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Learning Across Disciplines: A Collective Case Study Of Two University Programs That Integrate The Arts With STEM

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Abstract

There has been some debate and research that suggests the arts are well-suited to be combined with science, technology, engineering, and math disciplines making the STEM acronym STEAM. STEM education is an educational and political priority in the United States and is valued as a means of strengthening national security and ensuring global competitiveness. The STEAM paradigm also emphasizes the importance of STEM education, but argues that the arts have the ability to open up new ways of seeing, thinking, and learning. This study aims to share student learning experiences in two established university programs that integrate an arts discipline with a STEM discipline. Student and alumni interviews are compared within a collective case study methodology. Framed by principles of sociocultural theory and experiential learning theory, this inquiry explores the role of arts integration, collaboration, and experience centered learning in knowledge creation.

STEM to STEAM Introduction

One area that has received particular attention in education and policy debates is the STEM to STEAM movement, the impetus to include the arts in science, technology, engineering, and math learning (Maeda, 2013). The emerging STEM to STEAM movement is largely grounded by an effort to incorporate the arts with STEM as an equally important, and not simply a supplementary subject (Bequette & Bequette, 2011; Artworks, 2012). STEAM education is based on the premise that STEM and the arts function better together than they do apart. STEAM is a relatively new term, but collaborations across the intersections of the arts and STEM are not a novel idea. Dating back to thinkers like da Vinci, the inherent interconnectivity between the arts and sciences is an area of research and practice that can be traced throughout history (Atalay & Wamsley, 2008). Eisner and Powell (2002) also questioned the notion that art and science belong in different worlds, and noted synergies across the different disciplines. The STEM to STEAM movement presents new language to frame such interdisciplinary thinking.

STEAM-based programming and institutions are becoming more visible. The Stephen W. Hawking charter school in San Diego is one example of a school that was developed completely around the notions of STEAM (Dipping, 2013) and there are also other STEAM schools or academies that exist nationally. Union Point STEAM Academy, in Union Point Georgia, is another example of an elementary school employing the STEAM framework and creating bridges with regional arts organizations through a formal partnership with the Steffen Thomas Museum of Art (Mote, Strelecki, & Johnson, 2014). In higher education a STEAM program was created in part with support from Lockheed Martin, a prominent aerospace and technology corporation, and the State University of New York at Postdam. The STEAM program will be implemented as part of their Student-Initiated Integrative Major, and this research outlines the reasoning and process for establishing this new undergraduate opportunity (Madden, Baxter, Beauchamp, Bouchard, Habermas, Huff…Plague, 2013). Programs embracing the STEAM model exist at universities, for example, there is the STEAM program at the University of Texas-Dallas, and also the New York Film Academy has a collaboration with NASA scientists in their STEAM program. Despite emerging innovative STEAM programs, at this point there is minimal research sharing the process of creating STEAM based curriculums and partnerships and even less insight into the impact of existing programs.

STEAM is also visible in the political arena. Congresswomen Suzanne Bonamici and Congressman Aaron Schock created a Congressional STEAM caucus in January 2013. As former Rhode Island School President, John Maeda noted at the Congressional STEAM caucus kick-off event "Innovation depends on the problem solving, risk taking and creativity that are natural to the way artists and designers think, art and science – once inextricably

linked – are better together than apart" (*Reps Bonamici and Schock Announce Bipartisan Congressional STEAM Caucus*, 2013). The National Endowment of the Arts (NEA) and The National Science Foundation (NSF) have also partnered to create new ways to connect the arts and design with science and engineering (Malina, 2012). Using this momentum, this article aims to present a scholarly contribution to the STEAM movement. This study examines student learning at two established university programs that integrate an arts discipline with a STEM discipline. In a collective case study approach this inquiry aims to share student learning experiences and perceptions of how well learning goals were achieved.

Literature Review and Conceptual Frameworks

The research supporting arts integration informs the curriculum choices of both selected programs and sociocultural and experiential learning theories are used in tandem as a lens for understanding knowledge creation within university programs.

Arts Integration. While it is not the primary role of the arts in academia, visual and performing arts have the ability to enhance learning in other subjects. A large facet of arts coursework is *inquiry-based*, which means it revolves around questioning and understanding concepts versus finding the answer to a given problem. There are multiple right answers. An inquiry-based model of learning is analogous with principles of critical thinking that are typically highly sought after aims of university coursework (Heilig, Cole, & Aguilar, 2010; Goldblatt, 2006).

Studies have also suggested that learning through the arts has the ability to transcend across different disciplines and enrich learning in disciplines beyond the arts (Burton, Horowitz, & Abeles, 2000; Hetland, 2013; Lampert, 2006, Saraniero & Goldberg 2011). Similarly, one study revealed that when arts coursework was integrated in a university engineering program, students were able to capitalize on the inquiry-based nature of their arts coursework and apply this to their engineering coursework. Without this perspective from arts coursework there may have only been one solution or no solutions (Costantino, Kellam, Cramond, & Crower 2010). The arts promote imaginative thinking and create a deeper understanding of the visual world (Eisner, 2002). Looking at Root-Bernstein's (2008) study of international Nobel Laureates from 1901 to 2005 showed that this group of high-achieving individuals identified avocations in the arts significantly more than the general public. While this does not establish causation between arts involvement and heightened cognition it does provide a basis to challenge educational policies that marginalize the arts or concerns that arts integration is diluting learning in a particular subject.

The arts have intrinsic benefits and some scholars' caution against framing the arts as solely a means of improving learning in other disciplines. Furthermore, it is nearly impossible to

establish a causal relationship because positive traits associated with arts, such as creativity, imagination, and critical or divergent thinking, are not exclusive to the arts. The assumption that studies citing the transfer of learning from arts are unidirectional, meaning that the benefits are moving from the arts to another discipline, and does not account for a potentially symbiotic relationship (Burton, Horowitz, & Abeles, 2000; Eisner 1998). The cognitive capacities that are associated with the arts are not negligible, but the overemphasis on these outcomes has resulted in a skewed framework for justifying the importance of non-cognitive learning in the arts (Bresler 1995; Gullatt, 2008). The concern is that justifying the arts by their power to affect learning in a different academic area actually increases vulnerability by expecting too much from the arts (Winner & Cooper, 2000). The literature supporting arts integration and skeptical accounts of positioning the arts as a subservient discipline informed this study.

The History of STEM to STEAM

The STEM acronym emerged in the 1990's through NSF driven initiatives to group science, technology, engineering, and math together (Sanders, 2009). STEM became popularized through emphasis from policy makers. There is a federal strategic planning process for improving STEM education and the Obama administration has proposed the goal of producing 1,000,000 additional STEM graduates by 2020 (Holdren, 2013). The language supporting STEM education is typically framed as a means of remaining internationally competitive.

The addition of the arts to STEM is a more recent phenomenon. The STEM to STEAM movement is in part a reflection of collaborations and jointly funded projects through the NSF and the NEA, the two predominant federal agencies responsible for the promotion of STEM and the arts respectively. Despite the efforts to work across disciplines it is important to note the funding disparities between the two institutions. The 2014 NSF budget was 7.626 billion in comparison to the NEA budge of 146.021 million of the NEA (NSF Budget Request to Congress and Annual Appropriations, 2015; National Endowment for the Arts Appropriation History, 2015). While these are not the only funding sources in the respective fields in tells the story of the spending gap between STEM and the arts. Correspondingly, there is some criticism of STEAM as simply a means of piggybacking on well-funded STEM initiatives.

Why STEM. Some educators question why the arts would be a likely addition to STEM education, but I would like to frame why STEM education is in need of arts integration. STEM jobs are growing approximately three times as fast as non-STEM occupations (McDougall, 2012). This booming industry growth calls for strong STEM programs at the university level, but poor retention figures shows that many students are not successful in their

attempts to pursue a STEM degree. Only 43% of students that enter a four-year institution with a declared STEM majors actually graduate with a STEM degree (Holdren, 2013).

Students have different learning styles and studies in neuroscience shows that human beings have the ability to learn through visual, auditory, and kinesthetic cues. Artistic inquiry promotes rigor and creativity while also enabling an instructor to teach in multiple ways, which in turn creates more neural pathways and a higher probability of retaining knowledge (Asbury & Rich, 2008; Jeffers, 2009; Land, 2013). In addition to improving learning, the core content, arts integration can be engaging and bring joy to learning. "Whether drawing with free-form gestures or playing improvisational theater games, artists jump start creative work through activity that is fun, unrestrained, subversive, whimsical and free of a specific goal" (Brown & Tepper, p. 13, 2012). This type of process-oriented thinking is common and is conducive to creativity. Art and artists are able to create and contemplate serious pieces while maintaining a level of playfulness (Brown & Tepper, 2012).

Sociocultural theory. Learning is a complex process. The theoretical underpinnings that drive this inquiry of student learning in STEAM programs are sociocultural theory and experiential learning theory respectively. Sociocultural theory is largely informed by Vygotsky's seminal work in the field of psychology. In educational research, sociocultural theory is characterized by the notion that thought processes are culturally embedded and context bound and there are social, linguistic, and biological elements that all feed into knowledge construction (Vygotsky, 1980; Wegerif, 2004). By emphasizing the social relevance of learning, sociocultural theory aligns with the ideals of collaboration in learning environments and furthermore is consistent with principles supporting arts integration (Efland, 2002).

Experiential learning. With sociocultural theory as the primary cognitive framework, experiential learning is the principal educational theory utilized in the article. Experiential learning theory defines learning as, "The process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). Kolb's theory draws upon foundational ideologies from Lewin, Dewey, Piaget among other influential 20th century scholars with overlapping educational ideals (Kolb & Kolb, 2005). Experiential learning theory pulls from these theories and constructs a new framework based on six commonalities among seminal researchers. The guiding principles of experiential learning theory according to Kolb and Kolb (2005) are the following:

1. Learning is best conceived as a process, not in terms of outcomes.
2. All learning is relearning.
3. Learning requires the resolution of conflicts between dialectically opposed modes

of adaptation to the world.

4. Learning is a holistic process of adaptation to the world.
5. Learning results from synergetic transactions between the person and the environment.
6. Learning is the process of creating knowledge. (Kolb & Kolb, p. 3, 2005).

While both sociocultural theory and experiential learning are not specifically tied to the arts this cognitive and educational framework align with ideals of artistic inquiry.

Methods

Building upon the sociocultural ideals of cognition and an experiential framework of learning, this study is a collective-case study that examines data collected from two existing university programs. This methodology allows for one or more cases to be analyzed and compared (Baxter & Jack, 2008). I selected this design in order to collectively and distinctly view findings around student learning in two university programs.

The selected university programs are bound by the following criteria: integrate at least one arts discipline with at least one STEM discipline; reside within a Research 1 Institution; and be in existence for at least five years. I initially identified seventeen programs across the nation and proceeded to narrow the list to feasibly collect data over the course of one year. The two selected university programs abide by the aforementioned criteria and are undergraduate programs within the same public university system in the same state. I have named these programs the ArtScience and ArtTechnology program respectively.

The ArtScience Program

The ArtScience program was officially established in 2006 and aims to bridge arts and science learning through an experiential teaching model where site-specific contexts and hands on experiences become the forum for expression and learning. The ArtScience program presents a new paradigm for learning art and science by teaching the two in tandem to highlight commonalities across the disciplines. There is also a community-minded emphasis engrained within the culture of the program; interested community members are able to participate in weekly workshops with ArtScience faculty and students. In addition to general coursework, the ArtScience program hosts an ongoing visiting lecture series featuring scholars and practitioners working across the arts and sciences.

Founded through a collaboration between a professor in the sciences and a noted public artist in the community, the ArtScience program was created through a proposal that was supported by the Vice Chancellor of the university. It is open to students of all majors at the university

and one way that the ArtScience program is integrated in larger academic fabric of the campus is through the university-wide undergraduate honors program. The program includes faculty in design, the sciences, museum educators, and professional artists. It consists of five primary faculty members in addition to four collaborating faculty members. All of the core faculty teaching courses in the ArtScience program have expertise in at least one arts discipline and on science discipline. Students can take one or several courses in the program. As a reflection of the loose program model, there are varying levels of engagement from undergraduate students that participate in the ArtScience program. Some students are highly engaged and take all of the ArtScience courses offered, while others only take one course as a means of meeting the undergraduate honors requirement.

The program is comprised of 175 to 250 students per year, offers three general education courses, and has several specialty seminar courses, from which they offer two or three annually. The three general education ArtScience courses are an art and science focused photography course, an entomology/visual arts course, and a music/science course. All of the courses in the ArtScience program have instructional lectures paired alongside project-based assignments created at hybrid art studio/laboratory space designated to the ArtScience program. Final projects in ArtScience courses typically entail a collaborative project or exhibition. The program is situated in a large Research 1 public university where 73% of the students are White or Asian and 16% of the student population is classified as Hispanic.

The ArtTechnology Program

The ArtTechnology program is focused on technology in conjunction with art and culture and was created in 2001. This program is structured differently than the ArtScience program in that this program is the mandatory general education course series within an ArtTechnology focused college on campus. Institutionally there was a push to create an innovative college that reflected the current climate and revolutionary role of technology. The idea to integrate the arts as well as technology was voiced by some committee members and soon became embedded in the new college's strategic planning process. The group in charge was comprised of a steering committee of faculty across the academic spectrum and included voices from the arts. A Founding Provost, who was an established professor in the sciences, led the steering committee in establishing an art and technology focused college and its core curriculum, the ArtTechnology Program.

Students in the ArtTechnology program are required to take three sequential courses, complete an independent internship or practicum that applies course knowledge, and complete an upper division writing course. The titles of the courses shift depending on the faculty in charge. The arts are not stated in all course titles in the program, but according to the academic planning documents arts and technology are integrated in each course through

artistic exploration and projects that require creating or visualizing. There are six management and teaching positions dedicated within the program in addition to a pool of rotating faculty from various departments across campus. Since the faculty are rotating in the ArtTechnology program there is less consistency in course content. A few examples of courses taught in this program include: Music, Technology, and Society; Remix: Authoring the "Found" in Public Space; and Are We Alone? The course titles partially tell the story of the evolving curriculum that aims to be reflective of the current artistic and digital landscape. The aforementioned courses are taught by professors in music, visual arts, and physics, respectively. The depth of arts engagement can vary depending on the background of the instructor.

The scope of the ArtTechnology program is also much larger than the ArtScience program, there are 3,625 students in the college that requires ArtTechnology coursework and this accounts approximately 16% of the university's undergraduate student body. Demographics of the university show that almost 45% of the undergraduate student population classify themselves as Asian and the next largest ethnicity is White with 23% followed by Mexican-American at 12.5%. Both programs are housed in universities with a population of less than 5% population of African American students.

Research Objective

Both the ArtScience and ArtTechnology programs preceded the STEM to STEAM paradigm in education but the current and founding members of both programs attest that the mission and learning goals of these programs are using the concepts aligned with the current STEAM movement. By examining programs that pioneered STEAM concepts prior to the prevalence of this language this research sets to share experiences from established programs that have endured and flourished.

This paper aims to provide insight into the following research question and sub-question:
What are the learning experiences in the ArtScience and ArtTechnology university programs?

> If student learning outcomes have been established, how do students perceive the degree to which the outcomes were achieved?

I had preliminary conversations with the program founders at the ArtScience and ArtTechnology program followed by tours of the facilities for each program before embarking on the data collection process. At the ArtScience program I reviewed the course catalogue in addition to an overview of the program that encompassed its funding structure, mission, and learning goals. In addition to a course catalogue, the ArtTechnology program also had a formal academic plan that I reviewed—this document presented the general purpose of the program, but also contained specific learning outcomes that were outlined for the ArtTechnology program. Following a general program review I scheduled interviews with

students and alumni from both programs. The interviews were recorded and transcribed. I used open coding to examine and theme the data. 54 distinct codes were derived from the interviews.

Data Analysis

Learning Themes in the ArtScience Program

For the ArtScience program I conducted 13 student interviews, three alumni interviews, and two impromptu interviews with community members who also partook in program projects. In these interviews I started by asking basic questions like their major and what year they were in the program, or what year they graduated. I followed these questions by asking students, alumni, or community members about projects in the program, and the relationship between the ArtScience program and their career goals. Finally I asked what they thought the learning goals were for the program and how the program is doing in achieving this goal. Interviews were semi-structured to allow for additional follow up questions when necessary. All of the interviews ended with an open-ended question asking participants if there is anything else that they would like me to know about the program.

Sociocultural: Collaborative Learning

I visited the university that houses the ArtScience program during finals week and conducted interviews with students as they came in shifts throughout the day to work on an outdoor mural project for a science course about various types of bees. The program founders also arranged for alumni from the program to meet with me while I was on campus. Each student was assigned a particular type of bee, for example a nurse bee or a queen bee, and was responsible for learning about their bee and sharing that knowledge with peers. The project also had to function as a collaborative permanent sculpture. They were conversing and comparing their work to make sure their pieces were anatomically correct and fit within the broader mural that they were creating. They knew that there was a larger purpose to the art piece that they were creating and in order for the group to have a successful outcome there needed to be dialogue between the classmates. "The entire thing is basically a collaboration. You're trying to figure out where does this go? Where does that go? Can I borrow your mold?" said a student in describing the collaborative work in the course (ArtScience student, Sociology student, June 1, 2013).

Students also commented on the amount of collaboration in the ArtScience program as being atypical.

> It's a different way of approaching a problem by getting the solution as a team. Oftentimes I don't think I really have to do that in my other classes, getting all together to work on a project in a creative environment. It's a really nice way

> of looking at things and I think that it will help me in the future when I have other projects, even if it's not an artistic project (ArtScience student, Biological Science major 1, June 1, 2013).

Another student also commented that the experience of working as a collective and being part of a larger project help her not only understand the species she was creating, but also engage with her classmates about what they were working on as well. "It helped me realize that I shouldn't always focus on one thing but also take into consideration other people that are around me" (ArtScience alumnus, Sociology major, June 1, 2013).

An alumna with a science background also echoed the benefits of learning from her peers. She felt like the level of collaboration in the ArtScience courses helped her learning in both subjects. "It's highly collaborative in both aspects. Being collaborative in the arts trains you to be collaborative in the sciences" (ArtScience alumna, Entomology major, June 1, 2013). Course instructors made an effort to make arts accessible and students from all backgrounds commented on their ability to create and accomplish the creative expectations of program classes.

The social context of learning is fundamental to sociocultural theory and runs counter to the notion that learning is a one-way street where abstract concepts are digested by the student in a solitary fashion. Interviews revealed 18 different instances in the ArtScience program where students sited that they were learning concepts through collaboration.

Experiential Learning: Retention Through Doing

Another prominent pattern around student learning was the impact of learning through doing and the retention of this information. A few students with a science background were a particularly vocal about their appreciation for this type of applied coursework. A premedical student talked about the monotony of some science courses in relation to an ArtScience course co-taught by a professor in the sciences and a well-known public artist.

> Why can't all of our classes be like this? …In your average class you are in this mentality like, all right, I've just got to get this information down, memorize it, take a test and move on…the information that I've learned in this class I am going to retain so much better…I think what I am going to take from this program in the long term, aside from what I learned, is rethinking the way that I learn information and retain information (ArtScience student, Premedical Biology major, June 1, 2013).

Without being prompted, students suggested that they would like to see their other coursework incorporate a more artistic approach, which is reflective of the project-based ideals of experiential learning. "Honestly this information that I've learned through my work with my classmates, I'm pretty sure I'm going to remember it. It helps me retain information instead of just memorizing it for a test" (ArtScience student, Animal Biology major, June 1, 2013). Another student commented, "I wish I could take organic chemistry in a way where I could learn it in an artistic way" (ArtScience alumnus, Human Development major, June 1, 2013). A third student repeated:

> I would like this style of teaching to be incorporated into other classes…I take math and physics and computer classes, where we basically learn about theorems but then never apply it to anything. It feels like a memorization more than learning. It would be harder for classes like math, but I wish they could bring in examples and mix things up (ArtScience student, Computer Engineering major, June 1, 2013).

A recent alumna of the program also talked about her experience using her hands and learning through experience in the ArtScience program.

> Just being so hands on from day one, it clicked. I learned so quickly and I cared more because I was involved in it. It's definitely something that makes you learn content so much deeper and with so much more meaning in a shorter period of time…I'm a really visual person, and I think with science, a lot of times it's not visual enough for me. And then being able to create that with your in hands, it just it really stuck in new ways (ArtScience alumna, Human Development major, June 1, 2013).

Experiential learning theory emphasizes the overlap of experiencing, thinking, reflecting, and acting. The quotes above show how cognizant students are of their own learning and retention and what's more is that by going through this cycle of learning students will be, as Kolb and Kolb describe, (2005) empowered to take control of their own learning.

Enjoying Learning

Another significant theme throughout interviews was the seemingly simple notion that learning can be fun, or engaging. Interviewees used the words "stress-free environment," "relaxed," "casual," and "fun" to describe the ArtScience program (June 1, 2013). While having fun may not be a defined principle of sociocultural theory or experiential learning theory, there is no denying the power of enjoying learning, or the power of an engaged learner.

> I really like this course, especially compared to my other science classes, it offers a different way of learning. You go to lectures, and they're great because you learn so much, but it's really easy to forget why this stuff is

> important in real life. Coming out to [location of the ArtScience program] and seeing the research facility, I feel like it made it that much more real. It just makes me excited about science again (Biological Science major 2, June 1, 2013).

Excitement and engagement run hand in hand in creative transformative learning experiences.

> I think that this program changed my entire university experience. I never would have gotten into art…I'm really grateful that this has opened my mind…ArtScience program founders are absolutely incredible people who work so hard on this program, so I think it's inspiring when you see how much they care and how hard they work (ArtScience alumna, Entomology major, personal communication, June 1, 2013).

The students I conversed with talked about the encouraging nature of the program and the influence of the artist and scientist co-founders of the program. "They definitely want to bridge the gap between artists and scientists, and they focus on being creative, and that's a scientific thing as well…it just culminates in this really positive feeling that art and science are both valuable" (ArtScience alumna, Anthropology major, June 1, 2013).

Learning Themes in the ArtTechnology Program

At the ArtTechnology program I conducted three student interviews and six alumni interviews. These interviews were longer because the program had established specific student learning outcomes for the program. I asked the student and alumni the same questions that I asked at the ArtScience program, but since there were published learning outcomes for the ArtTechnology program I also asked participants how they felt the program was doing in respect to each of the learning outcomes set forth by the program. While the STEAM narrative and blending the arts with STEM was central to the creation of the ArtTechnology program, the learning outcomes did not focus on artistic or technological ability, rather the aims of the ArtTechnology program were to address broad educational ideals and produce culturally sensitive and competent learners.

One of the goals of introducing the practicum or an internship component to the program is interdisciplinary inquiry—it strives to "Establish and explore connections from more than one discipline or perspective." All nine participants felt that this goal was realized in their experience at the ArtTechnology program. When asked about this learning outcome, an Environmental Sciences major responded,

> The program does a really great job of this, especially the variety of instructors you have, and the variety of media that you are exposed to. You're asked to incorporate music, films, a lot of literature, and scholarly papers into your

> work, and they encompass a variety of backgrounds (ArtTechnology Student, Environmental Systems major, August 26, 2013).

The program pulls from disciplines beyond the STEAM paradigm, but still has a focus of incorporating technology and art as a connective thread throughout the program. Overall the interviewed students and alumni felt like the ArtTechnology program was successful in reaching its learning outcomes.

Sociocultural: Collaborative Learning

Like the ArtScience program, learning through collaborative projects was a theme that emerged from student and alumni interviews in the ArtTechnology program. "The practicum really sticks out for me. The whole practicum experience was basically a group project. It was a dialog among 16 students" (ArtTechnology alumnus, Cognitive Science major, December 5, 2013). The ArtTechnology practicum is a two-part requirement where students have a course alongside a hands-on internship. Students are able to select a practicum that aligns with their interests. For a faculty to create a practicum course it must go through an approval process at the ArtTechnology program to ensure the course content creates a project-based forum for blending art and technology. In addition to the practicum experience, there was also project-based learning and arts integration in general program courses. This type of collaborative coursework fosters collaboration across majors.

> It was interesting to see how an art major or communication major would attack the problem…I was very rigid with the way I thought, it was almost kind of computational, and it was good to see outside perspectives, someone who was more creative or right brain oriented as opposed to my rigid structure. The meshing of those different types of personalities was pretty interesting and it was nice to see how that all combined when we solved a problem (ArtTechnology Alumnus, Mechanical Engineering major, November 20, 2013).

As in the ArtScience program, sociocultural theory is highlighted through artful collaborations.

Experiential Learning: Influencing Careers

Interviews at the ArtTechnology program also revealed some examples of hands on learning, but this was not as prevalent as in the ArtScience program. Instead, interviews showed more of a focus on professional development and the importance of experiential learning in that context. Seeing that the ArtTechnology program requires a series of mandatory

undergraduate coursework it is logical that this program emphasizes preparing graduates for that next step. "They did a really good job of connecting your interests and future goals with the practicum requirement" (ArtTechnology alumnus, Biochemistry major, September 5, 2013). The practicum opportunity is flexible enough that students can cater the requirement into an internship that aligns with their interest. This requirement brings experience to the forefront. The practicum is paired with a writing requirement so experiencing, thinking, and reflecting is happening symbiotically.

Students also talked about the breadth of ArtTechnology classes and how it helped guide the major selection process. The program requires coursework in a student's freshman year in addition to upper division requirement that must be completed prior to graduating. Participants described the freshman sequential series as "theoretical," "diverse," and eye opening while the upper division requirements are "applied," "pragmatic," and "focused on career goals."

Broadening Student Perspectives

Interview participants seemed surprised by some of the big picture impact they felt from the ArtTechnology program. A psychology alumnus who is currently employed by the army explained how the program influenced him post-graduation. He spoke to a specific ethics course that blended art and technology in a contemporary cultural context.

> It was the first class I took that really made me look at a lot of things that I believe from a different angle…Realizing that not everyone views the world the same way I did. Looking at it from their side and realizing that they're coming from a completely different viewpoint (ArtTechnology alumnus, Psychology major, personal communication, December 4, 2013).

His eyes were opened to complex issues being analyzed through a range of perspectives and through a variety of mediums.

Students also talked about growing through challenges. "I think when we were able to make our own art, we were also given a chance to use different technology that we wouldn't normally use…it just asked us to step out of our comfort zone and use computer programs that we weren't used to" (ArtTechnology student, Environmental Systems major, August 26, 2013).

Through broadening perspectives and pushing new modes of learning the program has left a lasting impression on many of its participants.

> The program has helped me do many things better. I think the skills I have gained from this experience are self-reflective skills. Listening, really truly

> listening, to someone's story, listening to where they come from, their culture, and being able to see their biases and my own biases (ArtTechnology alumnus, Sociology major, personal communication, December 23, 2013).

These types of eye opening experiences help build strength of character and guide students on their respective paths after graduation.

> I was one of the people selected to do a speech in front of the class at the end of the quarter, which for me is kind of amazing because I used to have a really bad speech impediment, and it gave me so much confidence, and it's one of the experiences I look back on with so much pride (ArtTechnology alumnus, Cognitive Science major, personal communication, December 5, 2013).

She was able to face her fear and grow through the experience.

Discussion

While the programs content and structure are completely different they both conveyed powerful student learning experiences with largely similar themes. An overview of the discussed themes is presented in the table below.

Table 1. Student learning themes in the ArtScience and ArtTechnology programs.

Student Learning Themes by Program	
ArtScience	ArtTechnology
Sociocultural: Collaborative Learning	Sociocultural: Collaborative Learning
Experiential Learning: Retention Through Doing	Experiential Learning: Influencing Careers
Enjoying Learning	Broadening Student Perspectives

The Role of Learning Outcomes

One of the aims of this research is to present student perceptions of learning outcomes and how well these goals were realized. In respect to specific learning outcomes, the ArtScience program did not have published outcomes, but interviews still showed that participants had a clear understanding of program goals. Students and alumni were well aware that the program aims to bridge arts and science learning with a hands-on approach. This might be a reflection of the fact that classes are taught consistently by the same faculty members. I would

recommend publishing specific learning outcomes as the ArtScience program expands in order to measure program effectiveness and document student success stories and limitations within the program. This is one area where the ArtScience program can look to the transparently outlined learning outcomes of the ArtTechnology program as an example.

The ArtTechnology program focuses on preparing undergraduate students with the necessary skill-set entering the work force or continuing education and their goals are broader than strictly promoting STEAM. For this reason, learning outcomes encompass more than the integration of art or technology and focus on things like critical thinking, civic engagement, and information literacy. The programs broader focus on writing and scholarly aptitude fits clearly within the university mission and vision. While the scope of this study does not include a comprehensive program evaluation, interviews with students and alumni showed that the majority of these participants felt like goals were being met.

The program learning outcomes have remained as a consistent pillar of maintaining program quality throughout the years. Having formalized writing and practicum goals allows program leaders to track student learning and modify their coursework accordingly. By having a solid structure and position on campus, I expect that the ArtTechnology program will remain a central part of the larger university. However, the role of STEAM in the ArtTechnology program is less certain. There is a diverse array of digital and artistic coursework, but the variety of curriculum offerings and faculty makes it challenging to monitor the level of arts inclusion.

A Collaborative Experiential Learning Model in Practice

The student and alumni perspectives from the ArtScience program and the ArtTechnology program generally presented a common narrative. Students of all majors are able to converge and exchange ideas, and accordingly, this high level of collaboration was one of the most repeated themes from both programs. Similarly, both programs are committed to implementing an experiential learning model. Beyond simply learning through doing, to be fully realized, experiential learning requires thoughtful planning and reflection. Both programs incorporated a complete experiential model, but they had different strengths. Artist inquiry and physical making was central to the experiences of students and alumni from the ArtScience program. Participants talked about applying their knowledge into creating tangible objects. This process was not only enjoyable and new for many of the students, but also helped them retain the subject matter. At the ArtTechnology program students talked less about the act of creating and more about the thinking facet of experiential learning. Participants talked about how coursework influenced their college major and career choices, within and beyond the arts. There were clear opportunities, like the practicum, where students could explore and reflect on their own interests. Perhaps a more rigorous enforcement of the

artistic elements of the ArtTechnology courses would yield different results. A balanced convergence of opportunities for making and thinking is ideal.

The A in STEAM

The ArtScience program and the ArtTechnology program are both innovators in the STEAM community and were both created in a time when it was novel to have a formalized university program with an art and STEM focus. The ArtScience program in particular has integrated the arts comprehensively into their courses. The program has received local and national recognition for the art produced from their classes. The high level of arts integration and student engagement in the ArtScience program is a successful benchmark not only for the ArtTechnology program, but also for any emerging STEAM program.

Both programs were created with the intent that the arts are championed as an academic discipline and a tool to improve learning in other disciplines. In the mission and visioning of both programs there is acknowledgement of the merit of the arts and input from artists in the program creation process and continued involvement through teaching coursework. In the ArtScience program, there were more instances of students and alumni citing the arts as a tool to enhance learning in the sciences—more interviews would need to be conducted to see if the relationship between learning in the arts and STEM is truly mutually beneficial. If there is a disproportionate emphasis on solely improving STEM learning, versus bridging disciplines to create richer pedagogical experiences, then this runs the risk of devaluing the contributions of the arts.

Many of students cited their experience in both programs as an eye-opening interaction with the arts that they would not have been inclined to explore otherwise. While both programs were open to students of all majors and sampling of student and alumni interviews were random, this study showed a trend of STEM majors that cited these programs as a means of exposure to the arts. It would be interesting to deliberately sample students with an arts background to see if there are similar sentiments about STEAM programs as a vehicle for exposure to STEM fields. Echoing the initial notion that these disciplines are stronger together than apart and that STEM needs the arts, interview participants presented a strong case for arts integration at the university level. Increased creativity, broadened perspectives, and discovering unknown strengths are some of the comments STEM students shared about their learning through art-making.

Influences in Educational Policy

Looking at specific higher education policy implications from this study, there is a case for requiring incoming undergraduate students to partake in coursework that blends the arts with

STEM disciplines. Interpersonal skills are essential to learning, communicating effectively, and building relationships and through the ArtScience and ArtTechnology programs students and alumni developed these types of essential life skills (Spitzberg & Cupach, 2011). The high level of collaboration among individuals of different backgrounds is an ideal way to introduce university coursework to students, and furthermore, establishing an appreciation and understanding of the arts and sciences is productive and beneficial for any area of study. These programs could take various forms and integrate different combinations of arts and STEM fields. Based on this research, I recommend that university STEAM programs require students to participate in their Freshman year, are open to all majors, integrate at least one arts and one STEM discipline, and apply an experiential approach to learning. The policy influences of this research are not restricted to higher education. K-12 institutions would also benefit from modifying the curriculum to strengthen interpersonal skills and enrich learning through multiple disciplines. Ways of offering these opportunities include the addition of a STEAM elective course and integration of the arts and STEM appropriately in respective classes. This type of collaborative coursework would help prepare students for college.

Areas For Future Research

There is ample room for further investigation on learning experiences in programs that embody the STEAM model. More specifically, future research on programs with established learning outcomes should be conducted to see if there are differences in programs that integrate arts and STEM versus programs that keep the disciplines separate. Further research evaluating current STEAM programs is necessary to understand the impact of these university programs and continue to paint the narrative of these interdisciplinary academic programs. The field is new and growing but there is a wealth of unique partnerships and programs integrating arts and STEM fields. Research at innovative sites will help share various models and document the influence of STEAM-based learning. Beyond universities, non-profit and corporate entities have also initiated STEAM programming and a closer look at the outcomes of these programs will also benefit the field and enrich learning in various walks of life.

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