PARTNERING SCIENCE AND ART: PRE-SERVICE TEACHERS' EXPERIENCES FOR USE IN PRE-COLLEGIATE CLASSROOMS

Christy Belardo
Mohonk Preserve, New Paltz, USA
E-mail: Christy.Belardo@gmail.com

Andrea C. Burrows, Lydia Dambekalns
University of Wyoming, USA
E-mail: Andrea.Burrows@uwyo.edu, LyDart@uwyo.edu

Abstract

Research on teaching through discipline integration is currently emphasized as a gap in educational literature, and this study bridges discipline silos between the arts and sciences by indicating how science and art compliment content learning. A study of secondary education pre-service teachers (3 years, n = 52) participating in a science/art integration unit the semester before their last college experience, explores how integrated sessions capture both scientific and artistic discipline concepts. A mixed methods research approach measured changes in confidence of science and art knowledge, skills, and experiences of the participants. Quantitative and qualitative data support increased awareness and confidence in pre-service teachers' perceptions of how science and art can be incorporated into pre-collegiate classrooms, recognition of discipline similarities, and significant common themes when teaching both disciplines together. The researchers utilized a social constructivist framework with the qualitative data. Conclusions and implications include: 1) instructors can provide examples and modeling of interdisciplinary learning, which inspire pre-service teachers to explore new integrated disciplines in their own future classrooms, and 2) instructors can influence perspectives of pre-service teachers by offering integrated units, which produces open-mindedness of future teachers to use various teaching strategies.
Keywords: *science, art, pre-service teachers, pre-collegiate students, STEM education, STEM classrooms.*

Introduction

Overall, there is a lack of discipline integration at the elementary (ages ~five to eleven), but especially at the secondary (ages ~twelve to eighteen) teaching level in the United States (Czerniak & Johnson, 2014). Learning silos are seen across the world, and the trend is now towards subject integration (Taylor & Taylor, 2017). There are many research studies showing the integrated boundaries between disciplines such as the arts and sciences (e.g. see the Literature Review section). There are a variety of responses across the spectrum, but in some regions of the U.S. the arts are slowly being eliminated from the educational system. Although the science and art integration concept is not a new one, the authors of this article emphasize the learning context, and outline specific ways to utilize a similar unit and engage pre-service teachers (or future teachers of pre-collegiate students) while showcasing participant learning and perceptions before, during, and after the unit. With the push for future U.S. pre-collegiate students to lean towards fields such as science, technology, engineering, and mathematics (STEM), many U.S. schools marginalized the arts (Wynn & Harris, 2013). Thus, with a STEM focus, the arts are under the radar as "dispensable extras" (LaMore et al., 2013, p. 221). The arts do not need to take a back seat to the STEM movement, as integration showcases solid reasons to teach science and art concurrently and create a context for authentic learning that can spark student interest.

Literature Review

In the U.S. it is thought that STEM deepens students' understanding by contextualizing concepts, broadening minds about related fields, and increasing interest in STEM careers (Wang, Moore, Roehrig, & Park, 2011). STEM courses promote thinking where students are "purposely thinking about how STEM concepts, principles, and practices are connected to most products and systems we use in our daily lives" (Reeve, 2015, p. 8). STEM education often utilizes meaningful learning experiences by incorporating inquiry and structured activities that promote and develop a skill set that is successful for self-thinking, analyzing, and problem solving (NRC, 2011). Additionally, critique is a valuable tool to learn science (Henderson, MacPherson, Osborne, & Wild, 2015). The integration of the STEM-disciplines fosters awareness in future generations of real-world problems, situations, and issues by providing realistic perspectives, initiatives, solutions, and analytical-thinking (Wang, Moore, Roehrig, & Park, 2011).

The Next Generation Science Standards (NGSS), used in U.S. pre-collegiate classrooms, incorporate the idea of interdisciplinary learning through content, engineering skills and practices, and crosscutting concepts (NGSS Lead States, 2013; Woodruff, 2013). Working together, these aforementioned three dimensions provide engagement through active learning in project-based learning strategies and provide exploration through meaningful, relevant real-world situations (Krajcik, 2015). The NGSS contribute to students' learning opportunities by promoting strategies and identifying resources that prepare pre-collegiate students to use science to make their communities a better place (Penuel, Harris, & DeBarger, 2015).

There are seven crosscutting concepts provided by NGSS (NGSS Lead States, 2013) and they include: 1) patterns; 2) cause and effect; 3) scale, proportion, and quantity; 4) systems and system models; 5) energy and matter in systems; 6) structure and function; and 7) stability and change of systems. Within these crosscutting concepts, educators can expose science and art perspectives. For example, both the STEM disciplines and art develop and use models to make sense of phenomena and justify a position using evidence (Krajcik, 2015), and models enhance learning, influence collaboration, feedback, and reflection (Penuel, Harris, & DeBarger, 2015). Models constructed by students provide opportunities for them to engage in scientific practices such as engaging in argument from evidence and communicating scientific information and ideas about a phenomenon (Krajcik, 2015). Developing a model context and using critique is important in pre-collegiate schools (Henderson, MacPherson, Osborne, & Wild, 2015).

When convergent thinking and divergent thinking combine, they mutually benefit an individual to think creatively. Creative thinking and its relationship to higher order processing encompasses convergent thinking (analytical thinking), but also includes divergent thinking (associative thinking) for the learner. Divergent thinking is a skill needed for economic, social, and future successes (DeHaan, 2011). Convergent (analytical) thinking is the process where a student reaches one solution to a problem, whereas divergent thinking (associative) involves exploring several possible solutions to a problem (Madden et al., 2013). Combining both forms of thinking allows creativity to occur that benefits higher order mental thinking and problem-solving skills (DeHaan, 2011). Convergent and divergent thinking processes, when used in conjunction with each other, promote play, exploration, and deeper learning (Zubrowski, 1982). However, they also encourage the individual to test ideas, question issues, critique, and find solutions that may not always result in a single 'correct answer' but to multiple ones. More than just finding multiple solutions to problems, creativity promotes collaboration. Creativity increases peer-to-peer interactions and prolongs associative thinking (Davies, Jindal-Snape, Collier, Digby, Hay, & Howe, 2013). Collaboration and consultation are key skills that are significant to career and academic success (Burrows, 2015).

The arts promote essential skill development, such as image production and drawing, and contribute to whole brain development to enhance learning (Sousa, 2006). For instance the creation of images allows for visual cues to enhance learning objectives such as imaging and imagining (Sousa, 2006). Both disciplines rely on observation skills, and they are significant to careers in the scientific, artistic, and medical professions. Researchers should use the arts to enhance observation as well (Pellico, Friedlaender, & Fennie, 2009). Careful observation and interpretation of specimens, nature, and microscopic research are key components utilized in the scientific and creative processes (Dempsey & Betz, 2001). With a keen eye to specific detail, students are able to make connections between the lecture-content and hands-on field/lab experiences, interpret information through different modes of thinking, and develop an organizational reference tool (Baldwin & Crawford, 2010). While students are encouraged to use electronic media, they lose creativity skills by not practicing the art of generating personal images they observe (Sousa, 2006). Hence, visual representations are able to assist in connecting a student's understanding to lecture-content or information.

The arts add meaning to STEM. The U.S. goal of emphasizing STEM is not solely about expanding a presence in the industries of the world; the goal also includes making STEM meaningful to pre-collegiate students. This meaning is made relevant when the arts and culture are incorporated into STEM. Examining history, there are many well-known individuals that utilized their creative side to help advance the scientific field. Established scientific individuals such as Galileo, Da Vinci, and Einstein admitted to playing music, painting, drawing, and other fields of the arts (Baldwin & Crawford, 2010). "Galileo and Leonardo da Vinci used drawing both to observe and to learn" (Baldwin & Crawford, 2010, p. 26). They admitted that their art activities were the "driving force behind their scientific intuition" (Root-Bernstein & Root-Bernstein, 2013, p. 16). Zeidler (2014) explains that "science needs to be more interesting and relevant" (p. 4) for all global citizens whose everyday actions and decisions inevitably impact everything around them. The idea of incorporating the arts culture into STEM brings personal meaning and relevance to an individual's learning experience. The argument continues that pre-collegiate students are struggling to connect to STEM fields because these topics are impersonal, irrelevant, and removed from their immediate lives (Zeidler, 2014). By making the curriculum personal, it provides connections of how STEM is present in an individual's life. There is an opportunity in breaking down discipline silos for them to come together through a cultural stance, which inherently develops a personal meaning to understand not just science, but anything (Nichols & Stephens, 2013; Zeidler, 2014).

The opportunity for science and art integration exists in STEM programs that integrate the arts and sciences by providing more breadth, engaging, and meaningful learning experiences for pre-collegiate students. In fact, programs that incorporate both the arts and other curriculum areas offer the most powerful effects where both pre-collegiate students and teachers are able to understand how the arts are viewed while generating conditions that are significant for pre-collegiate student learning (Sousa, 2006). Dambekalns (2005) articulates that the idea of using art projects to convey scientific concepts, such as the satellite imagery, allows for understanding of Earth processes and geological features, map interpretations, and artistic application techniques to visually represent the landscape of the Earth's surface. Furthermore, exposure to both the science and art disciplines increases the knowledge of integration techniques and incorporates possible integration into future classrooms (Medina-Jerez, Dambekalns, & Middleton, 2012).

Successful instruction is an important component in motivating pre-collegiate students; therefore, there is a need to upgrade educators' knowledge and confidence as an equally important component to that motivation (Burrows, Borowczak, Slater, & Haynes, 2012). Building relationships with one another, partnering of both people and disciplines, to collaborate on ideas as well as build on content knowledge is vital (Burrows, 2015). STEM plus art is STEAM and provides the opportunity for teachers (pre-service or in-service) to gain confidence and utilize the knowledge of others and the surrounding community to develop partnerships based on strengths (Wynn & Harris, 2013).

Integrated learning experiences are an effective way to improve pre-service teachers' self-ratings of knowledge and ability to develop and eventually engage their students with interdisciplinary connections (Medina-Jerez, Dambekalns, & Middleton, 2012). Pre-service teachers can expose their future students to real-life tendencies and experiences, ill-defined problems through investigation, real-life design, and provide opportunities for higher-level thinking skills to develop. Giving pre-service teachers the opportunity to explore and investigate new ideas, concepts, and techniques, enhance their' knowledge, skills, and confidence in disciplines where they have little-to-no formal collegiate experience (Burrows, Borowczak, Slater, & Haynes, 2012). When schools utilize art and design in all their classes, but especially science, pre-service teachers can collaborate with each other while focusing on a common theme to create meaningful and positive learning environments and activities (Mote et al., 2014). Thus, pre-service teachers provide a future learning environment that improves their secondary students' learning and prepares them for successful, real-world careers.

Problem of Research

One answer to this integration problem of science with other subjects, however, could be in the discipline integration of seemingly disparate subjects such as science and art. One must ask if science and art are truly separate entities. Most educators view a disconnect between the two, such that curricula - outside of the visual arts - remain impoverished with a lack of visual learning strategies (Baldwin & Crawford, 2010). In reality, there is not a large difference between science and art skills, rather there are overlapping similarities and needs for the other (Lovelace, 2014; Needle et al., 2007; Ursyn, 1997; UW News, 2014). The arts are similar to the STEM fields, and are able to "re-invigorate the educational platform, providing not only an interesting approach, but also opportunities for self-expression and personal connections" (Land, 2013, p. 548) in pre-collegiate schooling.

Today's society challenges and changes professional and educational realms by advancing and altering technologies, skills, and literacies (Chittleborough, 2014; Johnson & Cotterman, 2015). In order for society to keep up with this fast paced and advanced intelligence, individuals must acquire knowledge "to work collaboratively within a collected intelligence, participate in social networks, negotiate across cultural differences, and navigate contradictory data available to them" (Land, 2013, p. 549). Combining the arts and sciences serves students' appreciation and learning for each discipline and develops life-long skills and creative perspectives needed beyond the classroom. Researchers agree that the integration of the two teaches individuals to think critically, creatively, and collaboratively (Milkova, Crossman, Wiles, & Allen, 2012; WDE, 2015a; WDE, 2015b; WY Videos, 2014). Skills that include problem solving and innovative thinking develop through scientific and artistic collaborations (Mote, Strelecki, & Johnson, 2014; Trueman, 2014). Success and progress is not accumulated by just knowledge and technology, but come from the melding of technology and creativity. Moreover, other disciplines show promise of true integration (Akerson & Flanigan, 2000; Bradbury, 2014; Burrows, Breiner, Keiner, & Behm, 2014).

Research Focus

For ten years (2006-2016), researchers utilized satellite imagery as a catalyst to visualize a scientific concept (Dambekalns, 2005). The pre-service teachers that they worked with designed pieces of art through silk batik painting that represents a part of the pre-collegiate science curriculum (Medina-Jerez, Dambekalns, & Middleton, 2012). Dambekalns (2005) articulates that the idea of using art projects to convey scientific concepts, such as the satellite imagery, allows for understanding of Earth processes and geological features, map interpretations, and artistic application techniques to visually represent the landscape of the Earth's surface. Furthermore, exposure to both the science and art disciplines increases the knowledge of integration techniques and incorporates possible integration into future classrooms (Medina-Jerez, Dambekalns, & Middleton, 2012).

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Vol. 75, No. 3, 2017

For this research, the science and art team (the authors) used a mixed methods approach, and they utilized data collected from three years of science/art integration unit quantitative and qualitative surveys (Fall 2012, 2013, and 2014), which measured pre-service teachers' perceptions of integrating science and art into future pre-collegiate classrooms. Specially, the research questions included:

- How have pre-service secondary teachers' perceptions about this science and art integration unit changed over a three-year period time?
- How has the silk batik activity influenced pre-service teachers' perceptions of science and art incorporation in their future classrooms?

Through an analysis of the Likert-scale survey quantitative data, as well as qualitative data including field notes (and the first author as a participant as well as master's student researcher, Belardo, 2015) and open-response survey question answers, the research team provides pre-service teachers' perceptions and uses of the science/art integration unit.

Methodology of Research

Instrument and Procedures

For three years (2012 – 2014), pre-service teachers of science and art methods courses (from a U.S. university) worked together during a science/art-integrated unit in the fall semester (each year is a cohort). The main focus of the unit was to identify attributes of teaching and learning science or art that were important to effective instruction. The methods courses offer pre-service teachers an opportunity to explore teaching approaches and strategies, review national reform documents and standards, and learn about major issues in their fields. Within the 16-week science and art methods courses, the pre-service teachers combined together for a 5-session science/art integration unit (approximately 7 total hours of instruction).

During each cohort's integrated science/art collaboration unit, the science and art pre-service teachers were asked to design and paint images onto silk batik while addressing secondary science and art curricular topics using both a macroscopic (e.g. satellite image of a river) and microscopic (e.g. virus) lens over four of the five class sessions. Unit objectives included: A) Connecting previous knowledge (instruction, teaching approaches, standards, and content) from pre-service teachers' methods courses and relating the knowledge to the integration unit; B) Creating a small individual and larger group silk batik that represented microscopic and macroscopic scales of scientific phenomena; C) Identifying artistic and scientific concepts from their microscopic art product; and D) Explaining the importance of science and art in the classroom based on a hands-on experience and collaboration with others.

Session 1- Introduction and Micro-teach: The instructors formed small, combined groups of pre-service science and art teachers. Each group consisted approximately of four team members (e.g. two science methods' pre-service teachers and two art methods' pre-service teachers). These teams remained intact throughout the duration of the five-session integrated unit to allow for close-knit team collaboration. Pre-service teachers performed a short 'micro-teach' on specific discipline topics that pertained to a variety of scientific and artistic areas during the first session (see Figure 1). They read pre-assigned literature (before or during the first session) that pertained to the discipline topics and then taught their peers about the topics through personally chosen activities and demonstrations. For example, the science pre-service teachers taught about solubility while the art pre-service teachers taught about tint and shading. The micro-teaches allowed the small groups to explore and experiment with a variety of scientific and artistic concepts, techniques, processes, and materials to develop depth of understanding in all the topics. Scientific concepts explored included: 1) primary and secondary colors of light, 2) surface tension of liquids, 3) adhesion and cohesion of liquids, and 4) the history of paints. Artistic concepts covered in the micro-teaches included: 1) primary, secondary, complementary, and neutral colors through mixing of paints, 2) understanding textures through paint application, and 3) defining composition of an image through hues, values, and saturation. After developing a foundation on the concepts of the science/art project to come, the pre-service teachers looked to the "sampler" of individual silk batik painting.

Session 2 – Exploring Connections through the Sampler: In the second session, the pre-service teachers created a small, individual sampler (a 12" silk-fabric round or square) using silk batik, dye, and other materials such as salt and vinegar. Each pre-service teacher chose and portrayed a macroscopic (large view not often seen by the naked eye) random GIS satellite image of a geographic location (images were provided by the instructors, but the pre-service teachers chose an image to use). The session introduced techniques and the process used to approach silk batik painting on the silk fabric rounds. The process included: 1) sketching the image with charcoal, 2) resisting lines of image, 3) drying the resist, 4) gathering supplies and paints, 5) application of the paints onto the fabric, 6) setting the paint with heat using a hair dryer, 7) washing with water to remove the resist, and 8) ironing the final product for a smooth finished product. The individual sampler activity enabled the pre-service teachers to get acquainted with the art materials, supplies, and techniques used for the upcoming microscopic image project. Pre-service teachers performed the first silk batik process on their own, experimented, and collaborated with peers on the creation of the silk round/square (see Figure 2). Although they each created their own sampler, the small groups experimented and discussed what to do throughout the sampler activity, using artistic concepts such as: color mixing, composition, and texture (from the micro-teaches in the first session). The small silk batik sampler that each art or science pre-service teacher created, prepared him/her for the main project of the unit – a larger-scale piece (approximately 3' x 4' silk batik), with a microscopic image (small view not able to be seen by the naked eye), created by the entire group (instead of the individually made samplers).

Figure 1: Micro-teach on solubility.

Figure 2: Sampler (right) & satellite image (left).

Session 3 –Silk Batik Image Consensus: The small groups of pre-service teachers used the microscopic image of their choice (books with images were provided by the instructors), drew, resisted, and painted that image onto a larger silk batik. The group controlled the decision of the chosen image for the larger-scale silk batik. Each group approached the decision of the prospective microscopic image by using the intended artistic and scientific knowledge that could be taught in their future pre-collegiate classrooms. These collaborative discussions assisted the groups in reaching a consensus for a microscopic image to portray in the larger silk batik, and later influenced the group's choice of scientific and artistic concepts discussed in their final group presentation at the end of the science/art integration unit. The pre-service teachers used session three to make decisions.

Session 4 – Finishing the Small Group Silk Batik: Once the pre-service teachers determined the image for their group's larger sized silk batik, they utilized the third and fourth sessions for completing the larger batik. The instructors demonstrated how larger amounts (3'x4' or 2'x4') of silk fabric was prepared and assembled on large wooden frames (slightly larger than the silk itself) for batik painting. Each pre-service teacher within the groups contributed to constructing the wooden frames (easily assembled with four boards and screws), preparing the silk by stretching it on the wooden frame, drawing out images, gathering and preparing supplies, implementing the groups' design/plan, resisting (creating the painting lines), painting, heat setting (with an iron), cleaning up, and finalizing the large batiks for whole class presentation/discussion, which included critique of their own work as well as the work of their peers (see Figures 3 and 4).

Figure 3: Starting the large silk batik (osteocytes).

Figure 4: Finishing the osteocyte batik.

Session 5 – Presentation of Art & Integration Understanding: After completion of the larger silk batiks, including rinsing and ironing the image, each group presented their finished larger silk batik to the rest of the class (and community members) in the last session (Figure 5). Each presentation included a discussion on their microscopic image chosen, scientific concepts that revolved around the image, artistic concepts used during the creation/presentation process, and how this integration unit incorporated both disciplines into the project with a reference from a pre-assigned article. Each small group worked through consensus to choose scientific and artistic concepts, key topics, and highlights portrayed within the microscopic image in the larger silk batik, and they explained the process. These concepts signify the key components to cover when utilizing the silk batik activity in a future classroom. Each group presented their experience in a 10-minute presentation that was recorded (see Figure 5), and their final silk batik was displayed for critique, questions, and discussion (contact second author for video link).

Figure 5: Presentation with chosen image (left) and painted image (right) of a butterfly's proboscis.

Methods and Data Analysis

The population sample presented here focuses on three consecutive years of the science and art pre-service teachers during fall semesters. The sample size of all three cohorts consisted of 52 pre-service teachers from the science and art methods' courses of (a U.S. university). The years were distinguished as Cohort 1 (Fall 2012), Cohort 2 (Fall 2013), and Cohort 3 (Fall 2014). The science and art methods courses consisted of undergraduate and graduate pre-service teachers of a science (physics, chemistry, earth science, geology, or biology) or an art discipline.

Data was collected through a mixed-methods approach to gain quantitative and qualitative information. All data were collected from the three cohorts through pre-and-post surveys. From an extension of previous works (Dambekalns, 2005; Medina-Jerez, & Middleton, 2012), the research team extended the study by also collecting data through observations, transcribed presentations, and peer interviews. Each year, pre-and-post surveys were administered to collect quantitative information on the perceived confidence and self-rating level of knowledge of science and art compatibility. Qualitative data were collected through open-ended questions. The open-ended questions asked each pre-service teacher to provide further insight into highlights, challenges, and his or her perspectives/experiences before and after the integration unit. Qualitative data from all cohorts were collected through final presentation of video recordings. In the recordings, groups presented their large silk batik and included: how the microscopic image was chosen, scientific concepts in the image, artistic concepts used to create the silk batik, and how the unit incorporated both disciplines into the project. During Cohort 3, qualitative data in the form of peer observation contributed to understanding how the activity personally motivated or caused resistance for incorporation of other disciplines into the participant's core-content curriculum, supplied the needs of the teachers, strengthened science and art together, and how science and art educators are partnering to create a combined unit. Pre-service teachers from Cohort 3 participated in 20-minute interviews to gain an in-depth perspective on their experiences of the unit. Interviews focused on emotional feelings and perceptions before, during, and after the science/art integration unit.

Pre-and-post science and art integration survey data contained 52 individual responses over the course of three years. Each participant was presented with nineteen questions in the pre-and-post survey. The first eight questions were used for a quantitative analysis that focused on perceived confidence and self-rated knowledge levels in science and art content progression, materials, thoughts, impressions, and perspectives. The next five questions captured personal information regarding individual skill and experience levels for the pre-service teachers in artistic and scientific mediums and skills, as well as prior experience working with other pre-service teachers of any discipline. These five questions asked the pre-service teachers to identify individual scientific and artistic skill levels, experience levels with scientific and artistic mediums, and level of prior experience in collaborative work with other pre-service teachers from any other discipline with respect to the science/art integration unit. The remaining six questions were used for a qualitative analysis that requested individual responses in regard to challenges and benefits of the integration, similarities between the two disciplines, and insight into the terms collaboration and partnership.

The research team ran a coefficient of reliability analysis test, computing Cronbach's alpha (.89 – relatively high internal consistency) and McDonald's omega (.94) (IDRE, 2016). These tests measure the anticipated correlation for two tests to gauge if they show the same construct. Additionally, the team conducted another internal consistency test, based on Guttman's six estimates of internal consistency reliability (lamba-6, .97).

The quantitative data collection (six questions) was divided into two sections including: 1) confidence in art, science, and interdisciplinary teaching knowledge and 2) skill and experience levels with art, science, and working with other pre-service teachers. For the pre-and-post science and art integration survey data, a mean was calculated with standard deviation for each confidence level in knowledge questions (questions 1-8) and personal questions (questions 9-13) answered by participants over a three-year period. Each pre-survey mean was compared to each post-survey mean for each cohort, as well as all three cohorts together to analyze change with respect to the pre-service teacher participation in science/art integration unit. Paired sample t-test comparisons were determined for statistical significance for a 95% confidence interval ($p < .05$) between the pre-and-post survey means for each question of each year.

For qualitative methods, three of the six open-ended questions were analyzed (questions 14-16 in the survey) for themes. These three questions asked the pre-service teachers to identify any benefits and challenges to the science/art integration unit and to identify similar skills that both scientists and artists practice. For the open-ended survey questions, the pre-service teachers answered the following: 1) What are the benefits of a science/art integration unit, 2) What are the challenges to a science and art integrated unit, and 3) How do artists and scientists practice similar skills? These three questions were analyzed by highlighting and color-coding specific common themes (Creswell, 2014) and concepts over the three-consecutive years of answers. Each theme/concept was counted for each individual year within a pre-and-post survey cohort. Once all themes were identified, highlighted, and counted, the most common themes were determined over the three consecutive years. Alongside the three-year qualitative themes that were gathered from the data, the common themes and concepts were compared to the observations, interviews, and presentations that were obtained from the sessions and presentations of Cohort 3 to determine cohesiveness, connections, and support.

Results of Research

Quantitative Findings

Overall quantitative results show (see Table 1), for all three cohorts, that the pre-survey means and post-survey mean scores were similar (6.0, 6.2, & 6.8 –and- 8.8, 8.2, & 8.3 respectively). Comparing pre to post survey scores, there was a significant increase in pre-service teacher self-reported science and art content knowledge and interdisciplinary teaching strategies ($p < .05$ for all questions 1-8) for all three cohorts (see Table 1 for p-values). Every question had a positive delta, or change, pre-to-post survey. All post survey means increased after completion of the science/art integration unit. All three cohorts demonstrated increased confidence in knowledge levels (cohort means) for the following: A) ways to engage learners with interdisciplinary connections, B) usefulness of satellite imaging, C) ways to develop interdisciplinary connection units, D) use of visual literacy made by both artists and scientists, E) implementation of instructional activities for visual learners, F) knowledge of mediums and physical principles, G) using scientific images as an artistic tool, and H) ways to integrate science and art.

The researchers conducted paired-sample t-tests on the individual pre-and-post survey questions for each cohort (see Table 1). All three cohorts showed 95% significance ($p < .05$) in seven out of the eight quantitative questions. Questions 1, 2, 3, 4, 6, 7, and 8 demonstrated significant increase in perceived confidence self-rating in knowledge from the pre and post survey among all three cohorts including: A) levels in finding ways to engage learners with an interdisciplinary connection, B) the usefulness of satellite imaging as a context for classroom science learning, C) ways to develop an interdisciplinary unit, D) the use of visual literacy made by both artists and scientists, E) the physical properties of mediums, and F) using satellite imaging as an aesthetic tool. Of the eight questions asked, there was one question that demonstrated significance in two of the three cohorts (Cohorts 1 & 3); Question 5 asked the pre-service teachers to indicate the level of confidence in implementation knowledge regarding instructional activities for visual learners in a teacher's discipline.

Table 1. Pre-service teachers' confidence: Science, art, & interdisciplinary teaching knowledge.

	Cohort 1 - 2012 (n=20)				Cohort 2 - 2013 (n=17)				Cohort 3 - 2014 (n=16)			
Question	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value
1	6.63 (1.81)	8.63 (0.87)	**2**	0.024	6.24 (1.31)	8.00 (1.08)	**1.76**	< 0.001	6.69 (0.91)	8.38 (1.33)	**1.69**	<0.001
2	4.79 (2.35)	8.63 (1.09)	**3.84**	< 0.001	4.47 (2.81)	7.65 (1.45)	**3.18**	< 0.001	6.54 (2.17)	8.15 (1.92)	**1.61**	0.038
3	6.05 (1.88)	8.47 (0.99)	**2.42**	0.007	6.00 (1.50)	8.00 (1.12)	**2**	< 0.001	6.69 (1.54)	8.15 (1.23)	**1.46**	0.001
4	6.42 (2.32)	9.05 (0.76)	**2.63**	0.010	6.12 (2.72)	7.94 (1.43)	**1.82**	< 0.001	6.46 (1.91)	8.38 (1.55)	**1.92**	0.028
5	7.26 (1.58)	8.89 (0.79)	**1.63**	0.047	7.59 (1.75)	8.11 (1.32)	**0.52**	0.250	8.00 (1.18)	8.77 (0.89)	**0.77**	0.018
6	6.16 (2.32)	8.63 (1.13)	**2.47**	0.003	6.88 (2.19)	8.65 (1.08)	**1.77**	0.003	6.38 (1.98)	7.38 (1.69)	**1**	0.047
7	5.42 (2.52)	9.00 (0.86)	**3.58**	< 0.001	6.82 (1.82)	8.82 (1.04)	**2**	< 0.001	7.15 (1.51)	9.15 (0.77)	**2**	0.001
8	5.53 (1.96)	8.95 (0.94)	**3.42**	< 0.001	5.82 (1.82)	8.35 (1.28)	**2.53**	< 0.001	6.54 (1.78)	8.23 (1.31)	**1.69**	0.014
average	*6.03 (0.77)*	*8.78 (0.22)*	***2.75 (0.79)***		*6.24 (0.92)*	*8.19 (0.39)*	***1.95 (0.75)***		*6.80 (0.53)*	*8.32 (0.51)*	***1.52 (0.43)***	

Regarding questions 9 to 13, pre-service teachers identified their individual scientific and artistic skill levels, experience levels with scientific or artistic mediums, and level of prior experience in collaborative work with other pre-service teachers from any other discipline with respect to the science/art integration unit (see Table 2). For questions 9, 10, and 13 (level of artistic skills brought to the project, level of scientific skills brought to the project, and level of previous experience with other pre-service teachers in any other discipline), there was an increase in cohort means from pre to post survey for all three cohorts. Questions 11 and 12 (level of previous experiences with artistic and scientific mediums) increased post survey cohort means for two of the three years. When analyzing significance between pre-and-post survey cohort means, questions 9, 10, 12, and 13 showed significance for only one year. Cohort 3 shows no significant question changes. Table 2 summarizes the answers in skills confidence and experience levels of the pre-service teachers for questions 9-13.

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Table 2. Pre-service teachers' confidence: Artistic, scientific, and experience levels.

	Cohort 1 – 2012 (n=20)				Cohort 2 – 2013 (n=17)				Cohort 3 – 2014 (n=16)			
Question	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value	Pre-Survey Mean (SD)	Post-Survey Mean (SD)	Delta	p-value
9	6.63 (2.74)	7.89 (2.36)	1.26	0.130	5.53 (3.18)	6.94 (2.62)	1.41	0.002	5.85 (3.55)	7.15 (2.25)	1.3	0.055
10	5.89 (2.85)	8.00 (1.78)	2.11	0.012	6.88 (2.37)	7.35 (2.27)	0.47	0.220	7.54 (1.50)	8.15 (1.70)	0.61	0.120
11	7.32 (2.43)	7.79 (2.24)	0.47	0.550	6.06 (2.92)	6.65 (3.01)	0.59	0.200	6.85 (2.88)	6.54 (2.87)	-0.31	0.680
12	6.32 (2.47)	7.74 (2.02)	1.42	0.046	6.94 (2.49)	7.24 (2.34)	0.3	0.350	7.77 (1.42)	7.69 (1.54)	-0.08	0.820
13	5.05 (2.58)	5.95 (2.48)	0.9	0.310	3.88 (2.16)	6.29 (2.32)	2.41	0.001	5.69 (2.70)	7.08 (1.86)	1.39	0.066
average	*6.24 (0.85)*	*7.47 (0.86)*	*1.23 (0.61)*		*5.85 (1.25)*	*6.89 (0.43)*	*1.04 (0.88)*		*6.74 (0.95)*	*7.32 (0.62)*	*0.58 (0.78)*	

Qualitative Findings

In overall qualitative results, the remaining six pre-and-post open-ended questions (#14 to 19) allowed pre-service teachers to freely voice their opinions, thoughts, and perspectives regarding the science/art integration unit. Three of the six open-ended questions (#14, 15, and 16) were analyzed for this study and highlight common themes amongst the pre-service teacher responses. Overall, there were 12 themes identified in the pre-service teachers' open response answers. Common themes that arose from the open-ended responses included: A) creativity, B) using visual tools and representations, C) engagement, D) collaboration/teamwork between teachers in a school, E) alternative learning strategies/styles, F) interdisciplinary learning, G) making real-world connections, H) observational skills, I) problem solving by similar methods, J) lacking a strong artistic background and skills, K) lacking a strong scientific background and skills, and L) time commitment. The frequencies of the themes are explored in the following paragraphs.

Question #14 asked the pre-service teachers to provide the benefits of a science and art integrated unit, and there was a general increase in overall awareness of benefits of a science/ art integrated unit. The most common themes that the pre-service teachers cited over the three years in a *pre-survey* response included: 1) interdisciplinary learning, 2) alternative learning styles and strategies, 3) real-world connections, and 4) collaboration and working together with other teachers in a school. From a pre-survey to post-survey standpoint, there were two highlights within the *post-survey* data including: 1) pre-service teachers transitioned from interdisciplinary learning as a leading benefit in the pre-survey to highlighting a variety of benefits after the unit (such as: engagement, alternative learning strategies, working together, as well as interdisciplinary learning); and 2) pre-service teachers did not acknowledge that problem-solving or making real-world connections were benefits (although they did on the pre-survey). This second point contradicts what is highlighted as benefits from the literature and is explored in the discussion. Table 3 shows the cumulative answer summary of the three cohorts (2012-2014) in regard to benefits of the science/art integrated unit.

Question #15 asked the pre-service teachers to provide the challenges that occurred within the science/art integrated unit. From a pre-survey to post-survey analysis, there was a general decrease of highlighted challenges. From the *pre-survey*, most common themes taken from the three years included: 1) interdisciplinary learning, 2) lacking strong scientific background and skills, 3) lacking a strong artistic background and skills, and 4) time commitment. *Post-survey* themes included: 1) interdisciplinary learning, 2) collaboration and working together with other teachers in a school, and 3) lacking a strong scientific background and skills. Table 4 highlights the cumulative challenges for the three cohorts.

Question #16 analyzed the responses on how the pre-service teachers thought scientists and artists practice similar skills. From a pre-survey to post-survey analysis, there was a general increase in awareness of similar skills that are shared between scientists and artists. Pre-survey responses did not include many similar skill sets. Upon completion of the science/art integrated unit with the *post-survey*, the pre-service teachers' responses included: A) problem solving by similar methods, B) observational skills, and C) using visual tools and representations in the post-survey (see Table 5).

Table 3. Cumulative summary of common benefits to a science/art integrated unit in 3 cohorts.

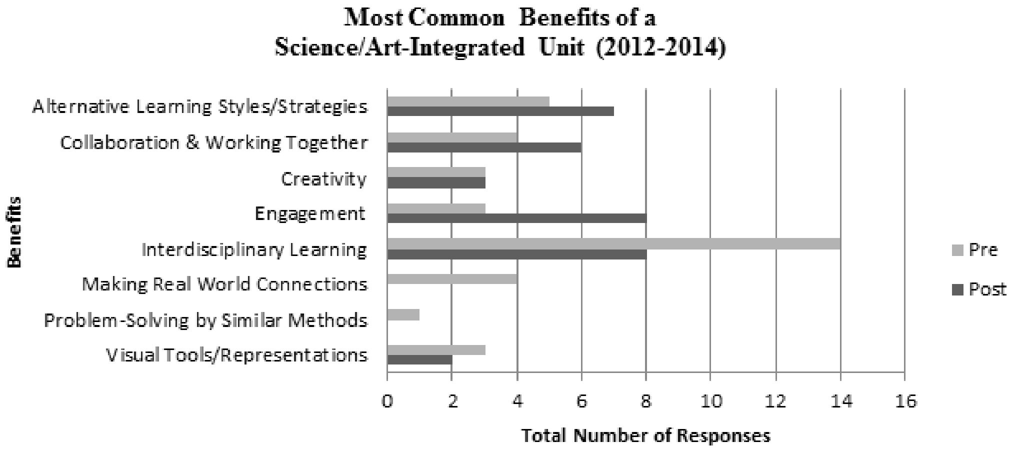


Table 4. Cumulative summary of common challenges in a science/art integrated unit in 3 cohorts.

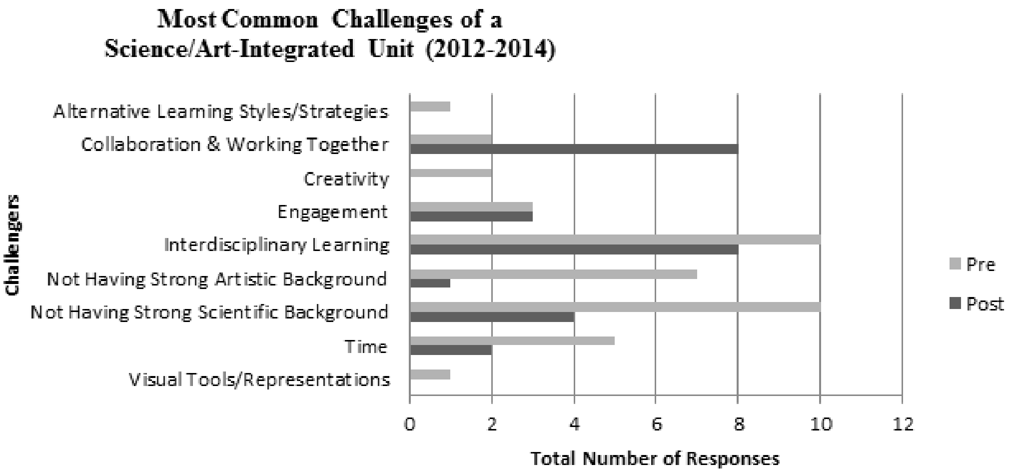
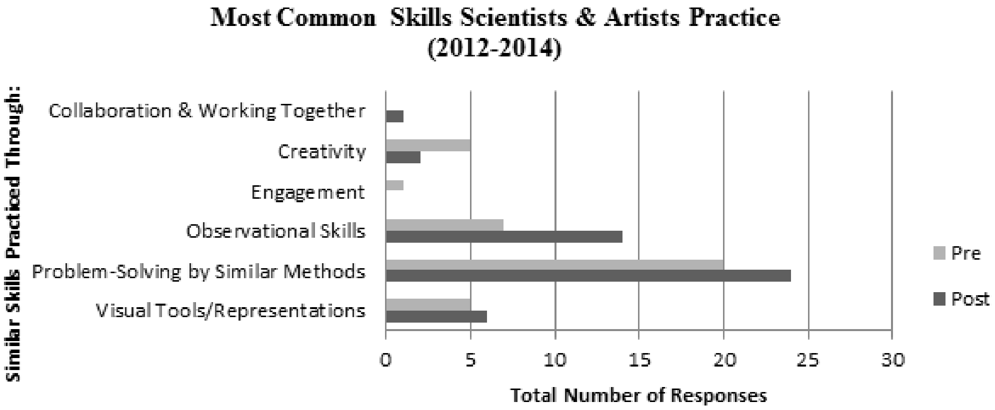


Table 5. Cumulative summary of scientist and artist common practices from 3 cohorts.



Each cohort presented their larger silk batiks and discussed their experiences and synthesis of the unit during the last session of the integrated unit. Example presentations can be viewed online [email the second author for a link]. Cohort 3 highlighted that despite the benefits that science and art integration brings to pre-service teacher learning, it can be incredibly challenging. One main challenge is time. This science/art integration unit encompassed five-sessions (over two and a half weeks) during a traditional 16-week fall college semester. Dedicating five sessions to the unit appeared to be incredibly short to the pre-service teachers. A few pre-service teachers expressed the need for more time to reflect on the science component interspersed with the art and then to create silk batiks. One pre-service teacher explained, "The unit was fun, we learned something new and unique, but we could have used more time to work on the piece."

Discussion

Researchers already know that science content and instruction can be complimented through art and creative endeavors by expanding modes of thinking (see the literature review). However, what is not known is if one experience (of approximately seven hours of science and art integration) can impact future teachers' thinking about science, art, and their expertise in each. By adding this data to the science education field, that 'yes' one science/art experience (~7 hours) can drastically influence pre-service teachers' science, art, and skill set perceptions, then researchers and pre-service teacher educators can purposefully integrate this type of experience into their classes, professional developments, and research projects. When researchers and educators include these science/art experiences into efforts to enhance the skill sets of pre-service and in-service teachers, it will be with the knowledge that integration experiences work to change perceptions and have a high impact factor.

Based on the pre-service teachers' experiences through the science/art integration unit, they demonstrated increased self-reported confidence in knowledge of the two combined disciplines and awareness that the disciplines are closely linked and similar. The researchers argue that the science/art unit helped steer pre-service teachers to the concept that the arts and sciences are not far removed from each other, and the research team believes that this trend would surface in other integrated discipline units as well.

When reexamining pre-service secondary teachers' perspectives about the science/art integration unit, they changed over time, and displayed an increase in 1) awareness of how the sciences and arts can be combined, 2) confidence in knowledge about art and science integration, and 3) skills and experiences to utilize in their future classrooms. This integrated unit allowed pre-service teachers to experience new ways to use both disciplines in the same classroom regardless of the discipline taught. This concept can be expanded to college and pre-collegiate classrooms of any discipline.

Using the integrated science/art unit, pre-service teachers collected both content and skill information for their personal teaching strategies in order to enhance their future classrooms. Their presented ideas for future integration are engaging, different, and meaningful for students. This unit supports pre-service teachers' understanding of how to engage their future students with interdisciplinary connections and ways to develop an interdisciplinary unit through science/art topics. Pre-service teachers' perspectives on integrated units, skills, and personal experience levels, positively shifted on pre to post surveys, in classroom interactions with peers, and through follow-up assignments. Originally, the pre-and-post surveys showed that pre-service teachers believed that not having an artistic or scientific background (depending if they were science or art students) would be challenging during the integrated unit, however, post-survey results supported that pre-service teachers of every background were successful with the unit. At the end of the fall semesters, all pre-service teachers realized that a lack of scientific and art knowledge could be overcome through collaboration and with support. Again, the authors of this article maintain that this is the power of the integrated unit, and the context created, regardless of the disciplines integrated.

Interestingly, the participant artistic and scientific skill levels brought to the science/art integration unit should stay constant from pre to post for the pre-service teachers (since the course offered just five class sessions), but they changed. Pre-service teachers indicated a significant post survey increase in artistic and scientific skills, experiences with artistic and scientific mediums, and experiences working with other pre-service teachers from other disciplines after the science/art unit. This finding is important in that such a small exposure working with another discipline on an authentic project, with a real-world application, can lead to a large change in perception. The pre-service teachers explored an authentic experience while their art and scientific skill set perceptions were altered by the unit. By the end of the integrated unit, the pre-service teachers gained confidence in both skills and experiences to bring into their future classrooms, and they could explain how they wanted to use an integrated unit as they plan to teach. The integrated unit provided pre-service teachers experiences that could be utilized in their future pre-collegiate classrooms. The pre-service teachers participated in this unit as a student audience (taught by the methods instructors as well as each other). The pre-service teachers were able to participate in the unit – similar to a future pre-collegiate student in their class – and experience the same processes and lessons that would be used in their own future classes. Additionally, they witnessed, from both a pre-service teacher and student point of view, the skills and standards that are and could be addressed during this unit.

A major component of the integration unit was the development of skills within the science/art context. The pre-service teachers learned how to use scientific and artistic materials effectively, while learning how to create silk batik with scientific content. Once these skills develop, pre-service teachers are able to relate the process of creating art with the science disciplinary knowledge. This unit connects the curriculum of science and art concepts to the NGSS (U.S. science standards), and the authors created Table 6 as a summary of art and science standards that could be addressed. Table 6 highlights a summary of the skills that the pre-service teachers worked on during the science/art integration unit based on the higher thinking skills that were developed through a Bloom's taxonomy model.

ISSN 1822-7864 (Print) ISSN 2538-7111 (Online)

Table 6. Bloom's taxonomy in relation to skills acquired, NGSS, & state standards.

Bloom's Taxonomy	Pre-Service Teachers' Skills Acquired	Pre-collegiate Students' Skills Acquired	Alignment of U.S. Next Generation Science Standards	Alignment of Wyoming Fine & Performing Art Standards
Knowledge: Student recalls or recognizes information	Recalls NGSS, WY State Science or Fine & Performing Arts from methods courses Relates own discipline into Science & Art-integration unit	Recalls previous art and science knowledge and experiences Records silk batik instructions Repeats silk batik activity through sampler and larger group silk batik	Starting with any Disciplinary Core Idea (Pre-collegiate Curriculum) Asking Questions and defining problems in 9-12 builds upon K-8 experiences and progresses	FPA 11.1.A.3: Students plan and create artistic works based on use of design elements and principles.
Comprehension: Student changes information into a different symbolic form/language	Explains his or her own discipline to others through micro-teaches Reviews scientific or artistic topics with peers through demonstrations or hands-on activities	Interprets and explains a scientific image through a silk batik art project	Scale, Proportion, & Quantity: some systems can be only studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	FPA 11.1.A.2; Students envision, create, communicate experiences and ideas, and work toward artistic goals through the use of media, techniques, technologies, and processes
Application: Student solves a problem by using the knowledge and appropriate generalizations	Demonstrates a scientific concept or process through an artistic concept or process Relates how this integration unit can be incorporated into their future classroom Practices an activity that can be transferred into future classroom	Demonstrates silk batik process by illustrating macroscopic and microscopic images onto silk Applies knowledge on color mixing, dye application, and artistic terminology in silk batik Recalls scientific processes of microscopic or macroscopic image being represented in silk	Developing and Using Models: design a test of a model to ascertain its reliability Planning and Carrying Out Investigations: selecting appropriate tools to collect, record, analyze, and evaluate data	FPA 11.1.A.4: Students collaborate with others in creative artistic processes FPA 11.2.A.1: Students observe and describe in detail the physical properties of works of art
Analysis: Student separates information into component parts	Compares and contrasts similarities between science and art disciplines Criticizes benefits and challenges of a science and art-integration unit Differentiates artists and scientific concepts explored within the silk batik activity	Compares artistic representation with actual image for likeness Experiments and tests with dyes, salts, and application techniques Questions composition in image representation	Systems & System Models: models can be used to simulate systems and interactions Analyzing and Interpreting Data: building on K-8 experiences, comparison of data sets for consistency and use of models to generate and analyze data	FPA 11.1.A.5: Students select, prepare, & exhibit their artwork & explain their choices. FPA 11.2.A.4: Students form and defend their preferences for artists, specific works and styles. FPA 11.3.A.3: Students analyze relationships of works of art to one another in terms of history, aesthetics, environment, and culture and place their work within the continuum of the visual arts.

***Synthesis*:** Student solves a problem by putting information together that requires original, creative thinking	Proposes ways that art and science can be taught in the same classroom Collects experiences of science and art-integration unit Prepares a presentation of experiences and perceptions had during unit	Creates representation and model of scientific images onto a different medium Designs a plan (with others) on how to approach silk batik problem/project	Engaging in Argument from Evidence: making and defending claims based on evidence Obtaining, Evaluating, and Communicating Information: reading scientific literature to determine central ideas or conclusions to summarize evidence and information	FPA 11.4.A.1: Students synthesize the creative and analytical process and techniques of the visual arts and other disciplines.
***Evaluation*:** Student makes qualitative and quantitative judgments according to set standards	Evaluates the integration unit as something a pre-service teacher would incorporate into their future classroom Selects and chooses what was successful and challenging of unit Rated their experience and perceptions through pre- and post-surveys	Evaluates presentation and explanation of scientific concept or process through the art product Selects and chooses what was successful and challenging of project	Constructing Explanations and Designing Solutions: making quantitative and qualitative claims regarding relationship between dependent and independent variables.	FPA 11.4.A. 2: Students identify artistic skills and determine how they apply a variety of careers and recreational opportunities

Referenced from NGSS Lead States, 2013; Wyoming Department of Education (WDE), 2008; WDE, 2013.

Furthermore, the integration unit aligns with standards that current science and art teachers are required to consider as they create lessons. Table 6 was created as a summary resource that all teachers – current and pre-service - can use to understand how the science/art integration unit can affect the content of their classrooms (perspectives, skills, and experiences), while understanding what pre-collegiate students could learn, develop, and experience. In considering how the silk batik activity influenced pre-service teachers' perspectives of science and art in the classroom, they were able to highlight challenges, benefits, and similarities of science and art presented in the same classroom. The pre-service teachers, after the science/art experience did not acknowledge that problem-solving or making real-world connections were benefits and this is disconcerting, as teacher educators want teachers to acknowledge the benefits of subject integration in solving problems. These revelations align with the objectives of the unit that introduces the idea of integrated classroom content, recognition of the challenges and benefits of interdisciplinary learning, and understanding of how collaboration and supporting others can be used in interdisciplinary units.

Conclusions

Based on the data analysis, the science/art integration unit was successful and easily employed in other settings. Pre-service teachers stressed how the unit benefited their learning by providing engagement, allowing for opportunities of fun and creativity, meeting needs of visual and other alternative learning styles within students, and providing opportunities to connect concepts and simultaneously teach differing fields. The pre-service teachers accepted the idea of interdisciplinary learning by combining multiple disciplines and imagining a science/art combination that was fun and engaging for pre-collegiate student learning. One recent pre-service teacher expressed, "[It's] a way to use science and art concepts to create lessons that are creative, engaging for students that are academically driven or who are not creative, and can help them understand the world around them." By incorporating these two disciplines – or others - into the classroom, the possibilities are endless and a series of skills can be developed, such as: problem solving, processing, analysis, and synthesizing of information, concepts, and processes.

The pre-service teachers discovered that both scientists and artists experience analogous processes in order to solve problems or approach projects. Both scientists and artists require observational skills in order to examine their artwork or a specimen under study. Another similarity is that both artists and scientists use and embrace the creative side of thinking.

There were challenges and lessons learned in this science and art project. Participants expressed that a common challenge was collaborating and working together with an unknown person. One pre-service teacher responded in the post survey, "Collaboration, open-mindedness, and willingness to adapt to uncomfortable academic disciplines are a challenge." While another pre-service teacher added in their post survey, "It would be challenging to find another [art] teacher willing to work with in the future." Also, when educators believe that they are knowledgeable only in one content area, interdisciplinary teaching is incredibly intimidating. Pre-service teachers noted that maintaining balance between the science and art concepts was challenging. As one pre-service teacher explained, "It was difficult to keep the science topics going during the artistic creative process [and vise-versa]." Another pre-service added, "Create a balance so one does not power over the other."

Incorporating the sciences and the arts together through an interdisciplinary approach, allows instructors to influence pre-service teachers and can inspire them to use another discipline in their future classrooms. Disciplines can and should complement each other while providing engaging, fun, and meaningful learning experiences. This science/art integration unit helped pre-service teachers to recognize that these two disciplines: 1) Utilize the same processes, methods, and skills; 2) Enhance observational skills of both disciplines; 3) Broaden understanding of a variety of curriculum and concepts; 4) Identify meaningful and real-world connections; and 5) Develop skills that are important to the '21st century society' now encouraged through STEM skills. Integrating artistic learning strategies into the science classroom makes the discipline less intimidating, and thus makes learning meaningful to a variety of styled learners. Providing artistic entry points into scientific lessons, promotes opportunities for hands-on participation, inquiry, testing individual questions and hypotheses, collaboration with others, and enhanced creativity.

Limitations and Implications

This science/art integration unit covered a small portion of interdisciplinary learning between only two fields, and the data collection focused on one example of a science/art integration unit for pre-service teachers. By expanding the study to other STEM topics and artistic mediums, different integrated units could provide pre-service (and in-service) teachers with further ideas beyond silk batik pictures using macroscopic and microscopic imaging. The participant-researcher collected observations and interviews only for Cohort 3, and this integrated discipline focus could benefit future studies.

The researchers introduced the pre-service teachers to interdisciplinary learning and they were inspired through a hands-on example of how the sciences and arts can be taught simultaneously before entering the classroom. The authors suggest that this trend will hold regardless of the disciplines combined. If instructors provide examples of and model interdisciplinary learning, they can inspire pre-service teachers to explore new integrated disciplines in their own future classrooms. By influencing the perspectives of pre-service teachers in a collaboration of science and art, before they embark on their teaching careers in pre-collegiate schools, this integrated unit provides an initial experience – a model - for STEM to turn into STEAM. Inspiration is derived from creativity, which allows for advancement to occur, and through the process of trial and error, students create, experiment, fail, succeed, and try again. This study represented true discipline integration, context learning, and authentic learning by showing how art can be added into a science curriculum and vice versa. However, there should be more research carried out on the interdisciplinary approach taught from all disciplines and the context of the learning. If the arts and other disciplines are included in the advancement of the STEM mission, then the pre-collegiate teachers of all disciplines – who shape all careers – could be empowered to highlight STEM aspects in schools.

Note

The pictures were taken by the corresponding author A. C. Burrows. The author has a permission from the students (signed consent) to use the pictures.

Acknowledgements

SWARMS (NSF#1339853) and RAMPED (WDE#WY1601506MSPA2) grant participants experienced this art/science integration project, and the authors are thankful for their participation and the funding of the various agencies. Note that the information in this article does not reflect the beliefs of the funders.

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Received: *May 29, 2017* Accepted: *June 22, 2017*

Christy Belardo	Masters of Science in Natural Science (MSNS), Citizen Science Education Coordinator, Mohonk Preserve, P.O. Box 715, New Paltz, NY, USA. E-mail: christy.belardo@gmail.com Website: http://www.mohonkpreserve.org/staff
Andrea C. Burrows	Curriculum and Instruction - Science Education, Ed.D., Associate Professor, University of Wyoming, 1000 E. University Ave., Dept. 3374, Laramie, WY 82071 USA. E-mail: Andrea.Burrows@uwyo.edu Website: http://www.uwyo.edu/seced/faculty-staff/andrea-burrows.html
Lydia Dambekalns	Art Education Ph.D., Associate Professor, University of Wyoming, 1000 E. University Ave., Dept. 3374, Laramie, WY 82071 USA. E-mail: LyDart@uwyo.edu Website: http://www.uwyo.edu/seced/faculty-staff/lydia-dambekalns.html