. Collaboration occurs from each discipline using inquiry from the other's perspective (Bequette and Bequette, 2012). Bequette and Bequette (2012) argue that using project-based learning (PBL); students can have an interdisciplinary experience that allows them to analyze aesthetic decisions and evaluate the aesthetic value in design solutions. This perspective seems to agree with Hoffman's characterization of Goethe's work, as it articulates the investigator using two different modes of inquiry, analytical and aesthetic, which overlap.

Constantino (2018) describes an art and design education which is comprised of three components: 1) critical making, 2) object-based learning, and 3) critique and exhibition. Critical making combines the idea of hands-on inquiry with an emphasis on critical and reflexive manipulation of materials. Constantino’s (2018) emphasis on the importance of this aspect is traced through Mark Johnson’s *The meaning of the body: Aesthetics of human understanding* back to the ideas of John Dewey; it is focused on the multimodal stimulus of mind and body experiencing creation through interaction with the environment in the process of making. Calvert and Schyfter (2017) also identify the creation of artifacts, or ‘making’ as an area of commonality between artists, designers, and synthetic biologists in the projects they studied. Calvert and Schyfter (2017) conveyed the sentiments of one artist that they could use the same technology and ask similar questions as the biologists when it came to using life forms as a vehicle for expression and a means to understand life. Calvert and Schyfter (2017) relate that synthetic biologists were happy to collaborate with the designers. They speculated that since design is at the heart of most engineering, synthetic biologists could more easily appreciate the contributions of the designers. For example, artists noticed that they were more interested in asking questions while designers, scientists and engineers were more interested in finding answers and solutions. Another observation of Calvert and Schyfter (2017) is the commonality between the artists and designers and synthetic biologists since making artefacts generates a physical presence and portability.

Object-based learning combines aesthetics, disciplines, context, and the process of investigation to develop multiple perspectives. The source of multiple solutions to design challenges is the set of common skills of observation, analysis, synthesis, and transformation (Constantino, 2018). To further elucidate on how this process can lead to STEAM, Constantino (2018) then discusses a research project that combined engineering and arts disciplines. Students used sculpture, flow charts and AutoCad to model the flow of ideas, energy, and materials. Students were presented with information and guidance from engineering, studio art and educational psychology speakers. Both technical and sociocultural factors were part of the design considerations. The culminating activity was an exhibition that raised community awareness regarding topics such as food, transportation, industry/commerce, residence/domestic and infrastructure. Constantino (2018) concludes with the perspective that carrying out STEAM from the art and design education perspective ensures that the art disciplines are treated coequally with whichever STEM disciplines are brought into the project. The author also states that more research is needed for this type of collaboration.

A key component of this theme of STEAM is the importance of the creation of a physical artefact. The importance of working with hands traces back to the era of manual arts from which arts and sciences evolved. This seems a natural outcome of asking questions and finding answers. Project based learning, problem based learning and critical making are pedagogical approaches that can naturally draw the STEAM disciplines together.

Professional development. Regardless of whether STEAM is cultivated through a collaboration of artists and STEM professionals, or through the development of an art tradition within STEM organically, professional development will be critical to disseminate this knowledge and skillset broadly in the world of teaching and learning. Wynn and Harris (2013) discuss the role that universities can play in professional development for teachers. Workshops, conferences and other activities are used to assist K-12 teachers to integrate art into their core content. In even a cursory perusal of professional development (PD) for STEAM, there are several characteristics which reveal themselves immediately.

First, there are the participants and a convener. In the PD studied by Kelton and Saraniero (2018), the stakeholders were mathematics-education researchers, science center exhibit designers and floor facilitators, youth and adult program educators from a photographic arts museum and the funders, the National Science Foundation (NSF). The conveners of this collaboration were the mathematicians. Lawson, Cook, Dorn, and Pariso, (2018) analyzed a project that was convened by museum professionals who were interested in helping third and fourth grade teachers to become more engaged in the museum going process from a STEAM perspective. Specifically, they were creating a professional development based on arts and science standards that teachers could implement before, during and after a field trip to the museum. The method by which this program was carried out began with an announcement distributed to over 1000 area schools which resulted in participants from 42 classrooms located in 27 public and private schools. The make-up of the participants was over 600 3rd graders, over 300 4th graders and 42 teachers. Over 75% of the participants represented underserved groups and over half were females. This outreach addresses one of the identified goals of STEAM; to attract underrepresented groups to STEM (Lawson, Cook, Dorn, & Pariso, 2018). Teachers were provided materials prior to visiting the museum and this supported a single classroom activity prior to the field trip to the museum. After completing the activity but prior to visiting the museum students and teachers were asked to complete a survey.

Second, the time duration of professional development is typically not short term. The Kelton and Saraniero (2018) project was comprised of 16 three hour workshops that extended over eight months. Lawson, et al. (2018) did not have a workshop style professional development. Instead, they provided online materials and access to museum professionals at the beginning of the school year to teachers. This way, they could complete pre-museum visit activities and pretest surveys within the timeframe of their curricular pacing plan.

Third, there is an interdisciplinary component. The skill sets brought to the Kelton and Saraniero (2018) project were mathematical content, educational research, studies of data on visitors to the center and museum, science, engineering, studio arts, visual literacy, and photography.

Fourth, there is a process of teaching and developing collaboration. The funding source of the Kelton and Saraniero (2018) project created the first precondition for collaboration; high stakes and high interdependence. This precondition was also established by the fact that there was significant investment of resources by the institutions the participating professionals represented. It suggests a framework for STEAM professional development workshops for STEM professionals While this characteristic is necessary for STEAM programs that utilize collaboration between art and STEM, it might not be as important when STEAM is cultivated in an organic fashion. Working in self-contained classrooms, third and fourth grade teachers were able to carry out pre-museum visit activities individually, learning at their own pace. (Lawson, et al., 2018).

Fifth, there are the artefacts of professional development. A precondition in the Kelton and Saraniero (2018) PD was the shared purpose to create programs, exhibitions and promote professional growth.

While not a universal characteristic, the role of museums in developing STEAM programs for professionals cannot be overlooked. Lawson et al. (2018) noted that museums which have support for interactive components can be helpful in contributing to STEAM-based programs. Under the direction of the Pavia University Science Museums, local teachers participate in project trainings which approached a yearly consistency in addition to update days on science and art topics. Students were then guided by teachers to create projects. Museums are places where the overlap of science and art occurs in tasks such as exhibit design, community outreach and creation of content to convey information to the community at large (Bequette and Bequette, 2012).

Sufficient time and interdisciplinary professional development are important because according to the Turkka et al. (2017) while 70% of surveyed STEM teachers we're interested in getting art integration materials, over half felt they did not have enough knowledge to integrate science and art and nearly half said they didn't have enough time to integrate science and art. Time and interdisciplinary professional development are equally important regardless of whether STEM instructors are pursuing STEAM individually or if STEM professionals are collaborating with art professionals.

It seems components of a typical pedagogical professional development should include interdisciplinary groups of participants. They should be taught how to collaborate. There should be an extended time frame for results to manifest. Not only should they be taught, but there should also be products created by their curriculum, the participants should create products as well. One thing that appears to be missing is a group of methods that will incorporate the audience. This should be part of the process, possibly in the form of including clients for the projects created in the curriculum.

Very few secondary science teachers are attempting STEAM. However, it may be due to a lack of capacity as opposed to a lack of interest. This points to a need for STEAM professional development that provides materials and interdisciplinary training. Primary school teachers were receptive to incorporating STEM into art. Culturally relevant STEAM can increase the perceived value of most STEM disciplines.

Collaboration Conceptual Framework

Collaboration Theory. Collaboration, based on the research, is described as when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures to act or decide on issues related to that domain (Wood &

Gray, 1991). In my application of this theory, the stakeholders are the artists and STEM professionals who are collaborating to address the problems the structure STEAM was created to address. Due to the interactive process, there have been a variety of shared rules and norms regarding STEAM, which will be represented in both the further development of the framework and in the literature review. The action or decision resulting from the collaboration will vary as well as the norms and rules, owing to the fact the outcome of the collaboration can vary from collaboration to collaboration. The problem domain varies according to the interests of the collaborators. If we look at the problems that created the interest in STEAM, then there are at least three global domains. The first could be considered the need for economic innovation as articulated by John Maeda (2012). In that case, whatever local project is undertaken, the theme or focus would always be ultimately encouraging innovation at the national level to increase global economic competitiveness. If the second domain is attracting more students to STEM (Yakman, 2008), the domain could be defined as the preK-12, post-secondary, graduate, or post-graduate academic domains. If increasing the inclusion and valuation of the arts is the third domain (Catterall, 2017), then the domain might include the academic, political, or professional realms. In any case, the domain would dictate the subsequent norms, rules and structures. In each case, the problem/project could be completed with the outcome not being achieved, which may be an acceptable result, depending on how open-ended the purpose of the collaboration is (Wood & Gray, 1991).

General characteristics of a collaboration includes the idea that structures are not permanent (although can be long-term). Collaborations are predicated on processes that lead to actions or decisions. Stakeholders don’t relinquish all their autonomy. Another characteristic is there may be an agent that acts as a convener who brings stakeholders together (Wood & Gray, 1991). The authors also identify three critical issues of collaboration: (1) the preconditions that make collaboration possible and motivate stakeholders to participate, (2) the process though which collaboration occurs and (3) the outcomes of the collaboration (Wood & Gray, 1991). The authors identify factors that impact the motivation to collaborate; the degree of group interdependence and value of resources at hand, the zeitgeist of the given sphere of concern, the impact of the issues on the involved groups, the need to improve efficiency and the degree of shared understanding and interest in each issue.

Although not required, a convener is typical of a collaborative effort (Wood and Gray, 1991). Conflicting factors cause interprofessional collaborations to require sophisticated norms of interaction to address complex professional allegiances (D'Amour, et al., 2005). The convener can be either an individual or an organization which brings the stakeholders together. If present, a convener can have far-reaching influence upon the creation of the collaboration (Wood and Gray, 1991). The referenced projects have examples of conveners that brought the disparate groups together to collaborate. The Pavia University Science Museums was the spearhead of the aforementioned project "Neverland." The Pavia University is the convener of participants for this project. The Pavia Museum of Natural History traces back to 1771 and the Museum of Electrical Technology was founded in the first part of our current century (Bernarduzzi and Albanesi, 2015). The museums provided access and assistance in planning activities. Seven museums participated. Bernarduzzi and Albanesi (2015) wrote that the university museum system not only wants to return to its educational roots but to also be a hub connecting and improving the regional school systems.

During the collaborative process, change and adaptation over the course of the collaboration are critical to the survival of the collaboration (Gray & Wood, 1991). Relevant factors at this stage of the process include organization of membership and decision making, the types of interactions among members and duration of collaboration. Based on their research, Gray and Wood (1991) identify five questions to ask regarding outcomes. They are 1) where problems solved, 2) whose problems were solved, 3) where shared norms achieved, 4) did the collaboration survive to the end of the project and 5) did the collaboration survive by transforming from a collaboration to a relatively permanent structure. This last point is relevant with respect to sustainability.

According to D'Amour, Ferrada-Videla, Rodriguez & Beaulieu (2005), there are several ideas associated with collaboration. They can be classified into two categories: one related to the dynamics between individuals in the collaboration and the other related to the overall group dynamic. These categories fit within the collaboration process of Gray and Woods (1991). Factors included in the first category are sharing, partnership, interdependency and power (D'Amour et al., 2005). The authors' research gives descriptions of these factors. Areas for sharing are responsibilities, decision-making, philosophy, values, planning and interventions and professional perspectives. Partnerships are characterized by collegial relationships, the state of being authentic and constructive, open, and honest, mutual trust and respect, awareness of the contributions and perspectives of other professionals and the pursuit of common objectives and outcomes. Interdependence entails surrender of autonomy and a dependence upon one another. It leads to a synergy that not only allows for the sum to be greater than the individual parts, but it also leads to collective action. Power has several perspectives. The first is the empowerment of the individual. The second is that the power is derived from knowledge and experience. The third is that the power is intertwined with the relationships through it is exercised (D'Amour et al., 2005).

The second category is associated with group dynamics. Their research (D'Amour et al., 2005) found three descriptions of group dynamics: multidisciplinary, interdisciplinary, and transdisciplinary teams. The authors prefer the terms multiprofessional, interprofessional and transprofessional because they reflect the field of practice as opposed to the development of knowledge. I have maintained this perspective in that I have used the term ‘disciplinary’ when discussing curriculum or standards and ‘professional’ when discussing collaborations. The description of a multiprofessional team is the structure that has the most autonomy of individuals. This arrangement may not require teammates to even meet; they can work remotely and coordinate their efforts. The second structure is the interprofessional team. This structure has less autonomy and more effort to integrate themes and strategies among professionals in a shared fashion. Concomitant with a reduction of autonomy is the creation of an agreed upon decision-making protocol, one that is common to all. A challenge that exists in this structure is the apportionment of professional jurisdiction over given aspects of the problem domain. The requirement here is for the professionals to become flexible with respect to the lines of demarcation that circumscribe their areas of expertise. The third structure is the transprofessional team. Consensus and the removal of boundaries between areas of expertise are hallmarks of this structure. There is a concerted effort to promote a sharing of skill, knowledge and expertise that makes boundaries and territoriality meaningless (D'Amour et al., 2005). As my framework is a synthesis of two frameworks, I created an outline based on the ideas of D’Amour et al. (2005), Gray and Wood (1991) and Wood and Gray (1991).

Table 1.

Synthesis of Collaboration Theory.

Author	Concept
Factors that impact the motivation to collaborate (Gray & Wood, 1991).	(1) **the preconditions that make collaboration possible and motivate stakeholders to participate.** • the degree of high stakes and high interdependence • the zeitgeist (social forces) of the given sphere of concern • the collective response to a common problem • the need to improve efficiency • shared purpose to produce change • protect common interests
According to D'Amour, Ferrada-Videla, Rodriguez & Beaulieu (2005), there are several ideas associated with collaboration. They can be classified into two categories: one related to the dynamics between individuals in the collaboration and the second category is related to the overall group dynamic.	**(2) the process though which collaboration occurs** Factors included in the first category. • Sharing • Partnership • Interdependency • Power
Their research (D'Amour et al., 2005) found three descriptions of group dynamics: multidisciplinary, interdisciplinary and transdisciplinary teams.	The authors prefer the terms • Multiprofessional • Interprofessional • Transprofessional because they reflect the field of practice as opposed to the development of knowledge.
Gray and Wood (1991) identify five questions to ask regarding outcomes.	**(3) the outcomes of the collaboration** 1) where problems solved 2) whose problems were solved 3) where shared norms achieved 4) did the collaboration survive and 5) did the collaboration survive by transforming from a collaboration to a relatively permanent structure.

Collaboration Evaluation. Reviewing program evaluation of collaborations can be a useful strategy for identifying and operationalizing variables for assessing the prospects of collaboration between artists and STEM professionals. Frey, Lohmeier, Lee, and Tollefson (2006) developed and validated a tool for evaluating collaborations of various groups. The tool they developed and validated allowed them to take snapshots of the state of collaboration among the various participant groups. Based out of the University of Kansas, Frey et al., (2006) were funded by the US Department of Education, the US Department of Health and Human Services, and the US Department of Justice. The first step that they undertook was to define collaboration based on the existing literature. Based on their framework, they were able to identify five levels of collaboration and their characteristics. From lowest to highest level of collaboration they are networking, cooperation, coordination, coalition, and collaboration. This compares to the organization of collaborations by D'Amour et al. (2005) of multiprofessional (networking, cooperation), interprofessional (coordination, coalition) and transprofessional (collaboration). Frey et al. (2006) then collected survey data from the stakeholders and use that date to create a map showing the collaboration between the stakeholders. They developed a social network map. Using their map, Frey et al. (2006) were able to identify the relative degree of strength of collaboration between the various stakeholders; some had very strong collaborations with other stakeholders whereas others had very little or no collaboration. They were also able to identify the direction of the collaborations, whether the collaborations were from one collaborator to the other or mutually reciprocal.

Woodland, Lee, and Randall, (2013) undertook the task of validating the Teacher Collaboration Assessment Survey (TCAS). According to the authors, teacher collaboration has long been identified as important for improving instructional quality and improvement student achievement. the authors sought to validate this scale which they described as having been used since 2008 in multiple school districts in the NE and mid-Atlantic regions of the United States.

They wanted to legitimize the document by showing it met standards established by American Educational Research Association (AERA), American Psychological Association (APA), and National Council on Measurement in Education (NCME).

Data was collected from nearly 600 respondents from within two school districts. In addition to the TCAS Likert-type questions used for collecting data on the four key components, the authors also used interviews to collect their data. The authors use pre- and post-test interviews in addition to focus groups for collecting qualitative data. The authors used a logit scale, examined the reliability of separation, and explained why they chose the Rasch model over factor analysis when evaluating evidence based on internal structure. Woodland et al. (2013) detailed the four key components of effective teacher collaboration. They are dialogue, decision making, action taking, and evaluation. These compared to the identification of intrapersonal dynamics by D'Amour et al. (2005) of sharing, partnership, interdependency, and power. For each of those components Woodland et al. (2013) goes into detail showing how the research supports the claim that these are critical components of effective teacher collaboration teams. They assert that the TCAS is designed to operationalize those four components.

Gajda (2004) explains how the role of a program evaluator can be used to help codify and evaluate the viability of a collaboration amongst entities. The author presents five principles of collaboration. Essentially, the first principle is one of necessity. Collaboration is necessary because of complex challenges that must be responded to with limited resources. The second principle is that since collaboration is described in so many ways in the literature, program evaluators have an important role in helping to clearly define the scope of collaboration between entities. Third is the idea that collaboration exists on a spectrum and that a group of entities should be moving along the spectrum from low levels of integration to high levels of integration if they want the collaboration to become sustainable. The fourth principle states that collaborations are most effective when the entities in the collaboration have personal and emotional connections with one another. The fifth and final stage articulates that collaborations are evolving processes. The five stages of Gajda (2004) compared to the preconditions for collaboration presented by Gray and Wood (1991); high stakes and high standards, shared purpose to produce change, to protect common interests, to maximize efficiency, a collective response and the societal forces in play.

Gajda (2004) believes that program evaluators can often act as support to the convener of the collaboration by becoming a facilitator of the collaboration. In effect, this is the stage where the collaborating entities established the norms of relationship and responsibilities to the collaboration and to each other. During this stage the program evaluator is described as helping to establish goals, objectives, variables for evaluation and collecting data. One thing the author noted repeatedly throughout the article is that the program evaluator should provide information not only on the program being implemented but also on the level of functionality of the collaboration as well.

There is good compatibility between the operationalized variables from evaluation of collaborations and the descriptors from my theoretical framework. Dialogue, decision making and action taking seem good pathways to operationalize measurement of prospects for collaboration with respect to the relative ease of developing norms of collaborative behaviors between art and STEM professionals. The five stages outlined by Gaja (2004) seem good prospects for operationalizing the variables useful for measuring the interest and desire for establishing collaboration among arts and STEM professionals.

Summary

The three main reasons for promoting STEAM are 1) to improve the support for the arts, 2) to promote innovation and 3) to meet the need for STEM professionals in the workforce. The question I wanted to investigate was whether it is more profitable for STEAM to originate from within a STEM profession or to be obtained through the collaboration between the STEM and Arts disciplines. The factors that led to both the union and dissolution of arts and science are not simple yet not extremely complex.

The belief system of a culture has been critical in determining whether arts and science operated as unified concepts. In Africa, this union was expressed in the religious or interpersonal relationships conveyed through objects by impressing upon them both form and function. In the far East, universal concepts of form, energy and function were connected throughout the history of their civilizations by way of philosophy. Artisans combined art and science from the earliest times. Art and science were united when functional objects were imbued with beauty and symbolic meaning (Liao, 2016). While function helped to accomplish daily tasks, form often communicated information of a social nature, such as the relationships between spirits or members of the community. Often artisans would collaborate to solve common problems. Architecture combines several disciplines, such as engineering design, sculpture and painting. Architecture both provided a backdrop for expression of residents and commissioners of structures as well as helped to convey the relationships between individuals, concepts and groups. Astronomy combined the need for information regarding time and direction with reverence for celestial objects given religious significance. Art became the means to express that reverence. Medicine combined the manipulation of elements and compounds found in plants and minerals with spirituality in the form of artistic artifacts that were used to interact with the spirits. What seems to be a common thread that held form and function together in these examples was a belief system that promulgated a philosophy, communal vision, or religion that art and science were used to express.

Several factors act to separate the arts and STEM professions. Classism has been identified as a dividing force. The desire to reside in a more privileged class has driven arts to separate from sciences in more than one culture. Political forces have been shown to be critical and separating arts and science. Typically, this reason is short term but can have long term impacts. The use of science or art to promote a specific agenda can be a source of division. Invasion by foreign entities can also cause the separation of science and art.

Economic forces seem to be a primary reason for the separation of arts and sciences. Capitalism has been identified as a major economic force separating arts and science because science can be more profitably exploited as opposed to the arts. It seems that specialization, due to demand of sophisticated products and the organizational structure of capitalism, was a primary driving economic force that separated art and science. It seems that in early times an artisan or craftsperson could both create the artifact and shape or aesthetically improve the artifact. But as time went on, competition and elevated preferences lead to greater and greater desire for intricacy and complexity in terms of detail. Therefore, the blacksmith who could refine and forge other materials besides iron, to compete, had to either focus on ferrous materials, collaborate with an artisan who could fashion the nonferrous materials provided by the blacksmith or abandon the blacksmithing to become the artisan who could refine and fashion nonferrous materials. Specialization is like the genie who escaped from the bottle or the toothpaste that is out of the tube. Demand both in terms of quantity of products, goods or services and quality in terms of sophistication are among the reasons why we cannot step back from specialization.

Support for the Arts professions. Artists themselves were the driving force to morph STEM into STEAM for this purpose. To address the first of the motivations to create STEAM, to support and promote the arts, artists must continue to not only experiment with STEM concepts, but they must also embrace STEM. Peppler and Wohlwend (2018) are right to question if artists who experience a cursory introduction of STEM concepts can really claim internalization of those concepts. It is reasonable to question if artists are truly incorporating STEM concepts when they only utilize STEM technology to enhance their creativity. Does utilizing a paintbrush, a guitar or a computer program make you a technologist? Must artists adopt the processes as well as the products of STEM? The STEM professions have well defined processes; the scientists have the scientific method, engineers and technologists have the design process and mathematicians have the computational algorithm. To truly adopt STEM, must arts professionals develop STEM related processes in the arts in such a way that it can be identified, replicated, and taught? If necessary and prudent, how this will be done will be based on the answer artists give to this question: Are artists incorporating STEM to assist in encouraging interest in STEM to merely gain greater access to funds and resources afforded to STEM programs, or for some other reason?

One recurrent idea in the art context is the desire to have a formal curriculum with associated research and standards to conduct STEAM education. This had been part of the arts formulation of STEM disciplines since the Age of enlightenment (Kemp, 1994) There are several efforts to establish the groundwork for such curricula (Liao, Motter, & Patton, 2016, Knochel, 2018) A possible venue for STEAM through the arts may in advocating a certain level of scientific literacy as a societal goal. That level of science literacy may not be to the level as desired by STEM professionals, but it may both meet the needs of artists and be a support of the goals of the STEAM program. STEM professionals want to incorporate arts to attract underrepresented groups to STEM and to promote innovation for economic purposes, why do artists want to incorporate STEM?

Increase interest in STEM professions. STEM professionals are the primary proponents for this motivation to promote STEAM. To attract underrepresented demographic groups into STEM professions could be accomplished by either cultivating STEAM from within STEM or through collaborations between STEM and arts professionals. This objective seems to require the most reflection on the decision to pursue STEAM through collaboration or organic development from within STEM. A high level of reflection is needed because this objective must be addressed at all levels of the educational process, from pre-K to the post-secondary level. How do art and STEM educators and professionals feel about collaboration? Which disciplines are more or less likely to collaborate? We have some preliminary information about what STEM educators are doing to develop STEAM organically from STEM in Finland, but what about other locales? It seems the best option is to establish a well-rounded PreK – 12 foundations, studying both arts and Sciences to attract underrepresented groups into STEM. STEM educators and professionals have given thought to elaborating on an aesthetic from within STEM to organically cultivate STEAM (Girod, 2007; Pugh & Girod, 2007). STEAM at the educational level is entirely viable and preferred. This, however, is if there is some overarching force that requires these two to remain connected. This could be easily accomplished at the local and statewide educational district level if STEAM was an institutionalized goal and objective. Moreover, this could provide a link between artists' interest in developing STEAM and the STEM professionals' desire to attract more students to their professions.

Promote innovation. While STEAM from STEM may need to be well developed in the academic world, STEAM from within a STEM context is not necessarily needed for the professional world due to specialization and professionalization of career paths. In terms of innovation, collaboration between arts and science seems to be preferable than the organically developed STEM professional well versed in the arts. This is because the more minds you have, the more innovation is possible. Additionally, the more specialized each one of those minds is, the more creative the innovations would be. When others have expertise, you do not possess, collaboration makes sense. Specific projects may drive the need to seek out these outside experts. Diverse perspectives breathe new life into structures that may grow stale with repetition of existing policies and procedures.

For STEAM to be a vehicle for innovation to keep the United States competitive on the global stage there must be the convening entity in art and STEM collaborations. Key for this arraignment is the willingness and prospects for forming collaborations of STEM and arts educators and professionals. The goal is to create a long-term collaboration between the specialized artist and specialized STEM professional, but that relationship would require a convener to bind those two together. Seeking innovation through collaboration is only a temporary an uneven means of obtaining your ends. This is because collaborations are by their nature temporary arrangements. Without some force or entity holding arts and science together, they will drift apart. This drift is due to specialization. The convener plays the role of an organizing entity, being a governmental body or some other structure, to combine and maintain the unity of arts and science. If the scientist and the artist are to collaborate because they need the specialized skill and experience of the other, what will keep them working together? If the two are going to collaborate on a sustained basis there must be something, be it an organizing document, individual or organizational entity, that will hold the two of them together in a sustainable way.

To promote STEAM through collaboration of art and STEM, the inhibiting influence of capitalism must be addressed. There is enough evidence that capitalism retards the development of science (Zisel, 2000) and art to state that innovation may be throttled and agenized in ways that run counter to the objectives of the collaborations. The role of capitalism in codifying the separation of art and STEM through the implementation of specialization, professionalization, and the division of labor points to both the conflict inherent in pursuing collaboration for the purposes of generating new products and the need for a convening entity to assist in the moderation of the detrimental tendences of capitalism.

STEAM organically from STEM. There are reasons why STEAM from within STEM may be a preferable arraignment. STEAM based on a science aesthetic would bypass a need for a convener; only interdisciplinarity would be necessary. It is reasonable that over time individuals who are cultivating STEAM from a STEM context would become more and more adept at integrating the disciplines, culminating with a transdisciplinary integration of the disciplines.

The components of modern examples of STEAM are already parts of the STEM tradition. If you consider the idea of STEM professionals who both embody both analytical and aesthetic inquiry, there are examples throughout history. The existence of professionals who currently possess expertise in both STEM and arts disciplines is evidence of that. If anything, it is the idea of social, environmental, and economic justice that has been lost by the STEM professional. I feel this can be traced back to the European Enlightenment when public utility replaced the public good. While issues of justice could be supplanted by collaboration with art disciplines, it could equally and perhaps more efficiently be cultivated in the STEM disciplines. This enhancement could be carried out by implementation of an aesthetic that values the role of the audience culture it originates from STEM professionals who have evaluated and developed programs to implement the various types of ethics and justices. As more engagement occurs between those concerned about both the environment and social utility and STEM professionals, the need for communication with non-STEM audiences will be addressed. Communication with an audience has an importance that is relative to the project undertaken. Additionally, there is the science tradition of communicating the results of your investigations, although this is usually peer to peer.

STEAM from within a STEM context would lead to the development of individuals trained as an artist and scientist in the vein of Wheatstone, Goethe or DaVinci. This would be the development of STEAM from within a STEM context. A variety of scenarios point to the need for such training. Let us imagine a team sent to a foreign planet. You would need a series of science specialists because creativity and innovation would be at a premium. You would need an artistic ability to capture and communicate the images and experiences in that endeavor to provide cultural meaning back to the general society. However, each one of those specialists must also be well grounded in the areas of expertise of the other specialists The reason for this is if one of the specialists is injured or killed, the others must have at least enough knowledge to do the work that that missing specialists would have been able to do. They may not be good enough to do it as well as the specialist. Nevertheless, if they all have a good foundation, they would be able to together collectively be able to carry out those responsibilities. Similar scenarios could be envisioned in other environments such as the undersea or in extreme climates.

The insular nature of science disciplines may make STEAM from within STEM la less challenging proposition because it would bypass a need for collaboration. STEM professionals could express the aesthetic through their individual disciplines. The idea of collaboration among STEM professionals may be challenging enough, let alone among STEM and non-STEM professionals. It is interesting to compare the ideas about collaboration originating from within the science disciplines with the collaboration theory I have been using, which originates from the healthcare professions. Both are considered STEM professions, but the way collaboration is formatted is vastly different. Specifically, the science version of collaboration outlined by Levine and Moreland (2004) seems like Darwinism in a not so veiled glove. From processes to becoming part of a collaboration to discussing ideas to the reasons for dissolution of the scientific collaboration, competition is the hallmark of the culture. These ideas of STEM collaboration lend themselves to organic STEAM due to temperament, the preferences to complementary disciplines and perspectives of the scientific community. Scientists have been described as preferring to collaborate with individuals in common social networks, disciplines, work areas, interests and whose work is judged to be of equally high quality as their own (Levine and Moreland, 2004, Boyack, 2006, Bennet and Galin, 2012). Scientists are also described as valuing trust because scientists often view their colleagues as competitors (Bennet and Galin, 2012). The strong inclination in the scientific community to work with professionals with like interests and disciplines also militates against collaboration with non-scientific professions. Indeed, this insular inclination may inhibit collaboration among STEM professionals. The competitive nature of STEM professions along with a cultivated nature of skepticism may be a factor that militates against STEM, much less STEAM. The type of cultural revolution required to produce STEM may in fact be what a movement of STEAM from within STEM creates.

STEAM from STEM and Arts collaboration. There seems to be two purposes for collaborations between arts and STEM professionals: 1) to teach STEAM and 2) to enable innovation. This corresponds to the academic and non-academic fields of endeavor.

Teaching STEAM for science literacy could lead to a renaissance in liberal arts in the form of a STEAM degree that prepares individuals to be trainable in a variety of disciplines, thereby contributing to a scientifically literate society. In the academic world STEAM would be able to provide that foundational understanding of all areas of human endeavor, providing a well-rounded understanding which would act as the basis for specialization in their professional world. This points to the importance of a scientifically and artistically literate society. Therefore, outside of being a teacher, it does not seem like a STEAM degree is all that preferable as a stand-alone degree. However, it could function as the foundation for the option of training in either STEM or arts professions. In the competitive world of the marketplace, demand will ultimately drive the STEAM professional towards specialization. At the academic level it makes good sense to have organic STEAM from the STEM or arts professions because all the disciplines have strengths and weaknesses; no one is technically superior to the other. However, by understanding and knowing all of them, the strengths can be used to cancel out the weaknesses and all-around mastery can be developed at the individual level. At this point, scientifically literate citizens will have options that include both STEM and artistic pathways.

A new model for STEAM. From a systems' view, the STEAM elements may interact in changing and evolving sub-groups to accomplish sub-tasks, be it to generate ideas, solve problems or acquire information. The interconnecting flow is information. In taking a historical view of the union of arts and sciences, the purpose of STEAM seems to require more than to unite form and function. Based on the historic view of art and science and the flow of knowledge between the elements of STEAM, the purpose of STEAM is to understand the world through a lens of all the disciplines, to be transdisciplinary. In the past, the union of art and science created objects that embodied aesthetic form and function. STEAM practitioners should firstly be able to appreciate the world and the objects and phenomena that constitute reality using an aesthetic that is both scientifically and artistically informed. Secondly, they should be able to also interact with the world such that STEAM practitioners can add to or expand that aesthetic through a union of form and function. This should lead to an appreciation of, and harmony with the natural world. The creations of STEAM become connectors within a larger system by connecting the audience with the STEAM practitioners and the natural world. STEAM is more than seeing from various perspectives, but seeing from all perspectives nearly simultaneously, a transdisciplinary perspective. I think this is the core into which the three articulated reasons for STEAM want to tap into. This perspective could attract underrepresented groups to STEM by offering new ways of seeing the world, although it could be argued whether they were attracted to STEM or STEAM. This perspective would also elevate the arts to equals of scientific and mathematical disciplines. This nexus of ideas could become a birthplace for innovative products that could be exploited for economic gain. This thinking has led me to consider a new model for STEAM. The major change in this model is the inclusion of the audience. The audience is included because if art is to truly be partnered with STEM, then the audience must also be partnered with STEM because the audience and art are inseparable. The role of the audience accentuates the interface of the STEM professional with culture and highlights the STEM professionals' responsibility to both society and the environment. I believe this sense of responsibility was lost when capitalism reduced the audience down from society to a small group of clients, the heads of economic concerns. Additionally, in many cases the audience is also the consumer for innovative products.

This brings in tech support through technology. This means that of all the STEM disciplines, technology has the most contact with the audience. Technology is the most people (socially) oriented of the STEM disciplines. While the other STEM disciplines interact with audiences, it is much less than technology and certainly less than art. Even though an engineer can design a device, typically, it is a tech person who will build it, install it, and explain how to use it. Regarding pure research, mathematicians, scientists and engineers appear to have more in common with each other than they do with artists, technologists or the audience. Mathematicians, scientists and engineers involved in theoretical research create knowledge that must be processed through more steps before it gets to the audience compared to the artists and technologists, who often interface directly with the audience. These are the reasons I feel the audience must be included in any real effort to practice STEAM, and why the audience should be connected to art and technology as opposed to the other STEAM disciplines. In the sense that the STEM aesthetic requires a certain level of specialized knowledge to appreciate it. Another question that arises is the applicability of science, especially research, to all three professed reasons for STEAM. While it could be readily adapted to the goal of innovation, the application to increasing the number of underrepresented groups and particularly to enhancing the role and value of art could be debated. If we are talking about citizen science, the question is easily answered that it can be adapted. However, if we are talking about research science, the answer is a bit more unclear.

If the audience is an integral part of the production of art, does the typical audience of art relate to the audience for this specialized science? Out of the acronym disciplines of STEAM, it seems that mostly artists and technologists have the broadest audience. It seems the more advanced the science, the more specialized the audience. At some point, the question arises, are you dealing with an audience or a client? The same issue equally holds for engineering and mathematics. Is the answer that different audiences appreciate different types of art?

Amid all this STEAM funding and implementation, has anyone asked how interested arts and STEM professionals are in collaboration? Artists seem extremely interested in STEM. However, the question is whether they prefer doing STEAM organically from within an arts framework or in collaboration with STEM professionals? If collaboration is the key to STEAM, the question is how likely are artists and STEM professionals to collaborate? If it is high, then time and effort need to be put into place to sustain a role of convener to keep the artists and STEM professionals together. If not, then efforts should be put in place to cultivate STEAM from within STEM and the arts respectively. There is reason to believe artists may not want to collaborate with STEM professionals. In a small pilot survey performed in 2018 artists seemed interested in learning about STEAM but not from STEM professionals.

The question becomes, based on the criteria for collaboration, what are the prospects for collaboration between STEM and arts practitioners? This seems to be a question that has gone unasked; it appears that it has been assumed that collaboration is a desired outcome. Do STEM professionals and artists agree on the preconditions such as an urgency and need for collaboration? How compatible are the cultures of artists and STEM professionals with respect to characteristics such as norms of behavior, goals, and objectives? Have dividing forces such as specialization erected barriers to prospects for collaborations? At a more fundamental level, are these professionals interested in collaboration? Do these professionals prefer to collaborate or not? These are the questions my research seeks to address.

CHAPTER 3

Methods

Population. I used purposive sampling to reach representatives of my population, members of the STEM and Arts communities. Using California Department of Education (CDE) organization of arts disciplines, my arts population were members of the dance, theater, visual, music and media arts disciplines. Members of the STEM population were scientists, technologists, engineers, and mathematicians. Although not included in CDE organization, I also sampled practitioners of the literary arts. This is because of the role of science fiction in STEM education and the historical poetic and philosophical connections between science and the humanities. Architecture professionals were surveyed because of the roles of art and engineering in their profession. Potential respondents were drawn from both academic and industrial career paths. Because I am seeking ideas about Arts and STEM collaboration, it seems this type of purposive sampling could be specifically classified as homogeneity sampling.

Variables. To develop variables for this study I combined the theoretical ideas regarding collaboration summarized in Table 1 with the operational concepts found in collaborative program evaluation. Key variables are the conditions that are required for collaboration to begin and attitudes and opinions regarding the value of collaboration. Table 2 organizes the themes used to create the study variables. There are several research studies (Gajda, 2004, Woodland, Lee & Randall, 2013, Frey, B. B., Lohmeier, J.H., Lee, S.W., & Tollefson, N., 2006, Bennett and Gadlin, 2012) that represent a variety of assessment methods to evaluate collaborations of organizations and individuals. Program evaluator Rebecca Gadja (2004) has developed a rubric that maps into three of the four variables listed by the TCAS. The rubric identifies five variables, purpose, strategies/ tasks, leadership/decision-making, the collaborative process, and interpersonal dynamics/communication. Of the five, only purpose does not directly map into the TCAS variables. However, this makes sense because the rubric is a tool used to assist in gauging the prospects of collaboration between groups and the TCAS evaluates activity after the collaboration has been formed. Moreover, it makes sense that you would evaluate whether you fulfilled your purpose.

Table 2.
Matrix of Selected Collaboration Themes.

Literature Reference	Categories of themes used to develop corresponding variables				
D'Amour, et al. (2005)	Sharing	Partnership	Interdependency	Power	Process
Woodland, Lee and Randall (2013)		Dialogue	Action Taking	Decision Making	Collaborative cycle of inquiry
Gadja (2004)	Purpose	Interpersonal and Communication	Strategies/Tasks	Leadership and Decision Making	Journey
Wood and Gray (1991)	Purpose		High Interdependency		Process
Bennet and Gadlin (2012)	Shared Vision	Trust and Communication		Decision Making	Enjoying the Science

The variables for this investigation represent elements that affect the existence of a collaboration. They are ***sharing***, ***action, dialogue, decision-making, process, collaboration,*** and ***affinity***. The first five variables represent concepts identified in my theoretical framework. They are also variables that are identified in the literature as variables that program evaluators use when evaluating collaborations. Sharing represents shared purpose and vison. Action represents the implementation that results from a sense of interdependency and synergy. Dialogue represents the communication needed to bring members into one accord. Decision-making references the power and authority to form conclusions regarding activity. Process represents the ongoing evolution of a collaboration. These elements that affect collaboration are groups or clusters of survey variables that correspond to each of the first five elements. For example, the sharing cluster is composed of seven variables.

The sixth variable, collaboration, represents a cluster of variables. It is the overall attitude a given STEM or arts discipline has towards collaboration. They are variables asked of one discipline regarding attitudes towards the other. These variables are designated with the suffix 'Collab' (e.g., AskStemCollab or AskArtCollab).

The seventh variable cluster, 'affinity,' is to be a direct measure of interest in collaboration as identified by the respondents. Affinity is a set of variables asked equally of both STEM and Arts professionals. These variables are designated with the prefix 'Affinity' (e.g., AffinityPrevStudy).

Based on a pilot project I carried out, there is evidence that would indicate that while artists are interested in creating STEAM programs, they are not necessarily interested in creating them with STEM professionals. Therefore, the variable affinity is relevant. It is an operationalization of the five stages espoused by Gajda (2004). The five stages map into the description of preconditions for a collaboration outlined by Gray and Wood (1991). The purpose of this variable is to find out if STEM and arts professionals are interested in collaboration.

Obtaining Data. The methods to be employed were mainly online surveys, i.e., five surveys identified below, plus noteworthy commentary. Surveys were sent via email to STEM and Arts 1) post-secondary academics at public and private universities, community colleges, 2) secondary and primary grade educators at public and private school districts, 3) professionals found in online services such as LinkedIn and twitter 4) professionals found in online industry and trade associations and 5) individual professionals found at public events such as art shows.

This data and subsequent analyses were useful in determining the prospects for collaboration between the arts communities and the STEM communities. A secondary benefit from identifying levels of compatibility is because not all goals and objectives require the highest level of collaboration between members of the participating communities (Gajda, 2004). The benefit in this collaboration-compatibility matching is that resources allocated for lower levels of collaboration are not as great as are needed for higher levels of collaboration. These resources can then be utilized for other purposes.

Surveys. Surveys were sent out using the Qualtrics survey software. The survey tool had Likert-type, categorical and interval response options. Survey questions designed to identify values for these variables provide insights for the development of the norms regarding how collaborations could operate. It would also identify areas where there would be challenges in finding commonality in the culture and beliefs of the potential collaborators. Surveys were sent to Arts and STEM higher education academics, Arts and STEM professionals, and Arts and STEM K-12 teachers. My strategy was to send out IRB approved Qualtrics surveys to academic instructors of these disciplines at U.S. academic institutions via their listed emails. My goal was to send out 500 to 1000 emails using MS Access database software to automate the process. I used some social media listings in conjunction with the online trade, craft, and professional associations to reach out to practicing Arts and STEM professionals. My goal was to send out emails to between 250 and 500 professionals.

Instrument Reliability and Validity

Instrument reliability is critical to data collection. To that end, I implemented several methods to ensure that various aspects of instrument reliability are addressed.

To establish instrument reliability, I created a small informal survey regarding the questions to be placed on the actual survey and in the interview list. I asked participants of this informal survey how well the questions match or solicit the intended information sought after. I stated the question and asked respondents to rank the question in a Likert format to indicate how likely the intended question will solicit the desired information.

To reduce measurement error, I have asked several questions about the same variable. The objective was to triangulate results for variables. This technique was used on a limited basis to prevent the survey from becoming unwieldy.

The different disciplines received slightly different surveys. Parallel form reliability was useful for comparing the surveys sent to the different disciplines. The goal was to ensure the various surveys were correlated so the analysis compared apples to apples.

Once the data was collected, a Cronbach's Alpha was calculated to determine the consistency of each thematic construct. This statistic was calculated for each theme in each version of the survey.

I guarded against external validity threat by asking the level of STEAM collaboration participants have engaged in. This allowed me to create profiles of different categories of participants' familiarity with STEAM. I solicited participants from a large geographic area to improve the generalization of my results. I may have had a degree of susceptibility to timing of data collection, but within the last year there appeared to be few or no events that could skew the thinking of the general population regarding STEAM.

The goal of data collection was to provide the basis for estimating the likelihood of establishing the compatibility and sustainability of collaboration between arts and STEM professionals as well as the feasibility of incorporating arts into the STEM framework for the purpose of determining which would be preferable. Since this is comparative, causality is not an issue in this investigation. Essentially, I am conducting surveys and looking for levels of compatibility between the surveyed groups.

Analysis of Data

In this investigation, descriptive statistics, Chi-squared analysis, t-tests, and multivariate analysis were used to evaluate the data. Although survey data represent most of the data analyzed, some qualitative data in the form of open-ended questions were analyzed to assist in identifying trends and meaning in the data.

Descriptive Analysis. In addition to identifying means and standard deviations for the survey questions, I tabulated data to assist in revealing any trends in the data. The tables include STEM responses, Arts responses, and the sum of responses for each survey variable item.

Inferential Analysis.

T-test Analysis. The strategy was that the more significant differences that exist between the means of variables that represent the responses of STEM and arts respondents, the least likely collaboration will be an effective means of creating STEAM projects and programs. Conversely, a lesser number of significant differences would suggest collaboration could be an effective means to develop STEAM projects and programs. Two-tailed analyses were performed.

The first t-test analysis compared STEM and Arts respondents across all Likert type and interval variables. The goal here was to identify all significant differences between the two groups of respondents for each survey question.

Chi-Square Analysis. Categorical data from nominal survey questions provided insights and context to the survey data. The data will be reviewed and synthesized to identify recurrent themes. The data collected by categorical variables was analyzed using a chi-squared approach. This will reveal if relationships exist among the categorical data.

Multivariate Regression Analysis. Using a sample from the population of STEM and Arts academic and industrial professionals, I wanted to predict prospects for collaboration between STEM and Arts professionals with several independent variables. I used the variables from the survey to create what I call 'Variable Clusters.' These variables are the conceptual framework variables and represent the five themes from the literature: namely, sharing, decision making, action, dialogue, and process. Each variable will be a cluster comprised of several items that fall within the theme of each framework variable. A summary of the analysis methods to be used can be found in Table 3 below.

Table 3.
Overview of Variable Analysis.

Mode of Analysis	Independent Variable	Dependent Variable	Purpose
T-Test	Group Membership	Questionnaire Items	To compare the means of STEM and Arts responses for specific variables to determine whether any difference in the means was significant.
Chi Squared	Discipline	Categorical Independent Variables	To determine if there was a relationship between the dependent variables and whether the respondent is a STEM or Arts professional.
Multivariate Regression	Ordinal and Interval Questionnaire Items	Preference	To determine the predictive strength of the independent variables regarding the prospects of collaboration between the STEM and Arts professionals.

The independent variables considered are:

Discipline of the STEM or Arts professional – discipline.

Inclination towards forming a collaboration – affinity.

Attitude towards collaboration – collaboration.

Attitude towards sharing in a collaboration – sharing.

Attitude towards the importance of dialogue in a collaboration – dialogue.

Attitude towards decision making in a collaboration – decision-making.

Attitude towards taking action in support of a collaboration – action.

Attitude towards the evolving process of maintaining a collaboration – process.

The dependent variable is:

Preference to collaborate with the STEM or Arts professionals – preference.

The two discipline variables will be respondents from the STEM or Arts disciplines. The variables affinity and collaboration are clusters of variables organized around the respondents' interest in collaborating and orientation towards collaborating with the other discipline, respectively. The five framework variables used in the analysis; sharing, dialogue, decision-making, action, and process will be comprised of clusters of variables. The clusters for each of the five independent framework variables are formed by grouping survey variables together under their common conceptual framework variables. The five independent clusters of framework variables and the dependent variable 'preference' will be used for regression analysis. I will use a hierarchical stepwise regression where a variable must be significant at the 0.05 level to enter the equation. Missing data will be replaced by the mean.

Qualitative analysis. In planning this research, a few pilot interviews helped to generate hypotheses. During the research, a few more interviews helped the interpretation of data and results.

Qualitative data from open-ended questions was useful for providing context to the survey questions. Two open-ended questions were used to collect data. Each respondent was asked to describe in one word what would be needed to create a successful collaboration. This information was placed in a word cloud to observe if any general trends revealed themselves. Respondents who had participated in STEM and Arts collaborations had the option to state in their own words what was their reason for collaborating.

Research goals and objectives

Given the responses to the survey questions, the analysis results predicted where STEM and Arts professionals stand with respect to the given collaboration variable. Given the set of values for the five independent collaboration variables, the analysis predicted where they stand regarding collaboration levels. Comparing the collaborations levels between disciplines showed which disciplines more easily collaborate with other disciplines (or if they prefer not to collaborate).

Coding

Two types of coding were used. The first was for survey data. That coding was derived from the variables found in the literature. Cluster variables that represented these themes were called sharing, dialogue, affinity, action, process, and decision-making. Questions were worded such that each choice ranked the response from least preferable to most preferable in a Likert type question. The four options were coded one for least preferable to four for most preferable. Questions that collected information from each set of variables were organized into groups that represented the cluster variables. The second type of coding will be for variables that can receive more than one selection such as demographic or discipline data. The above referenced themes will be used as guides but the final themes from the interview data will evolve from within the data.

CHAPTER 4

Data and Analysis

The purpose of this quantitative study is to investigate the prospects of creating STEAM programs and projects by either having STEM and Arts professionals collaborate or to cultivate Arts capacity in STEM professionals. This investigation was carried out by surveying STEM and Arts professionals in the academic and industrial. The areas solicited for respondents were academic institutions of higher learning, and the K12 educational setting. Industrial institutions were comprised of members of professional associations in the STEM and Arts disciplines. Arts professionals found at trade and arts shows were also sources of potential respondents. Higher educational institutions were comprised of four-year universities and two-year community colleges. The K-12 educational setting included primary (K-8) and secondary school (9-12) grade levels. Respondents provided information through an online collection tool for surveys (Qualtrics). This section includes data and analysis based on the strategy and tactics outlined in the methods section. The findings are based on evaluating the compatibility of STEM and Arts professionals as determined by their responses to questions designed to reveal their thoughts and opinions about collaboration between the two groups of professionals.

Descriptive Analysis.

Demographic Descriptive Analysis of Sample. A total of 419 STEM and Arts professionals participated in the study. Figure 2 presents the four areas including STEM and Arts academics and industry professionals. The STEM professionals comprise the disciplines of science, engineering, technology, and mathematics. The Arts disciplines are comprised of architecture, dance, music, literature, media arts, music, theater, and visual arts.

The respondent’s selections on questions from the demographics section provide the data necessary to describe the sample. Respondents answered questions in the final section of the survey instrument (see Appendix A). 399 of the 419 respondents reside in the Americas. Out of the 399 residents in the Americas, 395 reside in the United States. All Arts respondents reside in the United States and only four STEM respondents do not reside in the United States. Nine respondents did not indicate where they reside.

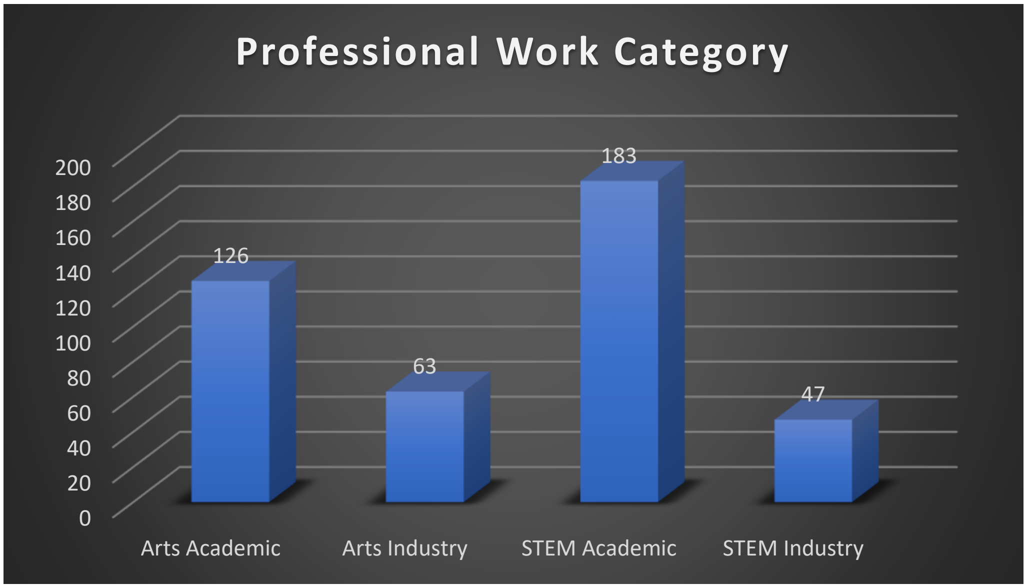

Figure 2. Career Path that Best Describes Most of your Professional Work.

Figure 3 shows that most respondents have a doctorate degree (189), followed by master’s degrees (155), a post-secondary degree (55) and high school graduates (9). When disaggregated by STEM and Arts disciplines, 60.3% of STEM professionals have a doctoral degree, 31.7% have a master’s degree, 7.1% have a college degree and 0.9% have a high school degree (Table 4). 29% of Arts professionals have a doctoral degree, 45.2% have a master's degree, 22% have a college degree and 3.8% have a high school degree (Table 4). This response was left blank by nine participants.

Table 4.

Comparison of Degree Attained by Respondents.

	Full Data Set by Education		STEM Data Set by Education		Art Data Set by Education	
Degree	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
H.S. Diploma	9	2.2	2	0.9	7	3.8
Baccalaureate	57	13.9	16	7.1	41	22
Master’s	155	37.8	71	31.7	84	45.2
Doctorate	189	46.1	135	60.3	54	29
Total	410	100	224	100	186	100

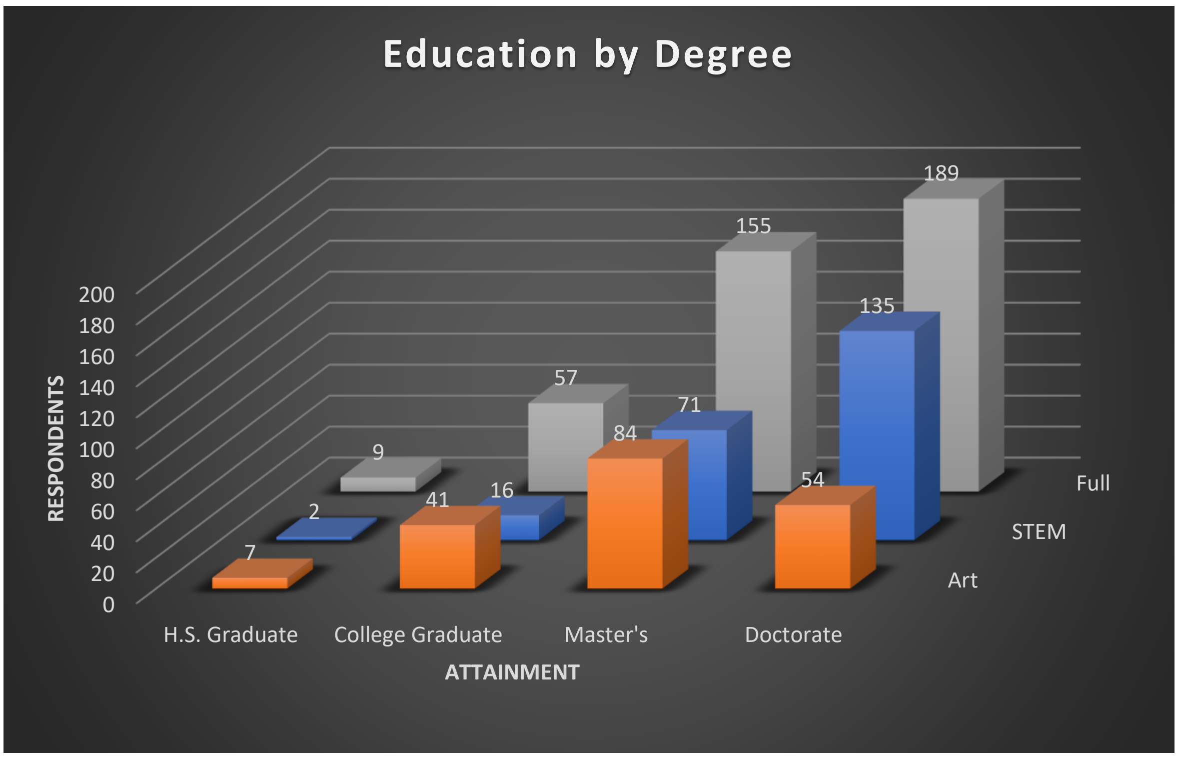

Figure 3. Distribution of Degrees Attained by Discipline.

Figure 4 describes the number of years the respondents have worked. Far and away, most respondents have worked 20 or more years. 49.1% of STEM professionals have worked for twenty or more years and 62.6% of Arts professionals have worked twenty or more years (Table 5). This response was left blank by ten participants.

Table 5.

STEM and Arts Respondents by Years Worked.

	STEM Data Set by Years Worked		**Art Data Set by Years Worked**	
Years	Frequency	Valid Percent	Frequency	Valid Percent
0 - 4	23	10.4	5	2.7
5 - 9	29	13.1	14	7.5
10 - 14	31	14	22	11.8
15 - 19	30	13.5	29	15.5
20+	109	49.1	117	62.6
Total	222	100	187	100

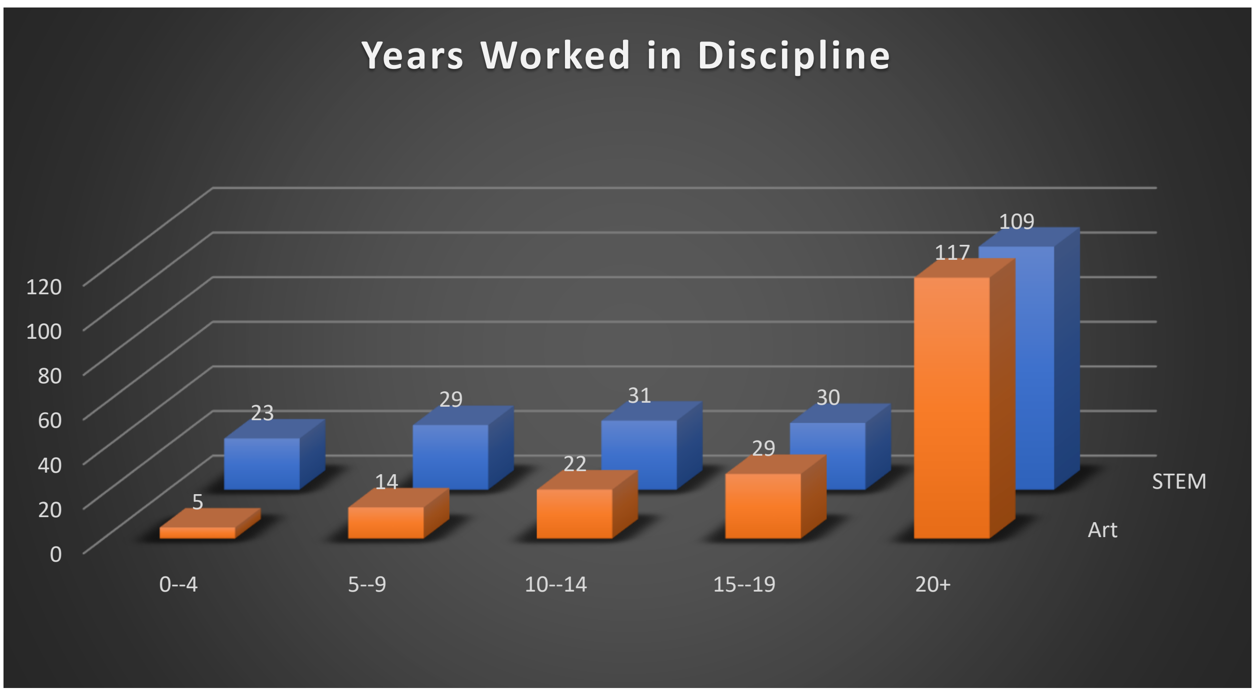

Figure 4. Distribution of Years of Work by Discipline.

Figure 5 shows slightly over half of the respondents (52%) self-identified as female. Self-identified as male comprised 42.4% with non-Binary/3rd Gender and Prefer Not to Say representing 2.2% and 3.4% of responses, respectively. Among STEM professionals the comparison of female to male respondents is 48.4% to 45.7% respectively (Table 6). Among Arts respondents the comparison of female to male respondents is 56.1% to 38.5%, respectively. This response was left blank by nine participants.

Table 6.

STEM and Arts Respondents by Gender Indication.

	Full Data Set		STEM Data Set		Arts Data Set	
Gender	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
Male	174	42.4	102	45.7	72	38.5
Female	213	52	108	48.4	105	56.1
Non-binary/3rd Gender	9	2.2	6	2.7	3	1.6
Prefer not to say	14	3.4	7	3.1	7	3.7
Total	410	100	223	100	187	100

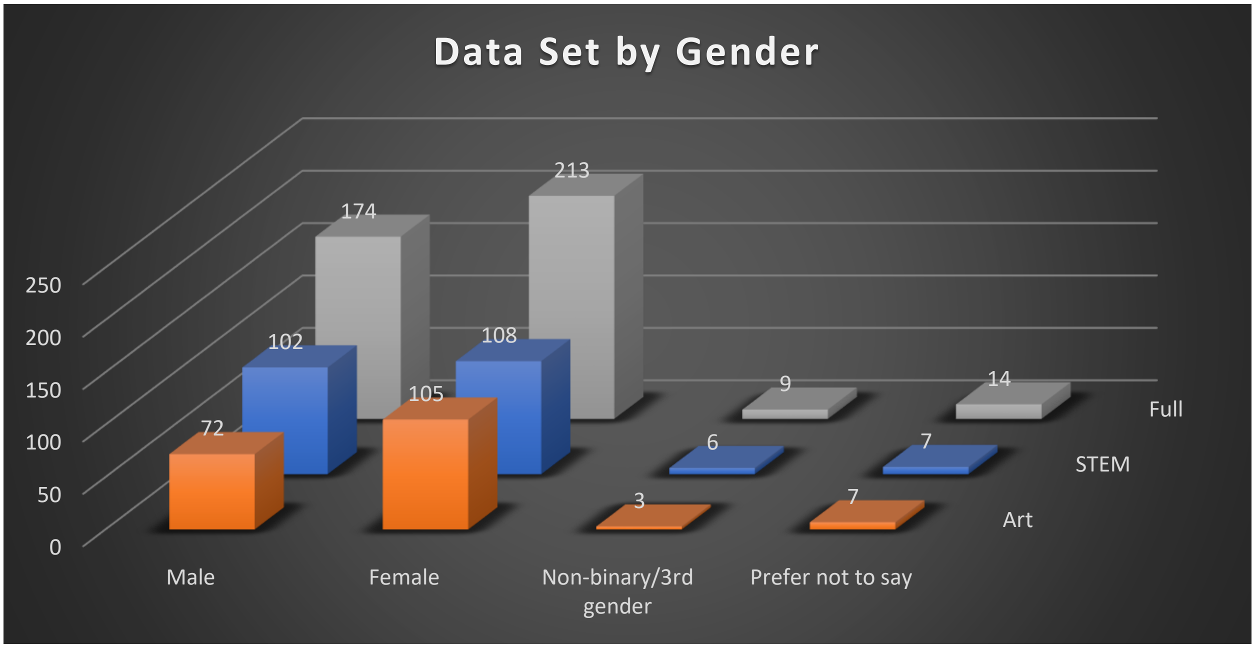

Figure 5. Arts Responses Disaggregated by Gender Identification.

Arts and STEM academics were asked which grade levels they teach. Figure 6 presents the responses to this question. Of the 307 responses to this inquiry, 79.5% teach at the post-secondary level, 9.8% at the 9-12 grade range and 10.7% at the preK-8 grade range (Table 7). Two academic professionals did not respond to this question and the remaining 110 respondents are industry professionals.

Table 7.
Grade Levels Taught by Respondents.

	Full Data Set		STEM Data Set		Arts Data Set	
Grade Level	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
PreK – 8	33	10.7	18	9.9	15	11.9
9 – 12	30	9.8	15	8.3	15	11.9
Post-secondary	244	79.5	148	81.8	96	76.2
Total	307	100	181	100	126	100

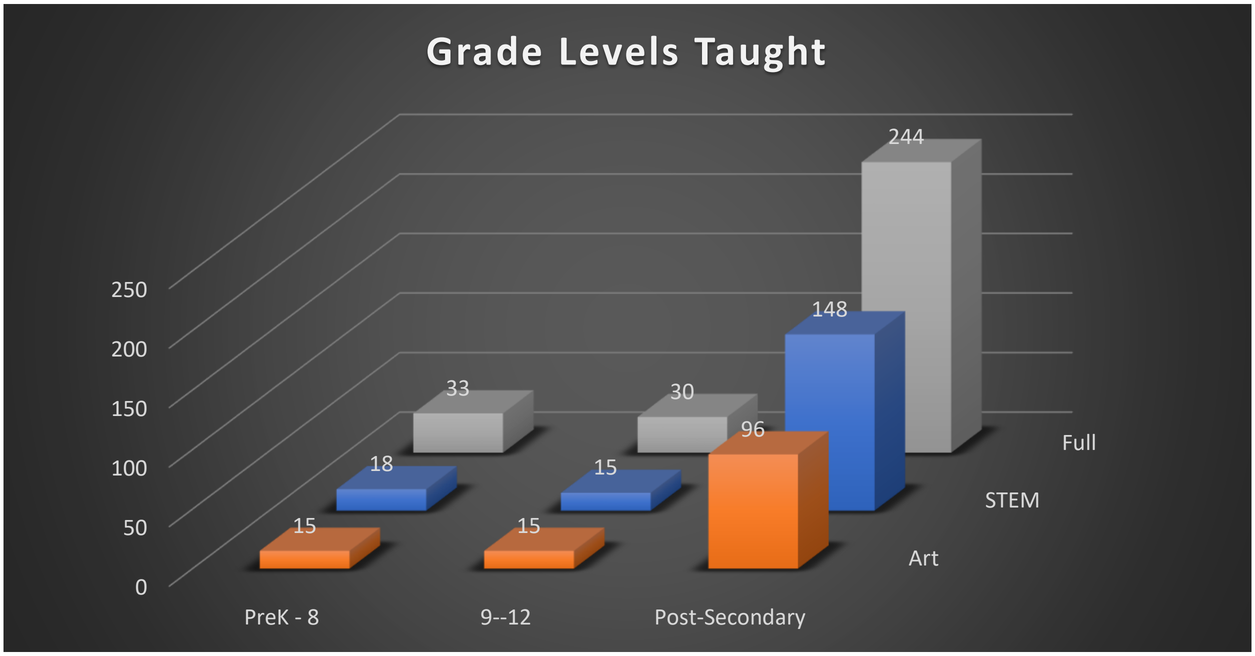

Figure 6. Academic Arts Responses Disaggregated by Grades Taught.

Three hundred and ninety-one of 419 respondents indicated their geographic area of origin. Respondents were allowed to indicate all the areas that applied to their ancestry. A total of 426 claims were tallied and summarized in Table 8. Europe was far and away the most often claimed region, either singly or in combination with other selections. Northern Asia was the least selected region. Aside from Europe, the only other regions with double digit entries are the Indigenous Americas and Africa.

Table 8.
Total Responses by Single and Multi-Geographic Ancestry.

	STEM Data Set		Arts Data Set		Totals	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Africa	14	6.03	23	11.86	37	8.69
Central Asia	1	0.43	4	2.06	5	1.17
Europe	155	66.81	135	69.59	290	68.08
Far East Asia	11	4.74	6	3.09	17	3.99
Indigenous Americas	29	12.50	18	9.28	47	11.03

Middle East	8	3.45	0	0	8	1.88
Northern Asia	2	0.86	0	0	2	0.47
Oceania	0	0	3	1.55	3	0.70
Southeast Asia	12	5.17	5	2.58	17	3.99
Totals	232	100	194	100	426	100

Conceptual Framework Variables Descriptive Data. The data associated with the variable clusters Action, Affinity, Dialogue, Decision-making, Process and Sharing is presented in a series of tables. Not all variables from each cluster are presented here, only the ones that appeared to be most illustrative of key findings. Brief analyses of trends in the data are included. The format of presentation within each variable cluster will be the Likert scale variables first followed by categorical variables, and finally, interval variables. All three types of variables do not appear in all clusters.

Sharing Descriptive Data.

Table 9.

Importance of Collaboration adding Value and Growth to Members' Lives.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Not at all important	2	0.9	2	1.1
Slightly important	30	13.4	13	7.1
Moderately important	93	41.5	75	40.8
Very important	99	44.2	94	51.1
Total	224	100	184	100
Mean	2.29		2.42	
SD	0.728		0.673	

408 respondents addressed the question about the importance of the collaboration adding relevant value and growth to the participants' lives. The predominant answer, 'Very important,' was selected by 193 (47.3%) of all respondents (Table 9). 99 STEM respondents (44.2%) and 94 Arts respondents (51.1%) chose 'Very important' as their first choice.

Table 10.

Importance of how Credit in the Collaboration will be Shared.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Not at all important	22	9.8	21	11.4
Slightly important	84	37.3	55	29.9
Moderately important	84	37.3	70	38
Very important	35	15.6	38	20.7
Total	225	100	184	100
Mean	1.59		1.68	
SD	0.867		0.929	

409 respondents addressed the question of how important the determination of how credit will be shared prior to beginning collaborative activity (Table 10). Both STEM and Arts respondents agreed on the order of the selections.

Table 11.

Importance of Various Factors in the Formation of the Collaborative.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Shared Vision	107	51	90	54.2
Common Strategy and Tactics	11	5.2	10	6
Agreement Between Personal and Shared Vision	36	17.1	26	15.7
Buy-in of Stakeholders	56	26.7	40	24.1
Total	210	100	166	100

376 respondents addressed the question of what is most important to the ongoing and evolving collaborative process. Table 11 shows the results of respondents who were given four options; ‘Shared Vision,' ‘Common Strategy and Tactics,' ‘Agreement Between Personal and Shared Visions,' and ‘Buy-in of Stakeholders.' 197 respondents (52.4%) chose 'Shared Vision’ as the first choice. 21 respondents (5.6%) chose 'Common Strategy and Tactics,’ as their first

choice. 62 respondents (16.5%) chose ‘Agreement Between Personal and Shared Visions' as their first choice. 96 respondents (25.5%) chose 'Buy-in of Stakeholders’ as their first choice.

Process Descriptive Data.

Table 12.
Importance of Planning for Structural or Relationship Changes in a Collaboration.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Unimportant	10	4.4	5	2.7
Somewhat important	52	23.1	27	14.5
Important	109	48.4	103	55.4
Very important	54	24	51	27.4
Total	225	100	186	100
Mean	1.92		2.08	
SD	0.803		0.724	

411 respondents addressed the question of the importance of a plan for changes in either structure or relationships in a collaboration. The percentage of Arts respondents (55.4%) who chose 'Important' as the top selection is 14.46% higher than the STEM respondents (48.4%) that made the same selection (Table 12).

Table 13.
Importance of Member Buy-in to the Ongoing Process of Collaboration.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Unimportant	2	0.9	1	0.5
Somewhat important	16	7.1	10	5.4
Important	68	30.4	50	26.9
Very important	138	61.6	125	67.2
Total	224	100	186	100
Mean	2.53		2.61	
SD	0669		0.617	

Four hundred ten respondents addressed the question of the importance of member buy-in to the ongoing process of collaboration. The percentage of Arts respondents (67.2%) who chose 'Very important' as the top selection is 9.09% higher than the STEM respondents (61.6%) that made the same selection (Table 13).

Table 14.
Importance of Various Factors in the Ongoing and Evolving Collaborative Process.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Personal Growth in Member Skills and Knowledge	55	25.7	40	23
Acquisition of New Organizational Goals and Objectives	23	10.7	25	14.4
Organized, Effective Meetings	76	35.5	61	35.1
Accountability Among Members	60	28	48	27.6
Total	214	99.9	174	100.1

388 respondents addressed the question of what is most important to the ongoing and evolving collaborative process. Table 14 shows that ‘Organized, Effective Meetings ' is the most selected first choice for both STEM and Arts respondents.

Dialogue Descriptive Data.

Table 15.

Respondents Believe Disagreement Can Lead to Greater Understanding.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	0	0	2	1.1
Disagree	23	10.3	8	4.4
Agree	153	68.6	124	68.9
Strongly agree	47	21.1	46	25.6
Total	223	100	180	100
Mean	2.11		2.19	
SD	0.551		0.557	

Most respondents of respondents agree that disagreements lead to greater understanding. The percentage ‘Agree’ approaches 70% for both STEM and Arts professionals (Table 15).

Table 16.

Importance of Pre-existing Relationships among Collaboration Members.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Not important	27	11.8	37	19.9
Somewhat important	81	35.5	70	37.6
Important	88	38.6	55	29.6
Most important	32	14	24	12.9
Total	228	100	186	100
Mean	1.55		1.35	

The importance of pre-existing relationships shows differences in perspectives between STEM and Arts respondents. 38.6% of STEM respondents felt this topic was important while only 29.6% of Arts respondents felt it was important (Table 16).

Table 17.

Important are norms and protocols of interaction for group collaboration.

	STEM		Art		Full	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
Not important	8	3.5	5	2.7	13	3.1
Somewhat important	87	38.2	53	28.5	140	33.8
Important	101	44.3	99	53.2	200	48.3
Most important	32	14	29	15.6	61	14.7
Total	228	100	186	100	414	100

Both STEM and Arts respondents agree on the importance of norms and protocols of behavior in a collaboration. A majority of 101 (44.3%) STEM respondents and 99 (53.2%) Arts respondents selected ‘Important’ as their first choice (Table 17).

Table 18.

Importance of a culture of critical peer analysis and professional disagreement.

	STEM Data Set		Art Data Set		Full Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
Not important	2	0.9	5	2.7	7	1.7
Somewhat important	20	8.7	15	8.1	35	8.4
Important	118	51.5	72	38.7	190	45.8
Most important	89	38.9	94	50.5	183	44.1
Total	229	100	186	100	415	100

While agreeing that peer review and professional disagreement are important, STEM and Arts respondents differed in the level of importance. Table 18 shows the percentage of STEM respondents who selected 'Important' is 33.07% higher than the percentage of Arts respondents who selected 'Important.' The percentage of Arts respondents who selected 'Most important' is 29.82% higher than the percentage of STEM respondents who selected 'Most important.'

Table 19.
Respondents' Preference for Resolving Disagreements in a Collaboration.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Fact-Finding	116	60.4	76	50
Negotiation	49	25.5	56	36.8
Mediation	20	10.4	16	10.5
Voting	7	3.6	4	2.6
Total	192	99.9	152	99.9

Fact-finding was chosen as the first choice to resolve disagreements by 60.4% of STEM and 50% of Arts professionals (Table 19).

Decision-making Descriptive Data.

Table 20.
Decision Making Authority should be based on Experience and Expertise.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	1	0.4	1	0.5
Disagree	7	3.1	13	6.9
Agree	134	58.8	103	54.8
Strongly agree	86	37.7	71	37.8
Total	228	100	188	100
Mean	2.34		2.3	
SD	0.559		0.618	

Table 20 shows that 416 respondents addressed the question whether decision making authority should be based on experience and expertise. 'Agree' (237) was the first choice of all respondents. The percentages of STEM respondents who chose the top selection is 7.30% higher than the Arts respondents that made the same selection. The percentages of Arts respondents who chose the second highest selection option is 0.27% higher than the STEM respondents that made the same selection.

Table 21.
Decision Making Authority should be based on Consensus.

	STEM Data Set		Art Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	5	2.2		
Disagree	18	7.9	7	3.8
Agree	133	58.6	101	54.6
Strongly agree	71	31.3	77	41.6
Total	227	100	185	100

Four hundred twelve respondents addressed the question whether decision making authority should be based on consensus. Table 21 indicates the predominate answer, 'Agree,' was selected by 234 of all respondents. The percentages of Arts and STEM respondents are in closer alignment with respect to the less strong choice of 'Agree' but are farther apart with respect to 'Strongly agree.' A larger percentage of Arts respondents favor consensus more strongly than STEM respondents.

Action Descriptive Data.

Table 22.
Importance of Careful Selection of Members in a Collaboration.

	STEM		Arts	
	Frequency	Valid Percent	Frequency	Valid Percent
Not important	2	0.9	4	2.1
Somewhat important	35	15.4	27	14.4
Important	123	53.9	93	49.7
Very important	68	29.8	63	33.7
Total	228	100	187	100
Mean	2.13		2.15	
SD	0.688		0.74	

Table 23.

Importance of Clarity of assignment in a Collaboration.

	STEM		Arts	
	Frequency	Valid Percent	Frequency	Valid Percent
Somewhat important	6	2.6	6	3.2
Important	77	33.8	48	25.7
Very important	145	63.6	133	71.1
Total	228	100	187	100
Mean	2.61		2.68	
SD	0.54		0.533	

Both STEM and Arts professionals agree on the importance of specific characteristics of a collaboration when it comes to accountability and completion of tasks. They both feel the selection process (Table 22) for membership is important (53.9% STEM; 49.7% Arts), clarity in assigned tasks (Table 23) is very important (63.6% STEM, 71.1% Arts).

Affinity Descriptive Data.

Table 24.

Indication whether Lack of Social Connection Hinders Collaboration.

	STEM		Arts	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	3	1.3	3	1.6
Disagree	38	16.9	43	23.4
Agree	135	60	85	46.2
Strongly agree	49	21.8	53	28.8
Total	225	100	184	100
Mean	2.02		2.02	
SD	0.664		0.768	

Overall, 81.8% of STEM and 75% of Arts professionals agree that lack of social connections would hinder a collaboration. Table 24 shows a larger percentage of Arts professionals (23.4%) than STEM professionals (16.9%) disagree that lack of social connection would inhibit collaboration. A larger percentage of Arts professionals (28.8%) than STEM professionals (21.8%) strongly agree that lack of social connections would inhibit collaboration.

Table 25.
I have personally reached out to Art (STEM) professionals to collaborate.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	57	24.9	43	23
Disagree	95	41.5	67	35.8
Agree	41	17.9	47	25.1
Strongly agree	36	15.7	30	16
Total	229	100	187	100
Mean	1.24		1.34	
SD	1.001		1.006	

Four hundred sixteen respondents indicated if they personally reached out to collaborate. 162 respondents (38.9%) selected 'Disagree.' 100 respondents (24%) selected 'Strongly disagree.' Table 25 shows the percentage of STEM respondents (41.5%) who selected 'Disagree' is 15.92% higher than the percentage of Arts respondents (35.8%) that made the same selection. In total, 66.1% of STEM professionals and 58.8% of Arts professionals have not reached out to the other discipline for collaboration.

Table 26.
Respondents are Receptive to Invitations to Collaborating to Develop STEAM.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	9	3.9	1	0.5
Disagree	31	13.5	13	7
Agree	130	56.5	107	57.2
Strongly agree	60	26.1	66	35.3
Total	230	100	187	100
Mean	2.05		2.27	
SD	0.743		0.609	

Most of all respondents either agreed or strongly agreed they would be interested in collaborating if approached (Table 26).

Table 27.

Only Members of a Discipline should Develop STEAM for that Discipline.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
Strongly disagree	53	23.5	38	20.7
Disagree	122	54	89	48.4
Agree	42	18.6	32	17.4
Strongly agree	9	4	25	13.6
Total	226	100	184	100
Mean	1.03		1.24	
SD	0.762		0.934	

Most STEM respondents either disagreed (54%) or strongly disagreed (23.5%) that STEAM should only be developed from within the discipline it is used for (Table 27). Most Arts respondents either do disagree (48.4%) or strongly disagree (20.7%) that STEAM should only be developed from within the discipline it is used for.

Table 28.

Reported Specialization of Colleagues who Studied both STEM and Art.

	STEM		Arts	
	Frequency	Valid Percent	Frequency	Valid Percent
STEM specialization	18	11.7	2	1.5
Mostly STEM	84	54.5	13	9.8
Equal amounts of each	17	11	25	18.9
Mostly Art	14	9.1	43	32.6
Art specialization	3	1.9	23	17.4
Not sure	18	11.7	26	19.7
Total	154	100	132	100
Mean	1.7		3.14	

STEM professionals reported their acquaintances ended up either specializing in STEM (11.7%) or doing mostly STEM (54.5%) (Table 28). Likewise, a majority of acquaintances of Arts professionals ended up either specializing in art (17.4%) or doing mostly art (32.6%). The STEM respondents reported that 11% of their acquaintances professionally performed equal amounts of each while Arts respondents report 18.9% did the same.

Table 29.

Respondents Reasons for Not Participating in a STEM and Arts Collaboration.

	STEM Data Set		Arts Data Set	
	Frequency	Valid Percent	Frequency	Valid Percent
I've never been approached /asked	58	47.5	78	71.6
Lack of opportunity	39	32	15	13.8
I never thought about it	24	19.7	12	11
Arts/STEM professionals don't respect STEM/Arts disciplines	1	0.8	4	3.7
Total	122	100	109	100
Mean	0.74		0.47	

Table 30.

Appearance Frequency of Reason for Collaboration Options.

	STEM		Art	
	Frequency	Valid Percent	Frequency	Valid Percent
I was asked	32	20.8	26	21.0
I wanted to collaborate	58	37.7	49	39.5
The Project Required both STEM and Art	50	32.5	39	31.5
Other	14	9.1	10	8.1
Total	154	100.0	124	100.0

Both groups indicated that not being approached is the main reason they had not collaborated (Table 29). A much larger percentage of Arts professionals (71.6%) report not being approached than do STEM professionals (47.5%). The most selected individual reason to collaborate was that the respondent wanted to collaborate (Table 30).

Table 31. Percentage of colleagues known who specialize in either STEM or Art
Percentage of colleagues known who specialize in either STEM or Art.

	STEM		Art		Totals	
Percentage Performing Either	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
0 - 9	10	4.8	16	9.8	26	6.9
10 - 19	7	3.4	12	7.4	19	5.1
20 - 29	7	3.3	8	4.9	15	4
30 - 39	10	4.9	5	3	15	4.1
40 - 49	5	2.4	9	5.5	14	3.8
50 - 59	11	5.2	11	6.8	22	6
60 - 69	8	3.8	8	4.9	16	4.3
70 - 79	21	9.9	14	8.5	35	9.3
80 - 89	35	16.6	23	14.2	58	15.5
90 - 100	98	46.3	56	34.6	154	41.1
Sub-Total	212	100	162	100	374	100
Missing	18		27		45	
Total	230		189		419	

Respondents indicated the percentage of their colleagues that specialize in either STEM or art in their professional careers. Over 65% of respondents indicated that between 80% to 100% of their colleagues specialize in either STEM or arts (Table 31). Most respondents indicate they know very few people who don’t specialize.

Table 32.

Percentage of colleagues known who combine both STEM and Art.

	STEM		Art		Total	
Percentage Performing Both	Frequency	Valid Percent	Frequency	Valid Percent	Frequency	Valid Percent
0 - 9	58	28.2	22	13.3	80	21.6
10 - 19	57	27.8	35	21.2	92	24.9
20 - 29	29	14.1	24	14.5	53	14.3
30 - 39	22	10.8	23	13.9	45	12
40 - 49	8	3.9	9	5.4	17	4.5
50 - 59	13	6.4	16	9.7	29	7.9
60 - 69	4	2	7	4.2	11	3
70 - 79	5	2.4	10	6	15	4.1
80 - 89	7	3.4	10	6	17	4.6
90 - 100	3	1.5	9	5.4	12	3.3
Sub-Total	206	100	165	100	371	100
Missing	24		24		48	
Total	230		189		419	

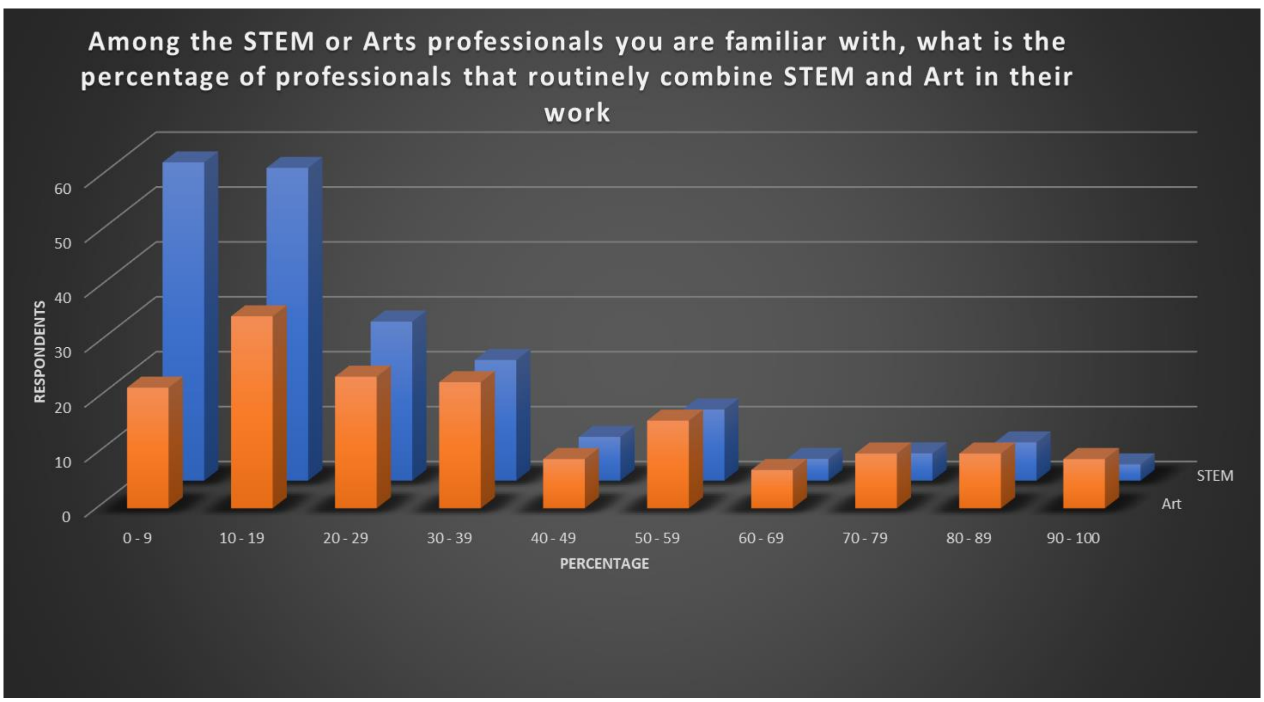

Figure 7. Respondents’ Colleagues who Routinely Combine STEM and Art in their Work.

Table 32 shows that very few respondents have colleagues that combine STEM and arts in their professional work. Over 60% of the respondents reported less than 30% of their colleagues combine STEM and arts in their professional work. Figure 7 shows that more STEM professionals are clustered in the 0% to 29% range of people having colleagues that combine STEM and art than Arts professionals. The appears to be an inflection point at the 30% to 49% range where there is a greater number of Arts professionals that know colleagues that combine STEM and arts as compared to STEM professionals. Between 50% and 100% more Arts professionals have colleagues that combine STEM and art than STEM professionals have.

Inferential analysis.

T-tests. To assist in determining whether STEM and Arts professionals should create STEAM through either collaboration or organically from within their respective disciplines, a question to answer is if the two groups see the various aspects of collaboration similarly. A T-test between the two groups, STEM and Arts respondents, was conducted over 36 variables. Levene's Test for Equality of Variances was used to determine whether equal variance should be assumed. Approximately two variables might be expected to be significant by chance, as Type 1 errors. Twelve of the 36 variables revealed significant differences between the means for the two groups. These are items 2, 4, 12, 18, 22, 28, 30, 32, 36, 37, 39 and 41. The remaining items showed no significant difference between the means. The variables and their meanings are summarized in Table 33.

Table 33.

Variable Identification for T-tests.

Variable Item Number	Variable Name	Variable Abbreviation	Variable Meaning
1	PwrDistrDecisions_1	PDD1	The decision-making authority should be distributed based on experience and expertise with issues at hand.
2	PwrDistrDecisions_2	PDD2	The decision-making authority in a collaboration should be distributed based on a rotating or revolving basis.
3	PwrDistrDecisions_3	PDD3	The decision-making authority should be distributed based on areas of responsibility (tasks, roles, components, etc.).
4	PwrMakeDecision_1	PMD1	The decision-making process in a collaboration of Arts and STEM professionals should use consensus.
5	PwrMakeDecision_2	PMD2	The decision-making process in a collaboration of Arts and STEM professionals should use majority rule.
6	PwrMakeDecision_3	PMD3	The decision-making process in a collaboration of Arts and STEM professionals should use hierarchical leadership structures.
7	PwrMakeDecision_4	PMD4	The decision-making process in a collaboration of Arts and STEM professionals should use committee driven decision making.
12	PwrOpenDecisions	POD	How important to the group is transparency in decision making.
13	DialogueDisagreePos	DDP	Disagreement can lead to greater understanding in a collaboration.
18	DialogueWrittenAgree	DWA	How useful it would be to have a written agreement of the rules and norms of collaboration interaction.
22	DialogueInterpersona_1	DI1	Importance of pre-existing collegial and interpersonal relationships among prospective members.
23	DialogueInterpersona_2	DI2	Importance of trust that other members of a collaboration will

			produce competent, feasible ideas, designs, and results.
24	DialogueInterpersona_3	DI3	Importance of a culture within the collaboration that actively supports critical peer analysis and professional disagreement.
25	DialogueInterpersona_4	DI4	Importance of norms and protocols of interaction for group collaboration.
26	ActionAccountable_1	AA1	A collaboration should have careful selection of collaboration members.
27	ActionAccountable_2	AA2	A collaboration should have sufficient clarity in assigned tasks.
28	ActionAccountable_3	AA3	A collaboration should have formal structures of committees and subcommittees.
30	AffinitySteamWitWhom_1	ASWW1	Preference to create STEAM projects and programs with a STEM professional.
31	AffinitySteamWitWhom_2	ASWW2	Preference to create STEAM projects and programs with an Arts professional.
32	AffinityCollabProspe_1	ACP1	21st Century challenges and opportunities were seen as more of a reason to collaborate.
33	AffinityCollabProspe_2	ACP2	Lack of a social connection will hinder collaboration development.
34	AffinityPrevStudy	APS	Know someone (yourself/colleagues/classmates/et cetera) who included both STEM and Arts in their studies.
36	AffinityPercSpecial_1	APS1	Among the STEM or Arts professionals respondents are familiar with, what is the percentage of professionals that routinely combine STEM and Art in their work.
37	AffinityPercSpecial_2	APS2	Among the STEM or Arts professionals respondents are familiar with, what is the percentage of professionals that specialize in either STEM or art in their work.
38	AffinityAesthSimilar	AAS	The aesthetic in STEM fields is similar to the aesthetic in Art fields.

39	ProcessChangePrep_1	PCP1	Importance to plan for changes in either the structure or relationships in a collaboration.
40	ProcessChangePrep_2	PCP2	Importance of member buy-in to the ongoing process of collaboration.
41	ProcessChangePrep_3	PCP3	Importance of the way people treat each other, outside of requirements to complete goals and objectives.
52	SharBeneMember_1	SBM1	The collaboration adds relevant value and growth to the participant's lives
53	SharBeneMember_2	SBM2	The determination of how credit will be shared prior to beginning collaborative activity.
65	AskStemCollab	ASC	Whether the STEM profession ever collaborated with an Arts professional.
66	AskArtCollab	AAC	Whether the STEM profession ever collaborated with an Arts professional.
67	StemInterestInCollab_1	SIC1	I am very interested in learning more about Arts disciplines.
70	StemInterestInCollab_4	SIC4	Art and STEM collaborations to create STEAM programs and projects should be long term instead of short term in duration.
71	StemInterestInCollab_5	SIC5	STEAM projects and programs used in STEM should be developed only by professionals from STEM.
72	ArtInterestInCollab_1	AIC1	I am very interested in learning more about STEM disciplines.
75	ArtInterestInCollab_4	AIC4	Art and STEM collaborations should be formed with the idea that the collaborations become permanent as opposed to ad hoc.
76	ArtInterestInCollab_5	AIC5	STEAM should be developed for use in Art only by professionals from the Arts.

Twelve variables associated with power (decision-making), communication (dialogue), implementation (action), interest in collaboration (affinity) and the evolving nature of a collaboration (process) showed significant differences between the means for STEM and Arts respondents. Statistical data for these variables is presented in Table 34. Only the variables associated with common beliefs (sharing) showed no statistically significant differences.

Table 34.
Statistically significant two-tail T-tests results.

Variable Item Number	Variable Name	Mean (STEM|Art)		Standard Deviation (STEM|Art)		t value	Sig t value
2	PwrDistrDecisions_2	1.38	1.61	0.727	0.704	3.335	0.001
4	PwrMakeDecision_1	2.19	2.38	0.668	0.559	3.069	0.002
12	PwrOpenDecisions	2.46	2.65	0.558	0.512	3.611	< 0.001
18	DialogueWrittenAgree	1.88	2.12	0.945	0.853	2.724	0.007
22	DialogueInterpersona_1	1.55	1.35	0.877	0.943	-2.158	0.032
28	ActionAccountable_3	1.18	1.37	0.853	0.854	2.3	0.022
30	AffinitySteamWitWhom_1	2.04	2.18	0.663	0.607	2.224	0.027
32	AffinityCollabProspe_1	2.03	2.34	0.786	0.715	4.099	< 0.001
36	AffinityPercSpecial_1	22.42	35.20	21.97	28.038	4.795	<0.001
37	AffinityPercSpecial_2	73.56	63.23	28.802	33.594	-3.129	0.002
39	ProcessChangePrep_1	1.92	2.08	0.803	0.724	2.039	0.042
41	ProcessChangePrep_3	2.66	2.77	0.584	0.468	2.158	0.032

There are three items under the decision-making variable cluster that showed statistically significant differences. STEM and Arts respondents were asked if decision making authority in a collaboration should be distributed based on a rotating or revolving basis (Item 2). STEM respondents were closer to selection ‘disagree’ with this strategy than Arts respondents, who were closer to the selection ‘agree.’ There were significant differences ($t(412) = 3.335$, $p = 0.001$) in scores for STEM ($M = 1.38$, $SD = 0.727$) and Arts ($M = 1.61$, $SD = 0.704$). The magnitude of the differences in the means (mean difference = 0.236, 95% CI: 0.097 to 0.375) was significant. Both STEM and Arts respondents were closer to the selection ‘agree’ than not regarding whether the decision-making process in a collaboration of Arts and STEM professionals should use consensus (Item 4). However, on average, Arts respondents felt more strongly about consensus than STEM respondents. There were significant differences ($t(410) =$

3.069, $p = 0.002$) in scores for STEM ($M = 2.19$, $SD = 0.668$) and Arts ($M = 2.38$, $SD = 0.559$). The magnitude of the differences in the means (mean difference = 0.189, 95% CI: 0.068 to 0.31) was significant. STEM and Arts professionals agreed regarding how important to the group is transparency in decision making (Item 12). On average though, the STEM respondents were closer to the ‘agree’ selection while Arts respondents were closer to ‘strongly agree’ selection. There were significant differences ($t(410.67) = 3.611$, $p < 0.001$) in scores for STEM ($M = 2.46$, $SD = 0.558$) and Arts ($M = 2.65$, $SD = 0.512$). The magnitude of the differences in the means (mean difference = 0.189, 95% CI: 0.086 to 0.292) was significant.

There are two items under the dialogue variable cluster that showed a statistically significant difference between the STEM and Arts respondents. Arts respondents had a stronger feeling regarding how useful it would be to have a written agreement of the rules and norms of collaboration interaction than STEM respondents (Item 18). There were significant differences ($t(411.255) = 2.724$, $p = 0.007$) in scores for STEM ($M = 1.88$, $SD = 0.945$) and Arts ($M = 2.12$, $SD = 0.853$). The magnitude of the differences in the means (mean difference = 0.24, 95% CI: 0.067 to 0.414) was significant. STEM respondents placed a greater importance on pre-existing collegial and interpersonal relationships among prospective members than Arts respondents (Item 22). There were significant differences ($t(412) = -2.158$, $p = 0.032$) in scores for STEM ($M = 1.55$, $SD = 0.877$) and Arts ($M = 1.35$, $SD = 0.943$) respondents. The magnitude of the differences in the means (mean difference = -0.193, 95% CI: -0.37 to -0.017) was significant.

There is one item under the action variable cluster that showed statistically significant differences between the two groups. Art respondents felt more strongly than STEM respondents when it came the opinion that to ensure assigned actions are carried out in a timely manner, a collaboration should have formal structures of committees and subcommittees (Item 28). There were significant differences ($t(413) = 2.3$, $p = 0.022$) in scores for STEM (M = 1.18, SD = 0.853) and Arts (M = 1.37, SD = 0.854). The magnitude of the differences in the means (mean difference = 0.194, 95% CI: 0.028 to 0.359) was significant.

There are four items under the affinity variable cluster that showed statistically significant differences between the two respondent groups. Arts professionals have a greater preference to create STEAM projects and programs with STEM professionals than STEM professionals prefer to work with other STEM professionals (Item 30). There were significant differences ($t(399) = 2.224$, $p = 0.001$) in scores for STEM (M = 2.04, SD = 0.663) and Arts (M = 2.18, SD = .607). The magnitude of the differences in the means (mean difference = 0.142, 95% CI: 0.016 to 0.268). 21st Century challenges and opportunities were seen as more of a reason to collaborate by Arts respondents than STEM respondents (Item 32). There were significant differences ($t(398) = 4.099$, $p < 0.001$) in scores for STEM (M = 2.03, SD = 0.786) and Arts (M = 2.34, SD = 0.715). The magnitude of the differences in the means (mean difference = 0.31, 95% CI: 0.161 to 0.459) was significant. Among the STEM or Arts professionals respondents familiar with colleagues who routinely combine STEM and Art in their work, they indicated that a higher percentage of Arts professionals have colleagues who perform activities that combine STEM and Art than STEM professionals (Item 36). There were significant differences ($t(305.798) = 4.795$, $p < 0.001$) in scores for STEM (M = 22.42, SD = 21.97) and Arts (M = 35.20, SD = 28.038). The magnitude of the differences in the means (mean difference = -10.322, 95% CI: -16.812 to -3.832) was significant. STEM professionals indicated a higher percentage of their colleagues specialize in either STEM or the Arts than the percentage reported by Arts professionals concerning their colleagues who specialize in either STEM or Arts (Item 37). There were significant differences ($t(316.472) = -3.129$, $p = 0.002$) in scores for

STEM (M = 73.56, SD = 28.802) and Arts (M = 63.23, SD = 33.594). The magnitude of the differences in the means (mean difference = -10.322, 95% CI: -16.812 to -3.832) was significant.

There were two items under the process variable cluster that showed a statistically significant difference between the two respondent groups. Arts professionals placed a greater level of importance on planning for changes in a collaboration than did STEM professionals (Item 39). Arts professionals were above the ‘important’ level of concern while the STEM professionals were below the ‘important’ level. There were significant differences (t(409) = 2.039, p = 0.042) in scores for STEM (M = 1.92, SD = 0.083) and Arts (M = 2.08, SD = 0.724). The magnitude of the differences in the means (mean difference = 01.55, 95% CI: 0.006 to 0.305) was significant. Arts professionals considered how people treat each other outside the requirements to complete goals and objectives of the collaboration to be at a higher level of importance than STEM professionals. Arts professions level of concern was closer to ‘very important’ than that of STEM professionals, although they both ranked the level of concern above ‘important.’ There were significant differences (t(408.633) = 2.158, p = 0.032) in scores for STEM (M = 2.66, SD = 0.584) and Arts (M = 2.77, SD = 0.468). The magnitude of the differences in the means (mean difference = 0.112, 95% CI: 0.01 to 0.214) was significant.

Chi square tests. Chi Square statistics were used to examine associations between categorical (see Table 35) variables group membership in either STEM or Arts professions. For each variable, the STEM and Arts respondent results were evaluated against the variables to determine if a relationship existed between the two respondent groups and each individual variable. All statistics were evaluated at the 5% significance level. The null hypothesis is that there is no relationship between the respondents and the given variable.

Table 35.

Categorical Variables used in X^2 Data Analysis.

Variable Item Number	Variable Name	Variable Abbreviation	Variable Meaning
8	PwrGroupDecision_1	PGD1	The whole group should give input in all decisions of a collaboration.
9	PwrGroupDecision_2	PGD2	The whole group should give input in only major decisions of a collaboration.
10	PwrGroupDecision_3	PGD3	The whole group should give input in most decisions of a collaboration.
11	PwrGroupDecision_4	PGD4	The whole group should give input in only final decisions of a collaboration.
14	ResoDialogueDisagree_1	RDD1	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through fact finding (facts-based resolution).
15	ResoDialogueDisagree_2	RDD2	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through negotiation.
16	ResoDialogueDisagree_3	RDD3	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through mediation.
17	ResoDialogueDisagree_5	RDD5	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through voting.
29	ActionOrganization	AO	Organizational feature that would be most productive in a STEM and Arts collaboration of 10 to 15 people.
35	AffinityStemArtSpeci	ASAS	The people that STEM and Arts respondents know whom studied both Art and STEM subjects.
42	ProcessPerformRev	PPR	How high on the list of priorities does periodic review of the collaboration's performance sit.
51	SharTimeSacrifi	STS	How much time should a member be willing to sacrifice for the collaboration.
59	EitherDidCollab	EDC	Reason(s) selected for participating in a collaboration between STEM and Arts professionals.

The Decision-making Cluster variables were evaluated to determine if the career choice (STEM or Arts) impacted the type of decision making preferred. The null hypothesis is that career choice is independent of the type of decision making preferred. The experimental hypothesis is that the preference in decision making is dependent on career choice.

There is an insignificant association between respondent groups and the preference for the whole group to give input in all decisions to be made ($X^2 = 2.296$, df = 3, p = 0.513). The null hypothesis is accepted.

The Fisher exact test was used to analyze the preference for whole group involvement in only major decision making because there were two cells with less than five responses. There is an insignificant association between respondent groups and the preference for the whole group to give input in only major decisions to be made ($X^2 = 2.732$, df = 3, p = 0.421). The null hypothesis is accepted.

There is an insignificant association between respondent groups and the preference for the whole group to give input in most decisions to be made ($X^2 = 1.749$, df = 3, p = 0.626). The null hypothesis is accepted.

There is an insignificant association between respondent groups and the preference for the whole group to give input in only final decisions to be made ($X^2 = 2.993$, df = 3, p = 0.393). The null hypothesis is accepted.

The Dialogue Cluster variables were evaluated to determine if the career choice (STEM or Arts) impacted the type of conflict resolution method preferred. The null hypothesis is that career choice is independent of the type of conflict resolution method preferred. The experimental hypothesis is that the preference in method is dependent on career choice.

There is an insignificant association between respondent groups and the preference for fact finding or a facts-based resolution ($X^2 = 3.922$, df = 3, p = 0.27). The null hypothesis is accepted.

There is a significant association between respondent groups and the preference for negotiation of a resolution ($X^2 = 7.958$, df = 3, p = 0.047). The null hypothesis is rejected.

There is an insignificant association between respondent groups and the preference for mediation of a resolution ($X^2 = 0.426$, df = 3, p = 0.936). The null hypothesis is accepted.

The Fisher exact test was used to analyze the preference for voting upon a resolution because there was one cell with less than five responses. There is an insignificant association between respondent groups and the preference for voting for resolution ($X^2 = 3.123$, df = 3, p = 0.381). The null hypothesis is accepted.

One Action Cluster variable was evaluated to determine if the career choice (STEM or Arts) impacted the type of organizational features preferred for a collaboration. The null hypothesis is that career choice is independent of the type of preferred features. The experimental hypothesis is that the preference in features is dependent on career choice. The Fisher exact test was used to analyze the preference for organizational features because there was one cell with less than five responses. There is an insignificant association between respondent groups and the preference for organizational features ($X^2 = 4.923$, df = 4, p = 0.307). The null hypothesis is accepted.

One Affinity Cluster variable was evaluated to determine if career choice (STEM or Arts) impacted the amount of time spent professionally between STEM and Arts by various professionals the respondent knew who had studied both STEM and Art subjects. The null hypothesis is that career choice is independent of the amount of time spent practicing STEM and/or Art by the known professionals. The experimental hypothesis is that the amount of time spent is dependent on career choice. There is a significant association between respondent groups and the amount of time spent by the known professions between STEM and Art ($X^2 = 96.767$, df = 5, $p = <0.001$). The null hypothesis is rejected.

One Process Cluster variable was evaluated to determine if career choice (STEM or Arts) impacted the priority placed on periodic review of the collaboration's performance. The null hypothesis is that career choice is independent of priority assigned. The experimental hypothesis is that the priority assigned is dependent on career choice. There is an insignificant association between respondent groups and the priority placed on periodic review ($X^2 = 2.539$, df = 3, p = 0.468). The null hypothesis is accepted.

One Sharing Cluster variable was evaluated to determine if the career choice (STEM or Arts) impacted the amount of time a member should be willing to sacrifice for the collaboration. The null hypothesis is that career choice is independent of the amount of time indicated. The experimental hypothesis is that the amount of time indicated is dependent on career choice. The Fisher exact test was used to analyze the preference for organizational features because there were two cells with less than five responses. There is an insignificant association between respondent groups and the amount of time indicated ($X^2 = 2.239$, df = 3, p = 0.524). The null hypothesis is accepted.

One Collaboration variable was evaluated to determine if the career choice (STEM or Arts) impacted the reason(s) for collaboration. The null hypothesis is that career choice is independent of reason(s) for collaboration. The experimental hypothesis is that the reason(s) for collaboration is dependent on career choice. The Fisher exact test was used to analyze the options selected for why the respondent participated in a collaboration because there were twelve cells with less than five responses. There is an insignificant association between respondent groups and the reason(s) for collaborating indicated ($X^2 = 10.800$, df = 11, p = 0.518). The null hypothesis is accepted.

Multivariate Regressions. Regressions were run on all Likert and Likert type variables to investigate their predictive strength with respect to collaborations between STEM and Arts respondents. The variables and their meanings are listed in Table 36.

Table 36.
Regression Variables

Variable Item Number	Variable Name	Variable Abbreviation	Variable Meaning
1	PwrDistrDecisions_1	PDD1	The decision-making authority should be distributed based on experience and expertise with issues at hand.
2	PwrDistrDecisions_2	PDD2	The decision-making authority in a collaboration should be distributed based on a rotating or revolving basis.
3	PwrDistrDecisions_3	PDD3	The decision-making authority should be distributed based on areas of responsibility (tasks, roles, components, etc.).
4	PwrMakeDecision_1	PMD1	The decision-making process in a collaboration of Arts and STEM professionals should use consensus.
5	PwrMakeDecision_2	PMD2	The decision-making process in a collaboration of Arts and STEM professionals should use majority rule.

6	PwrMakeDecision_3	PMD3	The decision-making process in a collaboration of Arts and STEM professionals should use hierarchical leadership structures.
7	PwrMakeDecision_4	PMD4	The decision-making process in a collaboration of Arts and STEM professionals should use committee driven decision making.
12	PwrOpenDecisions	POD	How important to the group is transparency in decision making.
13	DialogueDisagreePos	DDP	Disagreement can lead to greater understanding in a collaboration.
18	DialogueWrittenAgree	DWA	How useful it would be to have a written agreement of the rules and norms of collaboration interaction.
22	DialogueInterpersona_1	DI1	Importance of pre-existing collegial and interpersonal relationships among prospective members.
23	DialogueInterpersona_2	DI2	Importance of trust that other members of a collaboration will produce competent, feasible ideas, designs, and results.
24	DialogueInterpersona_3	DI3	Importance of a culture within the collaboration that actively supports critical peer analysis and professional disagreement.
25	DialogueInterpersona_4	DI4	Importance of norms and protocols of interaction for group collaboration.
26	ActionAccountable_1	AA1	A collaboration should have careful selection of collaboration members.
27	ActionAccountable_2	AA2	A collaboration should have sufficient clarity in assigned tasks.
28	ActionAccountable_3	AA3	A collaboration should have formal structures of committees and subcommittees.
30	AffinitySteamWitWhom_1	ASWW1	Preference to create STEAM projects and programs with a STEM professional.
31	AffinitySteamWitWhom_2	ASWW2	Preference to create STEAM projects and programs with an Arts professional.
32	AffinityCollabProspe_1	ACP1	21st Century challenges and opportunities were seen as more of a reason to collaborate.
33	AffinityCollabProspe_2	ACP2	Lack of a social connection will hinder collaboration development.

34	AffinityPrevStudy	APS	Know someone (yourself/colleagues/classmates/et cetera) who included both STEM and Arts in their studies.
36	AffinityPercSpecial_1	APS1	Among the STEM or Arts professionals respondents are familiar with, what is the percentage of professionals that routinely combine STEM and Art in their work.
37	AffinityPercSpecial_2	APS2	Among the STEM or Arts professionals respondents are familiar with, what is the percentage of professionals that specialize in either STEM or art in their work.
38	AffinityAesthSimilar	AAS	The aesthetic in STEM fields is similar to the aesthetic in Art fields.
39	ProcessChangePrep_1	PCP1	Importance to plan for changes in either the structure or relationships in a collaboration.
40	ProcessChangePrep_2	PCP2	Importance of member buy-in to the ongoing process of collaboration.
41	ProcessChangePrep_3	PCP3	Importance of the way people treat each other, outside of requirements to complete goals and objectives.
52	SharBeneMember_1	SBM1	The collaboration adds relevant value and growth to the participant's lives
53	SharBeneMember_2	SBM2	The determination of how credit will be shared prior to beginning collaborative activity.
65	AskStemCollab	ASC	Whether the STEM profession ever collaborated with an Arts professional.
66	AskArtCollab	AAC	Whether the STEM profession ever collaborated with an Arts professional.
67	StemInterestInCollab_1	SIC1	I am very interested in learning more about Arts disciplines.
70	StemInterestInCollab_4	SIC4	Art and STEM collaborations to create STEAM programs and projects should be long term instead of short term in duration.
72	ArtInterestInCollab_1	AIC1	I am very interested in learning more about STEM disciplines.
75	ArtInterestInCollab_4	AIC4	Art and STEM collaborations should be formed with the idea that the collaborations become permanent as opposed to ad hoc.

The following series of regressions were done with the Arts respondents dataset as the independent variables and the second series of regressions were done with the STEM respondents' dataset as the independent variables. The dependent variable from the Arts respondents' dataset was their preference to work with STEM professionals to create STEAM programs and projects (ASWW1). The dependent variable from the STEM respondents' dataset was their preference to work with Arts professionals to create STEAM programs and projects (ASWW2). The linear regressions were run using SPSS software with stepwise regression and mean substitution for missing data.

In the first regression analysis, STEM professionals' preference to work with Arts professionals was made the dependent variable and the STEM dataset variables were made the independent variables. The results can be found in Table 37.

Table 37.
Predictors of STEM Professionals' Collaboration with Arts Professionals.

STEM Respondent All Variables	Beta	t	Sig t
I am very interested in learning more about Arts disciplines.	0.300	4.957	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.164	2.737	0.007
The decision-making process in a collaboration of Arts and STEM professionals should use consensus.	0.186	3.201	0.002
Preference to create STEAM projects and programs with a STEM professional.	0.175	3.113	0.002
Importance of pre-existing collegial and interpersonal relationships among prospective members.	-0.162	-2.905	0.004
A collaboration should have sufficient clarity in assigned tasks.	0.135	2.370	0.019
The decision-making process in a collaboration of Arts and STEM professionals should use majority rule.	-0.118	-2.134	0.034

R= 0. 575 R^2= 0.331   F= 15.69   Sig F= <0.001

Seven out of 34 STEM relevant variables were determined to be significant predictors of STEM collaboration with Arts professionals. Only three conceptual framework variables; Action, Decision-making and Dialogue are represented in the results. In total, two variables were associated with Decision-making, one from Action and one from Dialogue. Two variables from Affinity and one variable from Collaboration were also present. The results did not include anything associated with the conceptual framework variable clusters Process or Sharing. STEM interest in learning about the Arts entered the regression first as a predictor of collaboration with Arts professionals. STEM professionals who prefer to collaborate with other STEM professionals to create STEAM projects and programs is the third strongest predicter of STEM professionals collaborating with Arts professionals (affinity). In terms of the process of power (decision-making), consensus is the second strongest predictor of collaboration. Lower importance of pre-existing relationships was a predictor of greater preference to work with arts professionals (dialogue). The STEM professionals' interest in majority rule is not only the least strong predictor of collaboration, it also predicts a disinclination toward collaboration (dialogue). Clarity of assigned tasks is the weakest predictor of proportional variables (action).

In the second regression analysis, Arts' preference to work with STEM professionals was made the dependent variable and Arts' respondent dataset variables were made the independent variables. The results can be found in Table 38.

Table 38.

Predictors of Arts Professionals' Collaboration with STEM Professionals.

Arts Respondent All Variables	Beta	t	Sig t
Preference to create STEAM projects and programs with an Arts professional.	0.438	7.138	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.214	3.467	<.001
Importance of norms and protocols of interaction for group collaboration.	0.195	3.156	0.002
The decision-making authority should be distributed based on experience and expertise with issues at hand.	0.127	2.066	0.04

R=0.559 R^2= 0.313 F= 20.946 Sig F= <0.001

Of the 34 variables utilized, only four of the Arts related variables entered the equation as predictors of Arts respondents' preference to create STEAM programs and projects with STEM professionals. Only two conceptual framework variables; Decision-making and Dialogue are represented in the results. Two variables were associated with Affinity, one with Decision-making, and one with Dialogue. The results did not include anything associated with the conceptual framework variables Process, Sharing or Action. No Collaboration variables entered either.

The first variable is associated with the Arts professionals' preference to create STEAM programs and projects with other Arts professionals (Affinity). This is the strongest predictor of whether they will be willing to collaborate with a STEM professional. Arts respondents see current and future world challenges as a reason to collaborate with STEM professionals (Affinity). Arts respondents indicated that higher levels of structure in how the collaboration functions predicts higher preference to collaborate with STEM professionals. In terms of decision making, Arts respondents indicate that authority for decision making vested in the hands of subject matter experts predicts collaboration with STEM professionals.

Variables associated with the evolving process of collaboration, and the sharing of attitudes and resources by members of the collaboration did not enter into the equation for either STEM or Arts professionals. Overall, predictors of Art professionals' interest in collaborating with STEM professionals were stronger than predictors of STEM professionals' interest in collaborating with Arts professionals. Decision making appeared once for Arts respondents and twice for STEM respondents. Affinity variables appeared twice for Arts professionals' regressions and three times for STEM professionals' regressions.

In the first series of individual cluster regressions, the Arts respondents' preference to collaborate with STEM professionals was the dependent variable. The independent variables were their responses to survey questions. The results are found in Tables 39 to 43.

Table 39.
Arts Respondent Decision-making Variables.

	Beta	t	Sig t
The decision-making process in a collaboration of Arts and STEM professionals should use consensus.	0.226	3.173	0.002

R= 0.226 R^2= 0.051 F= 10.069 Sig F= 0.002

Table 40.
Arts Respondent Action Variables.

	Beta	t	Sig t
Importance of norms and protocols of interaction for group collaboration.	0.205	2.861	0.005

R= 0.205 R^2= 0.042 F= 8.187 Sig F= 0.005

Table 41.

Arts Respondent Affinity Variables.

	Beta	t	Sig t
Preference to create STEAM projects and programs with an Arts professional.	0.433	6.812	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.242	3.802	<.001

R= 0.508 R^2= 0.258   F= 46.109   Sig F= <0.001

Table 42.

Arts Respondent Process Variables.

	Beta	t	Sig t
Importance of the way people treat each other, outside of requirements to complete goals and objectives.	0.172	2.368	0.019

R= 0.172 R^2= 0.029   F= 5.607   Sig F= 0.019

Table 43.

Arts Respondent Collaboration Variables.

	Beta	t	Sig t
I am very interested in learning more about STEM disciplines.	0.159	2.209	0.028

R= 0.159 R^2= 0.025   F= 4.88   Sig F= < 0.028

Three of five conceptual framework variable clusters, Decision-making, Action, and Process, which predict whether an Arts professional will prefer to collaborate with a STEM professional have an R^2 value of less than 10%. Of those five variable clusters two, Action and Process, have R^2 values of less than 5%. Dialogue and Sharing did not enter the equation.

The Collaboration cluster also has an R^2 less than 10%. In the Affinity cluster the explanatory strength is greatest, having an R^2 of 25.8%. Two predictive variables entered the equation from the Affinity groups of variables. The two Affinity variables have the largest values for Beta. Under Affinity, the preference to create STEAM projects and programs with an Arts professional and 21st Century challenges being a reason to collaborate were the greatest predictors of preference to collaborate with a STEM professional, receiving Beta values of 0.433 and 0.242, respectively.

In the second series of regressions, the STEM respondents' preference to collaborate with Arts professionals was the dependent variable. The independent variables were their responses to survey questions. The results are found in Tables 44 to 49.

Table 44.

STEM Respondent Decision-making Variables.

	Beta	t	Sig t
The decision-making process in a collaboration of Arts and STEM professionals should use consensus.	0.215	3.249	0.001
The decision-making process in a collaboration of Arts and STEM professionals should use hierarchical leadership structures.	-0.185	-2.805	0.005

R= 0.323 R^2= 0.105   F= 13.206   Sig F= <0.001

Table 45.

STEM Respondent Dialogue Variables.

	Beta	t	Sig t
Disagreement can lead to greater understanding in a collaboration.	0.174	2.678	0.008
Importance of pre-existing collegial and interpersonal relationships among prospective members.	-0.139	-2.147	0.033

R= 0.220 R^2= 0.049   F= 5.766   Sig F= <0.004

Table 46.

STEM Respondent Action Variables.

	Beta	t	Sig t
A collaboration should have sufficient clarity in assigned tasks.	0.195	2.974	0.003
How useful it would be to have a written agreement of the rules and norms of collaboration interaction.	0.235	3.293	0.001
Importance of norms and protocols of interaction for group collaboration.	-0.17	-2.39	0.018

R= 0.306 R^2= 0.093 F= 7.728 Sig F < 0.001

Table 47.

STEM Respondent Affinity Variables.

	Beta	t	Sig t
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.283	4.432	<.001
Preference to create STEAM projects and programs with a STEM professional.	0.152	2.432	0.016
The aesthetic in STEM fields is similar to the aesthetic in Art fields.	0.137	2.141	0.033

R= 0.399 R^2= 0.159 F= 13.975 Sig F= <.001

Table 48.

STEM Respondent Collaboration Variables.

	Beta	t	Sig t
I am very interested in learning more about Arts disciplines.	0.372	5.8	<.001
Art and STEM collaborations to create STEAM programs and projects should be long term instead of short term in duration.	0.145	2.263	0.025

R= 0.448 R^2= 0.200 F= 28.424 Sig F= <.001

Table 49.

STEM Respondent Process Variables.

	Beta	t	Sig t
Importance to plan for changes in either the structure or relationships in a collaboration.	0.170	2.583	0.01

R= 0.170 R^2= 0.029 F= 6.672 Sig F= 0.01

Two of six conceptual framework variables, Process, and Action, which predict whether a STEM professional will prefer to collaborate with an Arts professional have an R^2 value of less than 10%. Of those three variables one, Process, has an R^2 value of less than 5%. Within the Collaboration cluster, the explanatory strength is greatest, having an R^2 of 20%. Sharing variables did not enter the equation. Two predictive variables entered the equation from the Dialogue group and three predictive variables entered from the Affinity group of variables. The Collaboration variable had two variables to enter the equation. The first Collaboration variable had the highest Beta at 0.372. The Affinity and Action Clusters had the highest number of predictors at three each. Although the Dialogue group had two predictive variables enter the equation, its R^2 value was 4.9%. Process had one variable as a predictor, and it had the lowest explanatory value at 2.9%.

The R^2 values for the Collaboration group of variables was the largest for any of the STEM groups, nearly triple the R^2 values for all the STEM groups except the Affinity cluster. The R^2 values for the Collaboration cluster of variables was the largest for any of the Arts groups, more than triple the R^2 values for all the Arts groups except for Affinity.

The next regressions were conducted based on the selection of significant variables from the previous regressions run on each category of framework variables. Preference to collaborate was once again made the dependent variable. The significant variables from the framework variables were collectively made independent variables.

The last series of regressions were run using the variables that entered the equations when the regressions were run on each group of variables listed in Tables 39 to 49. Once again, preference to collaborate with the other discipline was used as the dependent variable. There were thirteen independent variables selected for the preference of STEM professionals to collaborate with Arts professionals. Of the thirteen, only five entered the equation. The results are presented in Table 50. There were eight variables selected for the preference of Arts professionals to collaborate with STEM professionals. Of the eight, only four entered the equation. The results are presented in Table 51.

Table 50.
Predictors of STEM Professionals' Collaboration with Arts Professionals.

Select STEM Respondent Variables	Beta	t	Sig t
I am very interested in learning more about Arts disciplines.	0.296	4.789	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.183	3.016	0.003
The decision-making process in a collaboration of Arts and STEM professionals should use consensus.	0.170	2.876	0.004
Preference to create STEAM projects and programs with a STEM professional.	0.156	2.717	0.007
A collaboration should have sufficient clarity in assigned tasks.	0.118	2.038	0.043

R= 0.541 R^2= 0.292   F= 18.516   Sig F= <.001

Table 51.
Predictors of Arts Professionals' Collaboration with STEM Professionals.

Select Art Respondent Variables	Beta	t	Sig t
Preference to create STEAM projects and programs with an Arts professional.	0.425	6.838	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.206	3.319	0.001
Importance of norms and protocols of interaction for group collaboration.	0.191	3.093	0.002
The decision-making process in a collaboration of Arts and STEM professionals should use consensus	0.124	1.99	0.048

R= 0.558 R^2= 0.312   F= 20.836   Sig F= <0.001

The regressions run on all variables (Tables 37 and 38) had the highest explanatory strength, for both STEM and Arts R^2 values, 0.331 and 0.313, respectively. Both the STEM and

Arts select predictors regressions had the second highest R^2 values, 0.292 and 0.312, respectively. The omission of the Decision-making variable PMD2 (Item 5) and Dialogue variable DI4 (Item 25) were the only differences in variables entering the equations between the STEM all variables regression and the STEM select variables regression. The omission of the Decision-making variable PDD1 was the only difference in variables entering the equations between the Arts all variable regression and the Arts select variables regression. Preference to collaborate with members of their own discipline was the greatest predictor of collaboration with the other disciplines to create STEAM programs and projects. The highest Beta values for this variable were returned from the select regressions, with the STEM respondents returning 0.425 (Table 51) and from all variables regressions for the Arts respondents returning 0.438 (Table 38).

Table 52.
Predictors of Art Professionals' Willingness to Collaborate due to STEM Outreach.

Arts Respondents All Variables	Beta	t	Sig t
I am very interested in learning more about STEM disciplines.	0.401	6.276	<.001
Art and STEM collaborations should be formed with the idea that the collaborations become permanent as opposed to ad hoc.	0.257	4.025	<.001

R= 0.508 R^2= 0.259   F= 32.433   Sig F= <0.001

Table 53.

Predictors of STEM Professionals' Willingness to Collaborate due to Art Outreach.

STEM Respondents All Variables	Beta	t	Sig t
I am very interested in learning more about Arts disciplines.	0.374	6.42	<.001
Art and STEM collaborations to create STEAM programs and projects should be long term instead of short term in duration.	0.212	3.463	<.001
21st Century challenges and opportunities are seen as more of a reason to collaborate.	0.160	2.63	0.009
Disagreement can lead to greater understanding in a collaboration.	0.110	2.059	0.041

R= 0.616 R^2= 0.380   F= 34.433   Sig F= <0.001

There was an alternative dependent variable, "If approached by a STEM (or Arts) professional, I would be interested in collaborating to create STEAM programs and projects." I felt this didn't come as close to the concept I was attempting to measure as compared to the variable I've already reported, partly because I inadvertently didn't ask the exact same duration question of both STEM and Arts professionals. Nevertheless, I thought it might interest the reader to see what the predictors were. I simply predicted that new variable with all the predictive variables in a stepwise regression. Table 52 and Table 53 indicate that these variables reveal that interest in the other discipline is a predictor of willingness to collaborate if approached by the other.

Regressions with Controlled Background Variables. Four background variables were identified in the research; US Residency, Gender, Years Worked and Choice of Career. To identify if these variables would have any important impacts regressions for the STEM and Arts respondents controlled for these background variables were run on the appropriate regression variables listed in Table 36. The results can be found in appendix B. There was no appreciable change in the regression results. There may be very slight differences in the results for the same set of variables because the use of control variables slightly changed the sample.

Qualitative analysis. Respondents who indicated they collaborated were offered the opportunity to provide open-ended responses if they selected 'Other' as a reason for collaborating. Twenty-one of 24 respondents who selected 'Other' provided text responses. Their responses are classified into four categories, 1) those who perform both STEM and Arts, 2) those who collaborated because they were part of a funded project 3) those who collaborated because of a required or mandated reason, and 4) those part of an outreach program.

Ten respondents were placed in the category of performing STEM and Art. The responses in this category included statements of being a combined Art and STEM professional or working in a profession that utilized both STEM and Art (e.g., animated, and special effects films, architecture). Five respondents were placed in the category of a funded project. Projects included grants, fellowships, summer programs, public competitions, and employment. Four respondents were placed in the category of mandated projects. One was a student-initiated project, directed by campus leadership, done to meet an educational standard and part of an academy. Two projects were placed under outreach programs. One was the work of a volunteer, and the other was to expose STEM to more people.

Most reasons for collaboration involved some specific purpose for collaboration. Individuals who combined both STEM and Art in their professional lives nearly outnumbered all the other reasons combined. Nearly half of the reasons for collaboration involved a third entity, either in the form of an external funder or institutional requirements. Outreach or exposure to STEAM related content was the least indicated reason for collaboration.

Summary

Four hundred nineteen STEM and Arts professionals participated in this investigation. Data was collected from STEM and Arts professionals who work in both academic and industry settings. The data was analyzed with descriptive, T-tests, X^2 tests and regression analyses. A path analysis with composite variables was attempted but was ultimately not feasible. STEM and Arts professionals show great amounts of commonality across multiple variables. T-tests revealed the majority of variables do not have significant differences in the means. The X^2 tests revealed that most categorical variables are independent of whether the test group is made up of STEM or Arts professionals. The multivariate regressions revealed predictors of collaboration for both STEM and Arts professionals. Specialization in both STEM and Arts professionals is greater than professional work that combines STEM and Art subjects. A small amount of qualitative data revealed the challenges of collaboration and specialization.

In Chapter 5 data will be re-organized to identify trends and support conclusions. Key findings and their interpretations will be discussed, along with limitations to this study. Finally, recommendations for policy changes and further research will be suggested. The final summary will be an overview of the entire study.

Chapter 5

Conclusion

One variable that resulted in data but was not part of a rigorous analysis was the request for one word to describe what would make a collaboration between STEM and Arts professionals work. The outcome can be taken as reflective of the outlook of the two groups. Turned into word clouds, the STEM word cloud is in Figure 8 and the Arts word cloud is in Figure 9. It becomes readily obvious that both groups see common factors that lead to successful collaboration. The two biggest words are communication and respect, although afterwards, there is some variation. This sets the tone of the findings. Overall, the two professions agree more often than not regarding factors that lead to collaboration. This commonality extends to the clusters of variables within each of the conceptual framework variables; Action, Affinity, Collaboration, Dialogue, Decision-making, Process and Sharing.

Figure 8. STEM Word Cloud

Figure 9. Arts Word Cloud

Principal claims. This journey began with curiosity about why it seemed that STEM professionals were always reaching out to Arts professionals to collaborate while the reverse appeared to not be the case. This curiosity evolved into the questions about how these two professions, STEM and Arts, should collaborate to create programs and projects that combine Science, Technology, Engineering, Arts and Mathematics, collectively known as STEAM. Ultimately, the question became whether it is better to create STEAM from collaboration as opposed to organically developing it within STEM. To answer this question, two aspects were focused upon:

How similar or different are the opinions of STEM and Arts professionals about the factors that affect the success of a collaboration?

Is specialization a force that may prevent STEM and Arts professionals from incorporating Arts and STEM skills respectively?

After performing research, data collection and analysis, I am ready to make the claim that it is better to create STEAM projects and programs from collaboration as opposed to organically developing it within STEM. It is better to seek collaboration as opposed to organic development. Additionally, to address the two specific aspects of the question, I am making the following claims:

> Art and STEM are more alike than not with respect to the factors that contribute to successful collaboration.
>
> Areas where STEM and Art are not aligned do not appear to be disagreements fatal to a collaboration effort.

Specialization is a force that will inhibit STEM professionals, and to a lesser degree Arts professionals, from organically developing STEAM projects and programs.

This chapter will summarize the results of this research project. It also contains a discussion of the findings and how they relate to the prospects of STEAM collaborations between STEM and Arts professionals. A subsequent section will discuss the implications of the findings and propose recommendations for policy, implementation, and future research.

Main Findings

How similar or different are the opinions of STEM and Arts professionals about the factors that affect the success of a collaboration?

Similarities between STEM and Arts.

Action Descriptive Data. When it comes to interdependency and synergy, hallmarks of the Action cluster of conceptual framework variables, STEM and Arts professionals are close in their opinions regarding the subject. Concerning the subject of importance in selection of members of the collaboration, the difference in percentages between the Arts and STEM respondents on a per choice basis is small. For each choice Arts and STEM respondents selected, from “Not important” to “Important,” 2.1% to 0.9%, 14.4% to 15.4%, 49,7% to 53.9%, and 33.7% to 29.8%, respectively (Table 22). Concerning clarity of assigned tasks, critical for successful completion of those tasks, “Very important” was the overwhelming choice of both groups, selected by 63.6% of STEM professionals and 71.1% of Arts professionals (see Table 23).

Affinity Descriptive Data. A larger percentage of Arts professionals (23.4%) than STEM professionals (16.9%) disagree that lack of social connection would inhibit collaboration. A larger percentage of Arts professionals (28.8%) than STEM professionals (21.8%) strongly agree that lack of social connections would inhibit collaboration. The percentage of STEM professionals that agree with the question's premise is much larger than the percentage of Arts professionals (60% to 46.2%). Although nearly one quarter of the Arts professionals don't think not knowing prospective collaborators is an obstacle, 81.8% of STEM professionals and 75% of Arts professionals believe it will be an obstacle (see Table 24).

Collaboration Descriptive Data. If you count the appearances of reasons in Table 30 why a STEM or Arts professional said they collaborated, wanting to collaborate is the greatest reason. Approaching 40% of STEM (37.7%) and Arts (39.5%) professionals choose wanting to collaborate most often as the reason to collaborate. Nearly one-third of STEM (32.5%) and Arts (31.5%) respondents indicated they collaborated because they project required it. In each category, the percentages of respondents are very similar, indicating that members of both professions will respond similarly to the same reasons for collaborating.

The primary reason for not participating in a collaboration given by STEM and Arts professionals was also the same. 47.5% of STEM respondents and 71.6% of Arts respondents stated that not being approached or asked was the reason they didn't collaborate (see Table 29). The least selected reason was lack of respect. Although almost five times as many Arts professionals (3.7%) than STEM professionals (0.8%) felt they would be disrespected, the number of respondents was very small. Conversely, 56.5% of STEM professionals and 57.2% of Arts professionals indicated they would be receptive to an invitation to collaborate (Table 26). Overall, both STEM and Arts professionals don't think STEAM for a given profession should be developed only by members in that profession. Either "Disagree" or "Strongly disagree" was selected by a total of 77.5% of STEM professionals and 69.1% of Arts professionals.

Dialogue Descriptive Data. Both STEM and Arts professionals were asked if disagreement can lead to greater understanding in a collaboration (Table 15). 153 STEM respondents (68.6%) selected 'Agree,' as their first choice. 124 Arts respondents (68.9%) chose 'Agree' as their first choice.

Decision-making Descriptive Data. STEM and Arts professionals were asked if experience and expertise should be the basis for decision making. 'Agree' (237) was the first choice of all respondents. The percentages of STEM respondents who chose the top selection is only 7.30% higher than the Arts respondents that made the same selection (Table 20).

Process Descriptive Data. When asked about the importance of planning for changes in the collaboration, STEM and Arts respondents are in alignment in order of choices. The percentages of STEM and Arts respondents who chose “Important” (48.4% to 55.4%) and "Very important” (24% to 27.4%) are in relatively close alignment (Table 12). They are farthest apart on the choice “Unimportant” (4.4% to 2.7%) and to a lesser extent on the choice of “Somewhat important” (23.1 to 14.5%) Art respondents have a higher percentage than STEM respondents for the choices “Important” and “Very important.” STEM respondents have a higher percentage than Arts respondents for the choices “Somewhat important” and “Unimportant.”

When asked about the importance of Buy-in to the ongoing process of collaboration, STEM and Arts respondents are in alignment in order of choices (Table 13). The percentages of STEM and Arts respondents who chose “Very important” (61.6% to 67.2%) are in relatively close alignment and the respondents who chose “Important” (30.4% to 26.9%) are aligned to a lesser degree as well. They are farthest apart on the choice “Unimportant” (0.9% to 0.5%) and to a lesser extent on the choice of “Somewhat important” (7.1% to 5.4%). STEM respondents have a higher percentage than Arts respondents for all choices except 'Very important.'

Insignificant T-test results. Out of 36 variables analyzed with the T-test, only twelve variables showed a significant difference between the means. Two-thirds of analyzed variables showed no significant differences between the means. These variables, listed in Table 33, are comprised of; five variables in the Decision-making cluster (Items 1, 3, 5, 6 and 7), four variables in the Dialogue cluster (Items 13, 23, 24 and 25), two variables in the Action cluster (Items 26 and 27), four variables in the Affinity cluster (Items 31, 33, 34 and 38), one variable in the Process cluster (Item 40), both variables in the Sharing cluster (Items 52 and 53), and all six variables in the Collab cluster (Items 65, 66, 65, 70, 72 and 75) had differences in the means between the STEM and Arts professions that were statistically insignificant.

Chi-Squared Categorical Variable Analysis. Eleven of thirteen categorical variables analyzed using Chi-Squared returned no relationship between the variable and which profession the respondent belonged to. The variables are listed in Table 54.

Table 54.

Categorical Variables Showing no Relationship to Profession.

Variable Item Number	Variable Name	Variable Abbreviation	Variable Meaning
8	PwrGroupDecision_1	PGD1	The whole group should give input in all decisions of a collaboration.
9	PwrGroupDecision_2	PGD2	The whole group should give input in only major decisions of a collaboration.
10	PwrGroupDecision_3	PGD3	The whole group should give input in most decisions of a collaboration.
11	PwrGroupDecision_4	PGD4	The whole group should give input in only final decisions of a collaboration.
14	ResoDialogueDisagree_1	RDD1	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through fact finding (facts-based resolution).
16	ResoDialogueDisagree_3	RDD3	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through mediation.
17	ResoDialogueDisagree_5	RDD5	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through voting.
29	ActionOrganization	AO	Organizational feature that would be most productive in a STEM and Arts collaboration of 10 to 15 people.
42	ProcessPerformRev	PPR	How high on the list of priorities does periodic review of the collaboration's performance sit.
51	SharTimeSacrifi	STS	How much time should a member be willing to sacrifice for the collaboration.
59	EitherDidCollab	EDC	Reason(s) selected for participating in a collaboration between STEM and Arts professionals.

Common Predictors in The STEM and Arts Regressions. Both STEM and Arts respondents indicated the same Affinity (see Table 47 and Table 41) and Decision-making (see

Table 39 and Table 44) predictors in the regressions for preference to collaborate with the other discipline when run on each individual framework cluster.

Differences between STEM and Arts. In the variables that contribute to successful collaboration, this is how STEM and Art are different.

Dialogue Descriptive Data. The STEM respondents conveyed a much higher level of importance on pre-existing relationships than Arts respondents. A higher percentage of Arts professionals indicated this issue was either “Not important” (19% to 11.8%) or “Somewhat important” (37.6% to 35.5%) than STEM professionals. Alternatively, a higher percentage of STEM professionals indicated this issue was ether “Important” (38.6% to 29.6%) or “Most important” (14% to 12.9%) than Arts professionals (see Table 16). The percentage of STEM respondents who feel this topic is “Important” is 9% higher than the percentage of Arts respondents who see this topic as “Important.”

Decision-making Descriptive Data. STEM and Arts respondents addressed the question whether decision making authority should be distributed on a rotating or revolving basis. The percentage of STEM respondents who chose 'Disagree' as the top selection is 21.95% higher than the Arts respondents that made the same selection. The percentage of STEM respondents who chose 'Strongly disagree' is 60.22% higher than the Arts respondents that made the same selection. The percentage of Arts respondents who chose 'Agree' is 22.29% higher than the STEM respondents that made the same selection. The percentage of Arts respondents who chose 'Strongly Agree' is 41.76% higher than the STEM respondents that made the same selection. STEM and Arts respondents are about the same distance apart from each other on the choices of 'Disagree' and 'Agree.' They are farther apart on the choice 'Strongly disagree' than they are apart on the choice 'Strongly agree.'

Significant T-Test Results. Twelve variables analyzed by T-test did have statistically significant differences between the means for STEM and Arts professionals. However, they represent only one third of the variables listed (see Table 34). They were comprised of three Decision-making cluster variables (Items 2, 4 and 12), two Dialogue cluster variables (Items 18 and 22), one Action cluster variable (Item 28), four Affinity cluster variables (Items 30, 32, 36 and 37) and two Process cluster variables (Items 39 and 41).

Chi Squared Categorical Variable Analysis. Two of thirteen categorical variables analyzed using Chi-Squared returned a relationship between the variable and which profession the respondent belonged to. The variables are listed in Table 55.

Table 55.
Categorical Variables showing a Relationship to Profession.

Variable Item Number	Variable Name	Variable Abbreviation	Variable Meaning
15	ResoDialogueDisagree_2	RDD2	The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through negotiation.
35	AffinityStemArtSpeci	ASAS	The people that STEM and Arts respondents know who studied both Art and STEM subjects.

Uncommon Predictors in The STEM and Arts Regressions. The regressions of all 36 variables listed in Table 36 produced only one common predictor of collaboration. Table 37, containing STEM predictors of collaboration between STEM and Arts, contains only one of the variables listed in Table 38, containing Art predictors of collaboration between STEM and Arts.

In the regressions run on the variables listed in Tables 39 to 49 that were indicated as predictors from the previous individual variable cluster regressions, the preference to create

STEAM programs and projects with members of their own discipline was common to both STEM (Table 50) and Arts professions (Table 51), although their predictive strengths were different.

Is specialization a force that may prevent STEM and Arts professionals from incorporating Arts and STEM skills respectively?

Of the respondents who knew someone who studied both STEM and Arts courses 66.2% of STEM respondents indicated that person performed either mostly STEM or specialized in STEM. Of the respondents who know someone who studied both STEM and Arts courses 66% of Arts respondents reported that person performed either mostly Arts or specialized in Arts (Table 28).

Only eleven percent of STEM professionals who have acquaintances who studied both STEM and Art indicated those acquaintances perform equal amounts of STEM and Arts professionally. However, 18.9% of Arts professionals who have acquaintances who studied both STEM and Art indicated those acquaintances perform equal amounts of STEM and Arts professionally (Table 28).

Reasoning. In collaboration theory sharing, dialogue, process, action and decision-making are very important concepts. Within these concepts, there is very little conflict between STEM and Arts professionals. Sharing is not a cluster of concern from a descriptive analysis, T-test analysis, Chi-Squared analysis, or stepwise regression analysis. Dialogue descriptive analysis shows commonality of opinion. Even where they have differences, it is in differences of degree of agreement. Dialogue T-tests show several variables that have insignificant differences in the means between the two groups. Only one of four Dialogue variables shows a relationship between profession and outcome in a Chi-Squared analysis. Additionally, there are more Dialogue predictors that favor collaboration than not. Action cluster descriptives show small differences in agreement in the cluster variables. The two Action cluster variables that appear in T-tests do not show significant differences compared to one that does. Out of four Action cluster variables, ActionOrganization (Item 29), appears in the Chi-Squared analysis as not showing a relationship between profession and organizational features and ActionAccountable3 (Item 28) does not contradict any other Action cluster variable. Decision-making cluster variables do appear often, but Decision-making cluster variables in one profession do not contradict Decision-making cluster variables in another profession. Both STEM and Arts professionals agree on two aspects of decision-making: authority and transparency. The two groups differ on a lesser selected option for decision making: rotating leadership. But once again, the difference is one of degree of agreement. Five Decision-making cluster variables appearing in a T-test show no difference in the means between STEM and Arts professionals while three did. Four categorical Decision-making cluster variables did not demonstrate any relationships between profession and decision-making. It can be concluded from the data that collaboration between the STEM and Arts professionals would not be difficult because they share so many perspectives and opinions regarding working in a collaboration.

An aspect of collaboration theory are the pre-existing conditions that will either lead to or are conducive to forming a collaboration. Both Arts and STEM professionals see 21st Century challenges as a reason for collaboration and STEM professionals' interest in the arts is a predictor of interest in collaboration. Therefore, from two separate directions, STEM and Arts professionals indicate the interest necessary for collaboration.

Because of specialization, STEM and Art will neither organically collaborate nor develop STEAM from within the disciplines on a meaningful scale. Most STEM professionals and many Arts professionals indicate that the individuals who they know who studied both STEM and art subjects ended up specializing in one or the other, either mostly or exclusively. By its very nature, specialization means the exclusion of other subjects of study. Therefore, specialization will not lead STEM or Arts professionals to incorporate the other profession organically.

Collaboration Theory indicates there would be little difficulty in getting Arts and STEM professionals to work together because they have common views regarding the concepts that are important to collaboration. Furthermore, the ongoing process of specialization will move the STEM or Arts professionals in a direction away from incorporating each other into their current professions organically. This is especially true of STEM professionals. These factors lead to the conclusion that it is better to seek collaboration between the STEM and Arts professions as opposed to attempting to organically create STEAM programs and projects from within either STEM or the Arts.

Discussion

Interpretation of findings.

Structure and Function. An overwhelming majority of STEM professionals (96.5%) and Arts professionals (92.6%) indicated that decision making should be based on experience and expertise with the issues at hand (Table 20). Both STEM (48.4%) and Arts professionals (55.4%) favor the planning for changes in the collaboration (Table 12). This lends to the members a certain degree of certainty even in moments of change and re-evaluation. As time is an important commodity to all professionals, it should be no surprise that both STEM and Arts professionals value organized effective meetings in collaboration (Table 14). One aspect of a collaboration that must be built into the endeavor is that it provides benefit to the membership. That collaboration adds value and growth to the members is very important to both STEM and Arts professionals (Table 9). This will create an additional secondary attraction to participation in the collaboration. The desire to collaborate and reasons such as addressing 21st century challenges should be established as the primary attractions to collaborate.

When evaluating the means of variables that relate to structure and function (Decision-making, Process) T-tests (Table 33) show only three items related to Decision-making (Items 2, 4 and 12) have means that are significantly different. However, only one of the three, Item 2, shows a difference in preference between STEM and Arts professionals (Table 14). STEM and Arts professionals differ in their opinions regarding decision making authority being based on a rotating or revolving basis. While such an arrangement may seem more egalitarian and favored by Arts professionals, it is not favored by STEM professionals. The other two, Items 4 and 12, differ only in degree of agreement. This means a convener of STEM and Arts professionals has options for a leadership and decision-making structure that will be acceptable to both groups.

Additionally, several variables show statistically significant differences in means between STEM and Arts professionals but do not seem to be critical issues in creating collaborations. Table 34 indicates STEM professionals felt it would be slightly less than useful ($M = 1.88$, $SD = 0.945$) to have written rules and norms of behavior while Arts professionals felt it would be slightly more than useful ($M = 2.12$, $SD = 0.853$). STEM and Arts professionals agree on transparency in decision making but Arts professionals feel more strongly ($M = 2.65$, $SD = 0.512$) than STEM professionals ($M = 2.46$, $SD = 0.558$). This appears to mean that organizing documents of the collaboration should be created but should not be of major importance.

Convener. Probably the strongest indicator of the need for a convener to create STEAM projects and programs from a STEM and Arts collaboration comes from Table 25. Two-thirds of STEM professionals and nearly six out of every ten Arts professionals indicated they have not reached out to the other discipline to collaborate. Data from Table 29 indicates the need for a convener because the primary reason neither group participated in a STEM and Arts collaboration is that no one approached or asked them. This role is the classic responsibility of a convener in collaboration theory, to bring stakeholders together (Gajda, 2004, Wood and Gray, 1991). Moreover, data from Table 26 shows that both STEM and Arts professionals would be receptive to the appeals from a convener to collaborate. The fact that both STEM and Arts professionals feel that STEAM should not be created in their profession solely by members of their profession also indicates that a convener could offer a preferable option in the form of collaboration. Often, the big picture of a project or program can only be seen by individuals who are facilitators, not directly involved in the minutiae of the activity. Since planning for changes in the structural or relationships within the collaboration is important to both STEM and Arts professionals (Table 12), this task would be well suited to a convener. Part of a convener's role should be to develop a sense of community among the members, as this is identified as important to both STEM and Arts professionals (Table 24). With such a large group of STEM and Arts professionals specializing, not reaching out to the other disciplines, and not being approached to collaborate, the need for a convener becomes obvious.

Communication. Figures 9 and 10 can imply that establishing lines of communication must be performed purposefully because of its high level of importance to both STEM and Arts professionals. STEM and Arts professionals appear to be comfortable with the rough and tumble of jostling and divergent ideas. Most agree that disagreement can lead to greater understanding

(Table 15) and both critical peer analysis and professional disagreement should be encouraged (Table 18). The communication translates into clarity of assignments which should lead to effective action. While disagreement is seen as useful in creating understanding, it is important to use fact-finding as a means for resolving those disagreements (Table 19). Fact finding could be seen as a more objective means of resolving issues. These factors are useful in creating a framework for the culture of a collaboration.

Membership. Data from Table 22 can be understood to indicate the membership roster must be pursued purposefully because of its high level of importance to both STEM and Arts professionals. In fact, data from Table 30 indicates the primary reason professionals from both disciplines collaborated was because they wanted to.

A very interesting result is that in both STEM and Art Select Variable Regressions is that the preference to collaborate on STEAM programs and projects with someone in their own discipline was a predictor of willingness to collaborate with someone in the other discipline. Willingness of an Arts professional to collaborate with other Arts professionals to Create STEAM projects and programs predicted willingness to collaborate with STEM professionals and vice versa. This result was revealed because the option to choose which preference the respondent had was not mutually exclusive. Each respondent was offered the option to indicate their preference regarding both STEM and Arts professionals separately. To gain further insights I looked into the mean median and mode for the variable. The results can be found in appendix C. When asked about the preference to Create STEAM with Art professionals the median for both STEM and Arts professionals was 2, the mode was 2 and the mean was 2.21 for STEM and 2.30 for Art respondents. When asked about the preference to Create STEAM with STEM professionals the median for both STEM and Arts professionals was 2, the mode was 2 and the mean was 2.04 for STEM and 2.18 for Arts respondents. The value 2 was coded to the response 'Agree.' The interpretation is that willingness to collaborate is a mindset that transcends discipline. A person willing to collaborate with someone is likely willing to collaborate with most anyone.

Over half of all respondents chose 'shared vision' as their number one factor in creating a collaboration. Buy-in and commitment are also important to approximately one quarter of both STEM and Arts professionals (Table 11). In fact, member buy-in is identified as 'very important' by both STEM and Arts professionals with respect to the ongoing process of evolution of the collaboration (Table 13).

Moreover, as data from Table 24 indicates, STEM and Arts professionals want a connection at the social level. This leads to ideas about the importance of team building and esprit de corps for the success of a group activity. Members should feel comfortable with challenges and disagreement because nearly equal majorities of STEM and Arts professionals feel that disagreement can lead to greater understanding (Table 15). As both STEM and Arts professionals see the importance of planning for changes in a collaboration (see Table 12), a degree of flexibility in the prospective members would be necessary. Finally, there should be a certain amount of selflessness in the members as both STEM and Arts professionals place lukewarm importance on how credit is shared in the collaboration (Table 10).

There is a significant difference in the means between STEM ($M = 1.55$, $SD = 0.877$) and Arts ($M = 1.35$, $SD = 0.943$) professionals when it comes to the importance of pre-existing collegial and interpersonal relationships among prospective members (Table 34). STEM professionals lean toward the idea of pre-existing relationships for creation of a collaboration while Arts professionals don't (Table 16). This is perhaps the most challenging aspect of creating a collaboration because it means there will be a feeling out period that may be longer for STEM professionals than for Arts professionals. However, when looking at predictors of collaboration between STEM and Arts professionals, the STEM related variable for pre-existing relationships has a Beta value of -0.162 (Table 37). This can be interpreted as STEM professionals placing less value on the importance of knowing Arts professionals prior to collaboration.

Specialization. Specialization is consistently identified as a factor which will militate against developing STEAM organically from within STEM.

There is a statistically significant difference in the means of Arts (M = 63.23, SD = 33.594) and STEM (M = 73.56, SD = 28.802) professionals (Table 34) who know colleagues who specialize or practice mostly either STEM or arts in their professional career (Item 37). More STEM professionals have colleagues who specialize than Art professionals. If it is reasonable to believe that STEM professionals spend most of their time around other STEM professionals and likewise for Arts professionals, then it could be argued that STEM professionals are more specialized than Art professionals.

There is a statistically significant difference in the means of Arts (M = 35.20, SD = 28.038) and STEM (M = 22.42, SD = 21.97) professionals (Table 34) who know colleagues who routinely combine both STEM and arts in their professional career (Item 36). If we assume that Arts professionals spend most of their time around other Arts professionals and likewise for STEM professionals, then it could be argued that Arts professionals perform more STEAM activities than STEM professionals.

If we continue the assumption that Art is less specialized than STEM, Arts professionals could arguably state they already employ STEM, especially since nearly 20% of Arts professionals indicate they know professionals who started out studying both STEM and art and now perform equal amounts of STEM and Arts professionally (Table 28). In other words, Arts professionals may feel they already do a version of STEAM, we could call it steAm. This would imply that STEAM is more relevant to Arts professionals as opposed to STEM professionals.

The fact that there was a significant association ($X^2 = 96.767$, df = 5, p = <0.001) between the choice of STEM or Arts profession (Table 55) and knowledge of colleagues who specialized after studying both STEM and Art subjects (Item 35) supports the conclusion that STEM is more specialized than Art. This means that while STEM professionals may have interest in STEAM, they will more likely not seek to incorporate the Arts in their work. This may not necessarily be out of any contrary feeling or opinions towards the arts; but merely from a sustained focus on their STEM work.

Data from Table 29 supports the idea that specialization is a reason STEAM will have a difficult time organically being created from STEM because nearly one out of every five STEM professionals never thought about working with an art professional. It could be argued that this doesn't mean that the STEM professionals aren't doing STEAM on their own, outside of collaboration. It could be argued that specialization isn't the only reason STEM professionals never thought about collaborating with Arts professionals. However, relatively speaking, it is the Arts professional that is doing both STEM and Art, and not the STEM professional, by a margin that approaches 2:1 (Table 28).

Interpretation in Context of Literature. The historical (Porter, 2009) and contemporary (Coccia, 2020) role of specialization in the evolution of science, and to a lesser extent in the arts, indicates that STEM and Arts professionals will generally evolve away from organically producing STEAM programs and projects. This is evident in the fact that many STEM and Arts professionals specialize (Table 28 and Table 55, item 35).

Data from this study reveals a difference in a preference for pre-existing collegial and interpersonal relationships between STEM and Arts professionals. STEM professionals prefer these relationships while Arts professionals indicated they are not that important (Table 16 and Table 34). The literature (Levine and Moreland, 2004, Boyack, 2006, Bennet and Galin, 2012) indicates that loyalty and trust in the skills of their colleagues are the prime motivators for wanting these relationships among STEM professionals. Lower importance of pre-existing relationships was a STEM related predictor of greater preference to work with arts professionals. This is contrary to literature regarding preference of STEM professionals to work STEM professionals they already know with respect to STEM collaboration. This could mean STEM professionals who would work on STEAM projects and programs are specifically interested in working with Arts professionals they are unfamiliar with, or they have different expectations regarding collaborating with Arts professionals.

As STEAM is routinely described in multidisciplinary, interdisciplinary and transdisciplinary terms, it is of benefit to examine the role of the convener and the collaboration from a transdisciplinary theory perspective. Augsburg (2014) outlines characteristics of a transdisciplinary individual. In the context of this investigation, that perspective can be applied to both the convener and the collaboration members. It is useful to look at the idea of the collaboration and the convener separately.

Augsburg (2014) made several comments that are relevant to the collaboration and its membership. She noted that a compelling issue or reason is motivation to engage in a transdisciplinary collaboration. This complements the finding that respondents indicated the need of a combination of Art and STEM to complete a project was the second highest reason for collaborating (Table 30). In discussing participants in a transdisciplinary collaboration, Augsburg (2014) reported five separate predispositions for prospective members of a transdisciplinary collaboration relating to their willingness to debate disagreement and attitudes towards knowledge, experience and understanding. The findings in this investigation revealed that respondents felt that the selection process for inclusion in the STEAM collaboration was important (Table 22), as was the ability to support a culture of critical peer analysis and professional disagreement (Table 18).

In terms of the convener, Augsburg (2014) conveniently distills the question that the STEAM convener must be prepared to answer; "How is transdisciplinary collaboration accomplished when participants from different disciplines and societal sectors are working from different assumptions, levels of expertise, types of knowledge, methodologies, and perspectives?" All we need do is replace the term 'transdisciplinary' with the term 'STEAM' and we can see how readily applicable this statement is. In addition to the characteristics that would make an effective member of a transdisciplinary collaboration, the skill set of a convener is such that they will be an effective shepherd or facilitator of the STEAM collaboration. A convener should be able to cultivate group skills such as communication, negotiation, and conflict resolution because they are indicated as successful to a transdisciplinary collaboration (Klein, 2018). A convener should have in their toolbox professional development techniques such as cross training activities, retreats and presentations because Klein (2018) reported that they are important to successful transdisciplinary collaboration. Furthermore, such techniques would be useful to the members because they indicated that a lack of social connection would hinder a STEAM collaboration (Table 24).

Implications. The number of member criteria for a successful collaboration means the vetting process takes on heightened importance. Certain items should be evident when looking at prospective member. Regarding STEM member selection, seven out of 34 variables were determined to be significant predictors of STEM collaboration with Arts professionals (see Table 37). Interest in learning about Arts disciplines is the strongest positive predictor of STEM preference to collaborate, followed by an interest in decision-making by consensus. Preference by STEM professionals to work with other STEM professionals was the strongest predictor that STEM professionals would work with Arts professionals to create STEAM programs and projects. This can be interpreted as if a STEM or Arts professional is interested in collaborating with a member of their own profession, they will also be interested in collaborating with members of the other professions.

Regarding Arts member selection, four out of 34 variables were determined to be significant predictors of Arts collaboration with STEM professionals (see Table 38). As with STEM professionals, preference by Arts professionals to work with other Arts professionals was the strongest predictor that Arts professionals would work with STEM professionals to create STEAM programs and projects. This can be interpreted as with the STEM professionals, if a STEM or Arts professional is interested in collaborating with a member of their own profession, they will also be interested in collaborating with members of the other profession. Current and future challenges are seen by Arts professionals as reason to collaborate with STEM professionals. Although 21st Century challenges can encompass a wide range of topics and issues, it is generally understood they are categorized as socio-economic, political, and environmental. This bodes well for STEAM as a vehicle for innovation.

The implications of Table 28 data are that at least 2 of every 3 students who studied both STEM and Arts ends up doing either one or the other. This would also imply that a) a STEAM degree may only be relevant to roughly one third of all STEM and Art students b) the remaining two thirds would be better served if one of the two is a major and the other is a minor and c) not all aspects of STEM and Arts are going to be relevant to most students who study both STEM and Arts.

Most Chi-square tests returned the null hypothesis (see Table 54). This can be interpreted as indicating that both STEM and Arts professionals feel the same way about the variable because regardless of which profession you choose, you will feel the same way. In other words, it would be relatively easy to find common ground between both professions.

Limitations

One limitation is the lack of student respondents. Most of my respondents are adults who are members of older generations. Professionals with 20 or more years worked made up 49.1% of STEM professionals and 62.2% of Arts professionals. Most respondents were contacted via emails to academic institutions or trade and professional associations. Social media contacts were not utilized as much as was planned. Additionally, time constraints limited the opportunities to get approval from academic institutions to survey students. Younger generations, who are more associated with upcoming technologies, may have different experiences planning STEM and Arts careers.

Another limitation is that the pool of respondents skews towards professionals in academic careers. The ratio of arts academics to arts industry professionals is 2:1 (126 to 63) and the ratio of STEM academics to STEM industry professionals is slightly less than 4:1 (183 to

47). Arts and STEM professionals in the industrial setting may have a more varied experience when it comes to combining STEM and Arts.

Compared to the numbers of STEM and Arts professionals active today, this research encompasses a small sample size. Although I sought to solicit responses from various parts of the United States, there was very little representation from the southern and southwestern parts of the nation. The predominate source of responses came from the southern California region. This may impact the generalizability of the results.

Another limitation was demographic. Far and away, most respondents were of either European lineage, or possessed a European admixture. This occurred despite efforts to reach out to a diverse group of academic and trade associations. A more diverse sample could reveal career and scholarly paths that exist outside of the normal channels of professional development.

Recommendations

Based on the data that only 11% of STEM professionals and 25% of Arts professionals perform equal amounts of STEM and Arts in their professional work, a degree in STEAM that seeks to teach a student to practice both STEM and Arts may not be able to provide long-term benefits. Instead, STEAM should be practiced at the K-12 level through the collaboration of STEM and Arts instructors. This way, students can get a truly holistic understanding of the relationship between the two and be able to focus on more clearly one or the other at the higher education level, in preparation for their career path. If a higher education student wishes to be part of the 11% or 25% of STEM or Arts professionals, respectively, who perform both in their career path, they can select the courses they feel will be of use.

If a STEAM degree may be of value to only about one third of STEM and Arts professionals, perhaps that indicates the confusion around creating a STEAM curriculum is because a STEAM career path isn't relevant. Coupled with the fact that there is no coherent concept of what STEAM should be, perhaps time and resources will be better spent teaching STEM and Arts professionals to collaborate to create STEAM programs and projects instead. That way, by creating a STEAM collaboration, members can assemble and disperse on an as needed basis, saving both time and money. Furthermore, implementing collaboration would enhance the so-called 'people skills' that have been bemoaned in the mainstream media as lost in the digital age.

A convener as described in Collaboration Theory will be necessary to develop STEAM projects and programs. This person should have a good understanding of transdisciplinary theory because they can use transdisciplinary descriptions of effective, successful members in establishing a vetting process for members, organizing a transdisciplinary framework of goals and objectives for a given STEAM collaboration focus, and organizing the process of developing the transdisciplinary collaboration into an effective, cohesive unit. A transdisciplinary STEAM convener should be a facilitator because the Art and STEM professionals, in conjunction with other relevant stakeholders, should be the ones to identify the specific goals and objectives of the collaboration. In this manner, the STEAM convener would be the catalyst for transdisciplinary collaboration, possessing skill sets that can be transferred from project to project.

At the K-12 level, a district level STEAM convener position should be created, either as a standalone or as part of human resources, that specifically implements professional development to create a bank of lesson plans that require STEM and Arts instructors to collaborate. To assist in the institutionalization of this policy, a culminating activity like the Pavia celebration that occurred in Italy, which incorporates the local community, should be implemented. The K-12 level should be the primary level for seeking to attract underrepresented groups to STEM because based on my twenty years teaching experience in the K-12 arena, I feel if the math and science skill sets are not developed early in a student's experience, it will be very challenging to attempt to attract them to STEM in their later years.

STEAM degrees should focus on training students to become conveners for Arts and STEM professional collaborations as opposed to becoming individuals that personally combine STEM and Arts skill sets. This would be a management level position. The function of this person would be to operate in business, government and academia promoting innovation through STEM and Arts collaboration. The degree should include training in:

STEM cross-cutting concepts (function and form, cause and effect, size, shape and scale, etc.)

Transdisciplinary Collaboration Theory and Techniques.

artistic creativity and design processes.

science and engineering practices (transferrable STEM skills).

language arts, especially in creative writing and the use of metaphor.

conflict resolution techniques.

human resources, planning and professional development techniques.

business management skills.

The above could represent a two-year or four-year course of training, depending on how in-depth the content delves. The degree would be a combination of STEM skills, arts skills, and people skills, all couched in transdisciplinary theory. The process would be to acquire the vocabulary of the disciplines, an understanding of the methods and processes of the disciplines, the skill to integrate the disciplines and finally, to facilitate the disciplines through transdisciplinary collaboration towards the creation of innovative programs and projects. The course should lead the student to the creation of a personal artifact (manual, handbook, etc.) embodying the student's personal philosophy and techniques for creating transdisciplinary collaborations between Arts and STEM professionals. This could become a renaissance degree.

Future Research

Another area for investigation would be the artists' opinions of creativity in the STEM professions. Is the perceived lack of creativity in STEM a reflection of the literature (i.e., lack of respect or appreciation) or a lack of awareness of the challenges and problem solving that go into the creation of new technological devices?

How do arts students view STEAM and STEM? This investigation focused on faculty and lecturers of arts professions in the academic setting. It would be insightful if it was known if students are a) already defining and establishing STEAM careers, b) accepting the guidance and perspectives of their academic advisors, c) willing to push against the boundaries currently established in the academic setting, or d) are interested in STEAM and STEM only to the extent that it has utility in further expressing their artistic vision.

What are the characteristics of a STEAM career? It would be extremely useful to be able to match articulated careers with the skill set being instilled in students under the guise of STEAM education.

Does STEAM education appropriately prepare individuals for STEAM careers? If as has been referenced in the literature, there is no data to verify the extolled virtues of STEAM either academically or in terms of the public good, then what, if any, is the benefit?

Analysis of the attitudes of STEM and Arts professionals on a per discipline basis (i.e., Media Artists, Engineers, etc.) should be undertaken to determine if specific combinations of disciplines will work together more effectively than others.

Summary

Chapter 1 contained the introduction to this investigation. The background literature established the history of Art and Science being unified and reviewed the reasons why they separated. The methods section described the proposed techniques for collecting and analyzing data. The results chapter revised the data analysis plan and presented actual results and analysis. The final chapter included the conclusion and discussion of the results.

A key finding is that STEM and Arts professionals have more in common than not. However, specialization will likely continue to be a force preventing not only the creation of STEAM projects and programs from within either STEM or the Arts, but also preventing collaboration from organically developing either. Therefore, the role of a convener becomes vital for the development of STEAM in any meaningful, coherent, and broad-based format.

APPENDICES

Appendix A

Dissertation Survey v8 - Association Invite

Start of Block: Opening Block

Science-Technology-Engineering-Arts-Mathematics

Thank you for taking the time to complete this very important survey. Your opinions about this important topic are vital to future decisions regarding policy and resource allocation. Your honest opinions and time are valuable and greatly appreciated.

This survey has nine sections and will take 10 to 12 minutes to complete. If for some reason you have to stop before completing the survey, use the bookmark in the upper left corner to return to where you left off.

On the following page you will see the Institutional Review Board Consent Form providing you details regarding this survey and your participation. After reviewing the form you will have the option to either opt out or continue with this survey.

Page Break

Informed Consent

You are invited to take a survey for a research project. Volunteering will not benefit you directly, but you will be helping us explore attitudes towards the idea of combining science, technology, engineering, and math (STEM) with the arts to promote a new paradigm with the acronym STEAM. If you volunteer, you will be asked to complete a survey. This will take about twelve to fifteen minutes of your time. Volunteering for this study involves no more risk than what a typical person experiences on a regular day. Your involvement is entirely up to you. You may withdraw at any time for any reason. Please continue reading for more information about the study and the participation link below.

STUDY LEADERSHIP: This research project is led by Darius Hines a doctoral candidate in the School of Educational Studies at Claremont Graduate University and supervised by David Drew, a professor of Education at Claremont Graduate University.

PURPOSE: The purpose of this investigation is to consider questions surrounding the ideas of STEM and STEAM. The existence of two options for doing this, seeking collaborations between the Arts and STEM disciplines or to develop STEAM organically within an Arts or STEM framework is at the heart of this investigation. This study seeks to answer the following:

1) What are the historic and contemporary contexts for evaluating the feasibility of these two approaches?
2) Would one choice be more effective than the other, or should the approaches be pursued simultaneously?
3) How do professionals in these disciplines feel about this initiative?

ELIGIBILITY: To be in this study, you must be 18 years of age or older and either a student or professional in one or more of the following disciplines: science, engineering, technology, mathematics, visual arts, media arts, architecture, literature, dance, theater, or music.

PARTICIPATION: During the study, you will be asked to complete a questionnaire that will take about twelve to fifteen minutes, asking about your gender, educational attainment, your geographic continent(s) of origin and residence, the discipline you practice, your familiarity with STEM and STEAM and your attitudes towards collaboration. Example of questions are “What is your gender? 1) male 2) female 2) non-binary 3) prefer not to state” and “I am familiar with combining the Arts with STEM to create STEAM projects. 1) strongly agree 2) agree 3) disagree 4) strongly disagree.”

RISKS OF PARTICIPATION: The risks that you run by taking part in this study are minimal. The risks include eye strain typical of everyday computer usage.

BENEFITS OF PARTICIPATION: I do not expect the study to benefit you personally. This study will benefit the researcher by helping me increase my knowledge and experiences. The data collected will provide useful information regarding prospects and directions for STEM and STEAM programs. My recommendations will be in the form of policy statements provided to my contacts at the local, regional and national levels in addition to journals and conferences.

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

VOLUNTARY PARTICIPATION: Your participation in this study is completely voluntary. You may stop or withdraw from the study at any time or refuse to answer any particular question for any reason without it being held against you. Your decision whether or not to participate will have no effect on your current or future connection with anyone at CGU.

CONFIDENTIALITY: Your individual privacy will be protected in all papers, books, talks, posts, or stories resulting from this study. We may share the data we collect with other researchers, but we will not reveal your identity. To protect the confidentiality of your responses, submitted information will be held in strictest confidence. Access to the survey responses stored in the survey software will be restricted to only myself and my supervisor. Only aggregated, analyzed data will be shared or published and no identifying information will be included. Because the survey software records the IP address of the computer used for the survey, there can be no guarantee of anonymity.

FURTHER INFORMATION: If you have any questions or would like additional information about this study, please contact Darius Hines at either (626) 390-3070 or darius.hines@cgu.edu. You may also contact Dr. Drew at either 909-621-8914 or david.drew@cgu.edu. The CGU Institutional Review Board (IRB) has certified this project as exempt. If you have any ethical concerns about this project or about your rights as a human subject in research, you may contact the CGU IRB at (909) 607-9406 or at irb@cgu.edu. You may print and keep a copy of this consent form. If you wish, I will be happy to send you a copy of this consent form.

CONSENT: If you click the 'Yes' radio button below, it means that you understand the information on this form, and you voluntarily agree to participate in this survey.

○ Yes

○ No

End of Block: Opening Block

Start of Block: Academics/Industry Choice

Which career path best describes most of your professional work?

Arts Academic - Arts educator working in either the K-12 or higher education setting.

Arts Industry - Arts professional working in either the for-profit or non-profit setting.

STEM Academic - Science, technology, engineering or mathematics educator working in either the K-12 or higher education setting.

STEM Industry - Science, technology, engineering or mathematics professional working in either the for-profit or non-profit setting.

○ Arts academic

○ Arts industry

○ STEM academic

○ STEM industry

○ Neither STEM nor Arts Professional

End of Block: Academics/Industry Choice

Start of Block: Collaboration Question Block

Have you ever collaborated with an Arts professional?

○ No

○ Yes

Page Break

Have you ever collaborated with an STEM professional?

- ○ No
- ○ Yes

End of Block: Collaboration Question Block

Start of Block: STEM Didn't Collaborate

I have not collaborated with an Arts professional/student because...

- ○ I've been never approached/asked
- ○ lack of opportunity
- ○ I never thought about it
- ○ Arts professionals don't respect STEM disciplines

End of Block: STEM Didn't Collaborate

Start of Block: Did Collaborate

My reason for collaboration was (check all that apply)

- ☐ I was asked
- ☐ the project required both STEM and Art
- ☐ I wanted to collaborate
- ☐ Other ____

End of Block: Did Collaborate

Start of Block: STEM Block

This section will ask you about your experience as a STEM professional and your interests in working with Arts professionals.

Page Break

To what extent do each of these fields occupy your professional time? Please give a response for each field.

	None at all	A little	Often	A great deal
Science	○	○	○	○
Technology	○	○	○	○
Engineering	○	○	○	○
Mathematics	○	○	○	○

How much time does an individual in your STEM field personally interact with the general public in a professional capacity?

○ None at all

○ A little

○ Often

○ A great deal

To what extent are you familiar with the idea of combining STEM disciplines with Arts disciplines to create STEAM programs and projects.

- Very unfamiliar
- Unfamiliar
- Familiar
- Very Familiar

How much do you agree with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
I am very interested in learning more about Arts disciplines.	○	○	○	○
I have personally reached out to Art professionals to collaborate on a project.	○	○	○	○
If approached by an Art professional, I would be very interested in collaboration to develop STEAM.	○	○	○	○
Art and STEM collaborations to create STEAM programs and projects should be long term instead of short term in duration.	○	○	○	○
STEAM projects and programs used in STEM should be developed only by professionals from STEM.	○	○	○	○

Please rate each of the Art professions in terms of which you would likely work with.

	Most unlikely	Unlikely	Likely	Most likely
Architecture	○	○	○	○
Dance	○	○	○	○
Literary	○	○	○	○
Media	○	○	○	○
Music	○	○	○	○
Theater	○	○	○	○
Visual	○	○	○	○

To what extent do you think STEM professionals can appreciate the aesthetic, or sense of what is beautiful, in the Arts?

○ Not at all

○ A little

○ A lot

○ Completely

End of Block: STEM Block

Start of Block: Arts Didn't Collaborate

I have not collaborated with a STEM professional/student because...

- ○ I’ve been never approached/asked
- ○ lack of opportunity
- ○ I never thought about it
- ○ STEM professionals don’t respect Arts disciplines

End of Block: Arts Didn't Collaborate

Start of Block: Arts Block

This section will ask you about your experience as an Arts professional and your interests in working with STEM professionals. As a reminder, STEM is an acronym for the science, technology, engineering and mathematics fields.

Page Break

To what extent do each of these fields occupy your professional time? Please give a response for each field.

	None at all	A little	Often	A great deal
Architecture	○	○	○	○
Dance	○	○	○	○
Literary	○	○	○	○
Media	○	○	○	○
Music	○	○	○	○
Theater	○	○	○	○
Visual	○	○	○	○

I am familiar with the group of science, technology, engineering, and mathematics (STEM) disciplines.

- ○ Very unfamiliar
- ○ Unfamiliar
- ○ Familiar
- ○ Very Familiar

To what extent are you familiar with the idea of combining STEM disciplines with Arts disciplines to create STEAM programs and projects.

- ○ Very unfamiliar
- ○ Unfamiliar
- ○ Familiar
- ○ Very familiar

How much do you agree with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
I am very interested in learning more about STEM disciplines.	◯	◯	◯	◯
I have personally reached out to STEM professionals to collaborate on a project.	◯	◯	◯	◯
If approached by a STEM professional, I would be very interested in collaboration to develop STEAM.	◯	◯	◯	◯
Art and STEM collaborations should be formed with the idea that the collaborations become permanent as opposed to ad hoc.	◯	◯	◯	◯
STEAM should be developed for use in Art only by professionals from the Arts.	◯	◯	◯	◯

Please rate each STEM profession in terms of which you would likely work with.

	Most unlikely	Unlikely	Likely	Most likely
Science	○	○	○	○
Technology	○	○	○	○
Engineering	○	○	○	○
Mathematics	○	○	○	○

To what extent do you agree or disagree that the aesthetic in STEM fields is similar to the aesthetic in Art fields?

○ Strongly Disagree

○ Disagree

○ Agree

○ Strongly Agree

End of Block: Arts Block

Start of Block: Academic Block

Which grade level do you teach?

○ PreK-8

○ 9-12

○ Post-secondary

End of Block: Academic Block

Start of Block: Decision Making/Power/Leadership Block

This section will ask your opinion about how power dynamics and decision making should be managed in a collaborative group of STEM and Arts professionals.

Page Break

Please indicate the extent to which you agree or disagree with the following statement:
Among STEM and Arts collaborators, decision making authority should be distributed based on;

	Strongly disagree	Disagree	Agree	Strongly Agree
Experience and expertise with issues at hand	○	○	○	○
A rotating or revolving basis	○	○	○	○
Areas of responsibility (tasks, roles, components, etc.)	○	○	○	○

When it comes to the decision-making process in a collaboration of Arts and STEM professionals, I prefer to use...

	Strongly disagree	Disagree	Agree	Strongly Agree
consensus	○	○	○	○
majority rule	○	○	○	○
hierarchical leadership structures	○	○	○	○
committee-driven decision making	○	○	○	○

I believe the whole group should give input in...
(Hover over choices, then click and drag options in order from 1-Most to 4-Least)

______ all decisions of a collaboration
______ only major decisions of a collaboration
______ most decisions of a collaboration
______ only final decisions of a collaboration

Compared to other factors which may influence a collaboration of individuals or organizations, how important to the group is transparency in decision making?

- ◯ Not important
- ◯ Somewhat important
- ◯ Important
- ◯ Most important

End of Block: Decision Making/Power/Leadership Block

Start of Block: Partnership/Dialogue/Interpersonal-Communication

This section asks your attitude towards the role of communication and interpersonal relationships in a collaboration between STEM and Arts professionals.

Page Break

Indicate the extent to which you agree or disagree that disagreement can lead to greater understanding in a collaboration.

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Agree
- ◯ Strongly agree

The best way to resolve disagreements in a collaboration between STEM and Arts professionals is through...
(Hover over choices, then click and drag options in order from 1-Best to 4-Worst)

______ Fact finding (facts-based resolution)
______ Negotiation
______ Mediation
______ Voting

In a collaboration of STEM and Arts professionals how useful would it be to have a written agreement of the rules and norms of collaboration interaction?

- ○ Not useful
- ○ Somewhat useful
- ○ useful
- ○ Very useful

In a professional setting where you are representing the contribution of your discipline, what would be your first reaction if someone from another discipline challenged....

	Denounce their ideas	Disregard their ideas	Listen to their ideas	Consider their ideas	Engage with their ideas
your ways of thinking?	◯	◯	◯	◯	◯
the boundaries of your field of expertise?	◯	◯	◯	◯	◯
your voice, authority or autonomy over the project outcome?	◯	◯	◯	◯	◯

Comparing all the items that can possibly affect a collaboration, how important are the following items for a successful collaboration?

	Not important	Somewhat important	Important	Most Important
Pre-existing collegial and interpersonal relationships among prospective members	◯	◯	◯	◯
The trust that other members of a collaboration will produce competent, feasible ideas, designs, and results	◯	◯	◯	◯
A culture within the collaboration that actively supports critical peer analysis and professional disagreement	◯	◯	◯	◯
Norms and protocols of interaction for group collaboration	◯	◯	◯	◯

End of Block: Partnership/Dialogue/Interpersonal-Communication

Start of Block: Interdependency/Action/Strategy/Tasks

This next short section seeks to find out what your opinion is regarding accountability and completion of tasks in a STEM and Arts collaboration.

Page Break

To ensure assigned actions are carried out in a timely manner, a collaboration should have...

	Not important	Somewhat important	Important	Very important
careful selection of collaboration members	○	○	○	○
sufficient clarity in assigned tasks	○	○	○	○
formal structures of committees and subcommittees	○	○	○	○

In general, which organizational feature would be most productive in a STEM and Arts collaboration of 10 to 15 people?

- ◯ Actions taken by the whole group.
- ◯ Actions taken by small teams within the group.
- ◯ Actions taken by a mix of small group and independent individual actors.
- ◯ Actions taken by a few small groups supported by the remaining members.
- ◯ Action taken by independently acting individuals.

End of Block: Interdependency/Action/Strategy/Tasks

Start of Block: Affinity/Interest to Collaborate

The following section asks you to share your level of interest in participating in a STEM and Arts collaboration. As a reminder, the acronym STEAM stands for Science, Technology, Engineering, Arts and Mathematics.

Page Break

In ***one word***, what do you think could facilitate successful collaborations between artists and STEM personnel?

____

I prefer creating STEAM projects and programs with...

	Strongly Disagree	Disagree	Agree	Strongly agree
a STEM professional.	◯	◯	◯	◯
an Arts professional.	◯	◯	◯	◯

How much do you agree with the following statements?

	Strongly disagree	Disagree	Agree	Strongly agree
21st Century challenges and opportunities demand Arts and STEM professionals collaborate.	○	○	○	○
Lack of a social connection will hinder collaboration development.	○	○	○	○

Do you know someone (yourself/colleagues/classmates/et cetera) who included both STEM and Arts in their studies?

- ○ Yes
- ○ No

Of the people you know who studied both STEM and Arts subjects, how much of their professional time is spent between the two?

- ○ STEM specialization
- ○ Mostly STEM
- ○ Equal amounts of each
- ○ Mostly art
- ○ Arts specialization
- ○ Not sure

Among the STEM or Arts professionals you are familiar with, what is the percentage that match the following statements (Slide the pointer to the desired percentage)?

	0 10 20 30 40 50 60 70 80 90 100
Percentage of professionals that routinely combine STEM and Art in their work	
Percentage of professionals that specialize in either STEM or art in their work?	

To what extent do you agree or disagree that the aesthetic in STEM fields is similar to the aesthetic in Art fields?

○ Dissimilar

○ Mostly dissimilar

○ Mostly similar

○ Similar

End of Block: Affinity/Interest to Collaborate

Start of Block: Process/Cycle/Journey

This section asks about your of acceptance of change during the ongoing processes of a STEM and Arts collaboration.

Page Break

Rate the importance of the below statements.

	Unimportant	Somewhat important	Important	Very important
How important is it to plan for changes in either the structure or relationships in a collaboration?	○	○	○	○
How important is member buy-in to the ongoing process of collaboration?	○	○	○	○
How important is the way people treat each other, outside of requirements to complete goals and objectives?	○	○	○	○

Compared to the issues and practices you are aware of regarding collaboration, how high on the list of priorities does periodic review of the collaboration's performance sit?

○ Bottom quarter

○ Third quarter

○ Second quarter

○ Top quarter

Rank the list below from most to least important in the ongoing and evolving collaborative process? (Hover over choices, then click and drag options in order from 1-Most to 4-Least)

______ Personal growth in member skills and knowledge
______ Acquisition of new organizational goals and objectives
______ Organized, effective meetings
______ Accountability among members

End of Block: Process/Cycle/Journey

Start of Block: Sharing/Purpose

The next short section asks about your attitude regarding members of a STEM and Arts collaboration sharing vision and purpose.

Page Break

Rank the below list from most to least important in forming a collaboration.

(Hover over choices, then click and drag options in order from 1-Most to 4-Least)

______ Shared vision
______ Common strategy and tactics
______ Personal and shared visions agree
______ Buy-in of stakeholders

To be effective, how much time should a member be willing to sacrifice for the collaboration?

- ○ When the member's outside interests permit
- ○ Depends on the task
- ○ A scheduled allotment of time
- ○ Whatever it takes

How important are the following to a successful collaboration?

	Not at all important	Slightly important	Moderately important	Very important
The collaboration adds relevant value and growth to the participant's lives.	○	○	○	○
The determination of how credit will be shared prior to beginning collaborative activity.	○	○	○	○

End of Block: Sharing/Purpose

Start of Block: Demographics Block

The last section of this survey asks you about your demographic information.

Page Break

Page Break

What is your current region of residence?

- Africa
- Central Asia
- Europe
- Far East Asia
- Americas
- Middle East
- Northern Asia
- Oceania
- Southeast Asia

What level of education have you attained?

- H.S. graduate
- College graduate
- Master's
- Doctorate

How many years have you been a working professional?

- ◯ 0-4
- ◯ 5-9
- ◯ 10-14
- ◯ 15-19
- ◯ 20+

What is your predominate geographic ancestry/origin (check all that apply)?

- ☐ Africa
- ☐ Central Asia
- ☐ Europe
- ☐ Far East Asia
- ☐ Indigenous Americas
- ☐ Middle East
- ☐ Northern Asia
- ☐ Oceania
- ☐ Southeast Asia

What is your gender identity?

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

End of Block: Demographics Block

Start of Block: America Block

Do you reside in the United States?

- ○ No
- ○ Yes

End of Block: America Block

Appendix B

Predictors of Collaboration with Controlled Variables.

Table B1.

Significant Predictors of STEM Professionals' Collaboration with Arts Professionals with Controlled Variables

STEM Respondent All Variables	Beta	t	Sig t
I am very interested in learning more about Arts disciplines.	0.264	4.551	<.001
Preference to create STEAM projects and programs with a STEM professional.	0.329	5.891	<.001
The decision-making process in a collaboration of Arts and STEM professionals should use consensus.	0.238	4.023	<.001
Importance of pre-existing collegial and interpersonal relationships among prospective members.	-0.190	-3.362	<.001
The decision-making process in a collaboration of Arts and STEM professionals should use majority rule.	-0.122	-2.178	0.03
How useful it would be to have a written agreement of the rules and norms of collaboration interaction.	0.125	2.136	0.034

R= 0. 575 R^2= 0.331   F= 12.097   Sig F= <0.001

Table B2.

Significant Predictors of Arts Professionals' Collaboration with STEM Professionals With controlled Variables.

Arts Respondent All Variables	Beta	t	Sig t
Preference to create STEAM projects and programs with an Arts professional.	0.431	6.843	<.001
21st Century challenges and opportunities were seen as more of a reason to collaborate.	0.216	3.473	<.001
Importance of norms and protocols of interaction for group collaboration.	0.186	2.921	0.004
The decision-making authority should be distributed based on experience and expertise with issues at hand.	0.132	2.112	0.036

R=0.562 R^2= 0.316   F= 11.92   Sig F= <0.001

Appendix C

Mean, Median and Mode for Survey Preference Variables (Table 36, Items 30 and 31)

Table C1.

Preference to create STEAM projects and programs with an Arts professional.

		STEM	Arts	Full
N	Valid	217	184	401
	Missing	13	5	18
Mean		2.21	2.30	2.25
Median		2	2	2
Mode		2	2	2
Std. Deviation		0.666	0.605	0.639
Minimum		0	0	0
Maximum		3	3	3

Table C2.

Preference to create STEAM projects and programs with a STEM professional.

		STEM	Arts	Full
N	Valid	216	185	401
	Missing	14	4	18
Mean		2.04	2.18	2.11
Median		2	2	2
Mode		2	2	2
Std. Deviation		0.663	0.607	0.641
Minimum		0	0	0
Maximum		3	3	3

Appendix D

Interview Questions with an Artist

Heading

Project: Artists attitudes regarding STEM and STEAM

Date: ________________

Time: __________________

Location: ____________________

Interviewer: Darius Hines

Interviewee: _____________________

Instructions (opening statement): Thank you for your participation. I really appreciate you help in furthering my research. I feel this will be an important contribution to both the arts and science fields. Your insights will provide vital context to data I collect in future surveys and data analysis.

The purpose of this interview is to collect data on the attitudes of arts professionals with respect to STEM and STEAM. This interview shouldn't take more than about an hour of your time.

I don't have any questions of a deeply personal nature so I hope you will be comfortable with my questions, but rest assured your answers will be held in strictest confidence and you don't have to answer any questions you don't want to. If you're comfortable with me quoting you, I have a release to permit such dissemination. Otherwise, the information will be used confidentially to provide additional interpretation of collected data. This information, along with other collected data, will become part of my dissertation and possibly published and presented at conferences and other similar events.

Questions

Demographics

What is your Arts background (training, work experience, etc.)?

How long have you been at your craft?

Decision-making

What kind of decision-making arrangement works best for arts professionals? Why?

How do you think arts professionals feel about giving up some autonomy in a group setting?

Dialogue

What are the ways that arts professionals establish norms of how they work together? Why?

What concerns or issues do arts professionals in collaborations typically agree/disagree over? Why?

Interdependency

STEM professionals have different kinds of action plans, such as the scientific method and the design processes. Do artists believe in utilizing action plans?

Is there a general guide for how artists implement plans of action?

Have you known artists to adopt plans of action from other disciplines, if only temporarily?

What are the ways that arts professionals organize how they work together?

Affinity/interest

What is your familiarity with STEM (Science, Technology, Engineering & Math) and STEAM (STEM plus Arts) concepts?

Do you think it is better for STEAM to be created by having STEM and arts professionals collaborate or through developing STEAM from within STEM and arts independently?

What impressions do you have regarding the use of STEM in an Arts curriculum?

What do you see as benefits and detriments to incorporating STEM and the Arts?

Describe any place where STEM is currently part of your curriculum.

What types of arts do you think would best fit with a STEM program?

Have you ever collaborated with a STEM professional to produce a transdisciplinary project?

What would be some of the resistance an arts colleague may have to engaging in STEM?

What would make STEM collaboration more appealing to artists?

What gaps do you see that need to be filled to enhance collaborations between STEM and the Arts?

Process

Which do you think arts professionals would be more drawn to, structured evolution of a collaboration or a more open-ended arrangement?

What have you observed about collaboration that arts professionals enjoy most about the collaborative process?

Sharing/Purpose

If you were asked to envision a STEM and Arts collaboration, what would it look like?

What are the reasons that arts professionals collaborate?

Specialization

If either you studied both STEM and arts disciplines or if you have friends or colleagues that studied both STEM and arts disciplines, did they specialize or do they continue to do both?

Do you know many professionals who combine STEM and arts in their work as opposed to those who specialize?

How often do you see arts professionals combining STEM and arts on a routine basis?

Do you think there is a greater demand for professionals who combine STEM and art or for those who specialize in either STEM or art? What about future demand?

Closure

Are there any topics that we covered where you would like to provide additional commentary?

Are there any thoughts or ideas you would like to share that we haven't already discussed?

Are there any questions you would like to ask of me?

Appendix E

Interview Questions with a STEM Professional

<u>Heading</u>

Project: STEM attitudes regarding STEAM

Date: ________________

Time: __________________

Location: ___________________

Interviewer: Darius Hines

Interviewee: ____________________

Instructions (opening statement): Thank you for your participation. I really appreciate you help in furthering my research. I feel this will be an important contribution to both the arts and science fields. Your insights will provide vital context to data I collect in future surveys and data analysis.

The purpose of this interview is to collect data on the attitudes of STEM professionals with respect to STEAM. This interview shouldn’t take more than about an hour of your time.

I don’t have any questions of a deeply personal nature so I hope you will be comfortable with my questions, but rest assured your answers will be held in strictest confidence and you don’t have to answer any questions you don’t want to. If you’re comfortable with me quoting you, I have a release to permit such dissemination. Otherwise, the information will be used confidentially to provide additional interpretation of collected data. This information, along with other collected data, will become part of my dissertation and possibly published and presented at conferences and other similar events.

<u>Questions</u>

<u>Demographics</u>

What is your STEM background (training, work experience, etc.)?

How long have you been at your craft?

<u>Decision-making</u>

What kind of decision-making arrangement works best for STEM professionals? Why?

How do you think STEM professionals feel about giving up some autonomy in a group setting?

Dialogue

What are the ways that STEM professionals establish norms of how they work together? Why?

What concerns or issues do STEM professionals in collaborations typically agree/disagree over? Why?

Interdependency

Is there a general guide for how artists implement plans of action?

Have you known STEM professionals to adopt plans of action from other disciplines, if only temporarily?

What are the ways that STEM professionals organize how they work together?

Affinity/interest

What is your familiarity with STEAM (STEM plus Arts) concepts?

Do you think it is better for STEAM to be created by having STEM and arts professionals collaborate or through developing STEAM from within STEM and arts independently?

What impressions do you have regarding the use of Arts in a STEM curriculum?

What do you see as benefits and detriments to incorporating STEM and the Arts?

Describe any place where art is currently part of your curriculum.

What types of arts do you think would best fit with a STEM program?

Have you ever collaborated with a arts professional to produce a transdisciplinary project?

What would be some of the resistance an arts colleague may have to engaging in the Arts?

What would make Arts collaboration more appealing to STEM professionals?

What gaps do you see that need to be filled to enhance collaborations between STEM and the Arts?

Process

Which do you think STEM professionals would be more drawn to, structured evolution of a collaboration or a more open-ended arrangement?

What have you observed about collaboration that STEM professionals enjoy most about the collaborative process?

Sharing/Purpose

If you were asked to envision a STEM and Arts collaboration, what would it look like?

What are the reasons that STEM professionals collaborate?

Specialization

If either you studied both STEM and arts disciplines or if you have friends or colleagues that studied both STEM and arts disciplines, did they specialize or do they continue to do both?

Do you know many professionals who combine STEM and arts in their work as opposed to those who specialize?

How often do you see STEM professionals combining STEM and arts on a routine basis?

Do you think there is a greater demand for professionals who combine STEM and art or for those who specialize in either STEM or art? What about future demand?

Closure

Are there any topics that we covered where you would like to provide additional commentary?

Are there any thoughts or ideas you would like to share that we haven't already discussed?

Are there any questions you would like to ask of me?

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