Summer July 1, 2012

Art and science education collaboration in a secondary teacher preparation programme

William Medina-Jerez, *Univerisity of Texas at El Paso*
Lydia Dambekalns, *The University of Wyoming*
Kyndra V. Middleton, *Howard University*

Research in Science & Technological Education
Vol. 30, No. 2, July 2012, 209–224

Art and science education collaboration in a secondary teacher preparation programme

William Medina-Jerez[a]*, Lydia Dambekalns[b] and Kyndra V. Middleton[c]

[a]*Department of Teacher Education, University of Texas-El Paso, El Paso, TX, USA;* [b]*Department of Secondary Education, University of Wyoming, Laramie, WY, USA;* [c]*Department of Human Development and Psychoeducational Studies, Howard University, Washington, DC, USA*

Background and purpose: The purpose of this study was to record and measure the level of involvement and appreciation that prospective teachers in art and science education programmes demonstrated during a four-session integrated activity. Art and science education prospective teachers from a Rocky Mountain region university in the US worked in partnership to produce a science-related art piece using a silk batik painting technique. This project incorporated the use of two hands-on activities (a sampler and a final piece). In addition, pre- and post-activity surveys helped researchers investigate whether an integrated activity led to changes in attitudes towards collaborative instruction among students from art and science education. A practical implication of these results could guide students' teaching assignments and professional careers.

Sample: This project involved the participation of 34 prospective teachers enrolled in secondary art and science education pedagogical content courses at a public university in the Rocky Mountain region of the United States.

Design and method: Prospective teachers in art and science education programmes worked together in a four-session integrated activity for three consecutive years. Participants were tasked with the design of art pieces addressing a core concept from the secondary school science curriculum using the batik painting technique. This project included two hands-on activities (a sampler and a final piece). In addition, they responded to pre- and post-activity surveys.

Results: Overall, the data show significant variation at pre- and post-survey, indicating that students had more knowledge after the study than before regarding the integration of art and science in the secondary school curriculum. The mean of interdisciplinary teaching ratings increased on all four target survey items according to the 10-point rating scale. Based on the results, the integrated art and science instructional approach significantly influenced prospective teachers' attitudes about collaborative practices.

Conclusion: In general, students' responses on survey items addressing content skills and previous experience of art or geological/biological images in the classroom were affected by their major area. Our experience suggests that an integrated learning experience is an effective way to improve prospective teachers' self-ratings of knowledge and ability to develop and engage students from secondary school classrooms with interdisciplinary connections.

Keywords: art; science; science teacher education; interdisciplinary teaching

*Corresponding author. Email: wjmedinajerez@utep.edu

ISSN 0263-5143 print/ISSN 1470-1138 online

http://dx.doi.org/10.1080/02635143.2012.698603
http://www.tandfonline.com

Introduction

Currently, faculty members in teacher education programmes are increasingly trying to optimise their work with prospective teachers by incorporating interdisciplinary connections in their pedagogical content knowledge (PCK) courses. The integration of the visual arts and science, in particular, provides examples of instructional approaches that can be readily implemented in primary and secondary classrooms and even in post-secondary education settings (Flannery 1991; Eisenkraft et al. 2006; Needle, Corbo, and Wong 2007; Baldwin and Crawford 2010). The merit of this integration resides in the power that visual representations have in scientific communication (Coleman, McTigue, and Smolkin 2011), an *art* that has been documented across the ages from Da Vinci onwards. This marriage of art and science has had international play across history and global boundaries, all the way from African bronze and smelting practices to early Renaissance pigment experimentation. For instance in the so-called 'Nature study' instructional approach, a multidisciplinary science teaching model established in the late nineteenth and early twentieth centuries in Europe, students were encouraged to make accurate observations while studying objects, organisms, and processes they found in nature (McComas 2008). This focus on observation skills is still a major goal in current science education reforms. When students engage in these types of activities, they experience a different way of knowing, thus visualisation becomes a tool to develop critical thinking skills, both visual and verbal.

In concomitance with this approach, current methodologies in science education call repeatedly for the inclusion of visual literacy instructional strategies as a tool intended to enhance student understanding of scientific information which they often encounter in textbooks, and on tests in graphic and symbolic formats, and even in nature as part of their day-to-day experiences (Campbell and Fulton 2003; Coskie and Davis 2008; McTigue and Croix 2010). The role of accurate observation skills is evidenced in strategies such as technical drawings. In this activity, students improve their observation and communication skills by engaging in a detailed depiction of an organism or phenomenon in nature. This task requires students to use their understanding about the target topic in a way that can be transferred into the final pictorial representation. Dempsey and Betz (2001) contend that 'one excellent way to describe an object is to draw it' (271). They also argue that although scientists recognise the value of drawing as a routine exercise in the lab and in the field, this practice is rarely taught and promoted in school classrooms. An accurate understanding of the nature of scientific knowledge suggests that students' ability to engage in scientific investigations should involve making observations and inferences (NRC 2007). While recording observations through technical drawings students pay close attention to detail 'noting every small feature and fine line' (Campbell and Fulton 2003, 31). Others (McTigue and Croix 2010) see visual literacy as a great mechanism to provide students with the necessary skills to become good communicators, test takers, and consumers of scientific information. From an aesthetical standpoint, students learn to see natural phenomena in ways that become ingrained in their conceptual understanding of scientific concepts (Pugh and Girod 2007). Regarding the history and nature of science, Clary and Wandersee (2010) highlight the benefits that graphic information in textbooks has on visual representation as a mechanism to address the history behind the development of scientific knowledge.

Currently, both art and science educators use the intersection of these disciplines for similar purposes. The integration of the arts in science teaching practices, and vice versa, allow students to practice and refine communication and problem-solving skills (Shaw, Baggett, Daughenbaugh et al. 2005; Chessin and Zander 2006) and from an artist-as-scientist angle, this collaboration fosters students' creativity and understanding of scientific concepts (Eisenkraft et al. 2006). This integration also 'promotes engagement in other disciplines and increases academic performance.' (Baggett and Shaw 2004, 3). Girod and Wong (2001) contend that 'the arts can educate people in ways few other disciplines can' (200). In addition to helping students achieve conceptual understanding and science talk, the authors propose that equally important is to know how students experience the world around them. In support of this goal, they submit that science education could build on the practices of aesthetic and artistic pedagogy. Particularly, in the chemical education community, the technical examination of art has been used as an effective tool in the teaching of science to students in primary and secondary classrooms. Although cases of the integration of art and science in science college courses are reported in the literature (Uffelman 2007), there is still a need for research in this area.

An example of this integration in higher education is the Picturing to Learn Program (PTL) created by Felice Frankle, a research fellow at Harvard University, and an expert in visual expression of science (MIT News 2006). In this programme students in science and engineering courses are encouraged to produce drawings from content delivered in lectures that could inform instructors about their understanding of abstract information, particularly in subjects such as chemistry. Students with different interests or learning styles (e.g., visual learners) may greatly benefit from this approach. Similarly, in school classrooms students commonly get involved in activities such as interactive note-taking and 'picture walls' (a variation of the well-known word-wall) in which they share their understanding of science concepts via graphic representation formats. These are strategies that teachers use both as instructional and assessment tools. In a teacher education programme, this approach gains relevance in that it is intended to model teaching practices that show prospective teachers connections that up to a point, 'may not be obvious to even students majoring in each discipline' (Needle, Corbo, and Wong 2005, 115).

In support of an art and science integrated instruction, it has been noted that both artists and scientists share a good deal of skills involved in the practice of their disciplines. As pointed out by Flannery (1991), 'they all feel the tension of a developing idea and the elation of a successful creation, whether of a work of art or of a scientific theory or discovery' (580). As members of their communities, both artists and scientists – to which our students are members of – practice standard procedures. For instance, they use precise terminology in their written and oral communication with their peers and with the public, practice observation skills which are at the core of the conceptualisation of an art piece or phenomenon under investigation, they both design experiments (approaches) to test their hypotheses (predictions), they approach prior knowledge in an attempt to inform their current work, they follow standard protocols in the practice of experimental work, and both artists and scientists dedicate a big portion of their work to reflect and assess their 'product' before presenting it for public scrutiny (Chessin and Zander 2006). Although their perceptions of what counts as science and art may be tinted with the traditional distinctions inherited from past generations (Eisner and Powell 2002), they 'have their criteria of validity and make intellectual and aesthetic decisions choices that are governed by a sense of concordance with nature' (Oppenheimer 1972, 4).

As university faculty, we feel called to model interdisciplinary teaching for our prospective teachers, the notion being that if they witness collaboration in their own pedagogy classes, they will be better prepared to transfer and implement such collaborations when they go out to their own classrooms. Additionally, our project sought to shed light in the convergence of art and science education where little research has been reported (Girod, Twyman, and Wojcikiewicz 2010) and even scantier studies have been conducted in the field of teacher education, particularly in terms of curricular materials for use in art and science education. This thinking was the impetus behind the research collaboration of science and art education students' joint silk painting project. The purpose was to have senior art and science education prospective teachers enrolled in teacher preparation courses (referred to as 'methods courses' in the US) describe the characteristics and relationships that exist between art and science through collaboration on a four-session integrated activity which culminated with the production of an art piece addressing art and science content from the high school curriculum. In this exploratory study, we sought to evidence the promise of positive outcomes and curricular adaptations in 'real-world' educational settings through collaborative teaching and learning in science and art. Our integrated approach revolved around the following question: How does an integrated art and science instructional approach influence prospective teachers' attitudes about collaborative practices?

Methodology

An art and science combined activity

In this integrated activity, implemented during three consecutive fall semester courses, a group of prospective teachers from art and science secondary education programmes from a university in the Rocky Mountain region of the United States had the opportunity to experience team work as they went through planning and decision-making procedures, discussion of visual challenges (i.e., message, use of colour, emphasis), and identification of possible ways to communicate scientific understanding of a given concept through a Batik piece at the end of the project. The focus of the activity was a combination of geological, biological, and nature imagery and a technique of silk painting called Batik, which has been a research interest of the art educator in this project. The reason for the selection of this approach is that it is widely flexible in terms of age and artistic abilities and is a natural platform for the practice of geospatial understanding that students could employ as they recreate their scientific perceptions (i.e., representation of a tissue viewed under the microscope). Adapted from Subramaniam's (2006) rules for integrating the arts, the art and science project in this study followed a six-step integration process, which students used as an activity guide and the instructors as an assessment tool (Table 1).

Table 1. An art and science integrated approach.

Step	What students do	Gathered information
(1) Alignment between the artistic processes and natural phenomena	List questions and explanation posed by group members. Brainstorm concepts from both art and science that support the conceptual understandings to be explored and represented through artwork.	Research question statements Scientific and artistic skills in the team
	Share experiences from their fields. For instance, terms such as visual literacy could be discussed by art education majors while their science education counterparts would address concepts such as scientific literacy.	Critique of artwork in the museum and sculptures on campus Feedback from museum director and artists
	Identify elements of existing artwork (e.g., art museum, sculptures displayed on campus) that will inform the design of the team's project.	Role assignments
(2) Reach consensus on the theme and question to explore	List the scientific concepts that go into the artistic process as well as scientific inquiry procedures (e.g., observations, inferences). These elements serve as the blueprint of the artistic rendition.	Question statements assessed vis-à-vis high school science and art education standards
	Formulate the question statement that will guide the group's project.	Science topic that guides the team's project
(3) Integration of the essential features of classroom inquiry	Give priority to the conceptual understanding that connects scientific explanations and the artistic process.	Inquiry-oriented process skills to be practiced throughout the project
(4) Brainstorm instructional strategies for future implementation in science classrooms.	Decide on an instructional strategy that would guide the implementation of an activity of this sort in high school classrooms.	Instructional strategies to facilitate the teaching of a science topic in high school classrooms
	Propose and explain instructional approaches.	
(5) Examine your 'imagined worlds' – what is the basis of the creation and do they have links to the big ideas and to the process and inquiry skills?	Engage in continuous dialogue; review preliminary sketches that may offer a closer look at the target conceptual understanding and at the chosen approach the team will use to create a work of art for a museum exhibition.	Placard draft

(*Continued*)

Table 1. (*Continued*).

Step	What students do	Gathered information
	Prepare a placard that explains the theme (scientific concept) in the group's project, and that the artistic aspects involved in the production of the painting.	Self-assessment of the work done
	Discuss progress made in the integration of the two fields.	Feedback provided on everyone's artwork during he exhibition

Links to standards

The combined art and science activity presented itself as a unique opportunity for the incorporation of national standards, both as promoted in science and art content areas. In the United States, as is true in many countries, most education necessarily must relate back to national or state expectations in each discipline. For example, the United States' National Science Education Standard (NSES) (NRC 1996) in its Teaching Standard A, states: 'Teachers of science plan inquiry-based science programmes for their students' (NRC 1996, 30). Likewise, the NSES also recommend teachers to collaborate within and across disciplines and grade levels. In this activity, prospective teachers had the opportunity to work first, individually and then with peers to plan, design, and produce an artistic piece focused on the secondary school science curriculum. Initially, each group chose a concept (e.g., states of matter) and then incorporated art principles into the process of learning about the target topic. They also shared arguments to support the concept represented in their final piece. The conceptualisation resulted from a brainstorm exercise that was planned on the second session. Further, an example from the United States' National Art Education Standard 6 (NAEA 1994) states: 'Students make connections between visual arts and other disciplines' (22). Quite often students are encouraged to consider content beyond 'art for arts' sake', but they may be unsure of how to actually apply this in their lesson-planning. This combined activity let them see how scientific concepts can inform the subject matter and style of the created art pieces.

Likewise, The National Science Education Standards (NRC 1996) recommend that science teachers pay close attention to the needs and interests of their students and the standards also encourage teachers to share various modes of teaching visual language. An art and science integrated activity is a good example of how teachers could respond to those demands; visual, oral, and collaborative learning practices will make art and science education practices affordable to students with diverse learning styles and interests.

The survey

In order to look at the relationship bridging the work done by teachers as scientists and artists among our art and science education students, an art and science attitude survey, designed by the science and art education university faculty, was administered to the participating prospective teachers both prior to and after the four-session activity (Table 2). The 15-item survey uses a 1–10 rating scale ('1' = *less likely to possess and practice the mentioned skills and understandings*; '10' = *much likely to possess and practice the mentioned skills and understandings*) and is organised into three sections. The first one, content ability, contains seven items and is intended to gather information about art and science content-based knowledge that is of interest for a combined project of this nature. The second section, interdisciplinary teaching, contains four items and addresses prospective teachers' knowledge about their pedagogical competencies regarding an art-and-science collaborative teaching approach. Since this instrument was developed for the current study, the instrument was validated to ensure it was valid for the group used. The internal consistency of the content ability section ranged from .679 to .812 as measured by Cronbach's alpha. The interdisciplinary teaching section's Cronbach alpha values ranged from .633 to .945, indicating the survey seems to be valid for the sample used. The reliability, along with the measure of internal consistency, allows the survey to be validated. The reliability results are discussed below in the pre-test/post-test results section. Finally, the third section offers four open-ended items for the participants to provide their feedback on the joint learning activity. Researchers hypothesised that the integrated art and science activity experience would improve attitudes and willingness to design and use collaborative teaching and learning for students in art and science education.

Participants

This project involved the participation of 34 prospective teachers enrolled in secondary art and science education pedagogical content courses. All the participating prospective teachers were in the final phase of their training programmes at the time of the study. They all completed and returned an informed consent form approved by the Institutional Review Board (IRB) of the university. Participants were also aware of the exploratory purpose of the study before completing the first survey. A total of 34 prospective teachers had valid surveys at pre-study, while 30 participants completed surveys post-study that were used in the data analysis. At pre-study, the majority of the 31 participants in this project were secondary science education majors (21 out of 31 or 67.7%). The remainder of the participants corresponded to students in secondary art education. It should be noted that three students were

Table 2. Example of items in the art and science attitude survey.

Section I
The usefulness of science-related imagery as a context for learning in the science classroom.
Your ability to implement instructional activities for visual learners in your discipline.
Section II
Your knowledge of ways to engage students with interdisciplinary connections.
Your understanding of the use of the concept of visual literacy made by both artists and scientists.
Section III
How do artists and scientists practice similar skills?
What do you see as the outcomes/benefits of this art-and-science integrated activity?

excluded from the study since they were missing post-study scores. Of the participating prospective teachers, 20 out of 31, or 64.5%, were female. In order to capture the key moments of the integrated project, we videotaped each session for future analysis; these images would also support the observed patterns and attitudes.

Sessions of the project

Session 1: the introduction

The art and science integrated project began by taking the prospective teachers to visit the Art Museum on the university campus where an exhibition detailing evolution was on display. Prospective teachers also considered a series of outdoor sculptures on campus as an information source for further connections between art and science. Museum employees and the instructors led a discussion about cross-curricular connections, and art and science concepts (e.g., visual literacy, light properties, colour spectrum) and applications of combining the two subjects. Then the instructors had prospective teachers form teams of four consisting of approximately three science education students and one art education student. This ratio reflects enrolment trends in the science and art education programmes at this university. These teams remained together for the rest of the project, with the hope that participants' content skills would help out group members at various points in the process. Participants took turns to lead the discussion of articles addressing this type of interdisciplinary project. They were also given prompts by the instructors which helped to add depth to the discussion sessions. The ideas were recorded and summarised on the board. At this point, the combined art and science classes moved to the art classroom to begin the next stage: painting of the samplers.

Session 2: the sampler

Step two was the completion of a 'sampler' piece as a preliminary activity for the final product that would be completed by a team consisting of art and science education students (Figure 1). The art education instructor then gave a brief presentation on the use of the medium, fabric dyes and batik techniques. Batik is an ancient fabric-based artistic medium that is rarely found in American schools, even in the art room. Since no one was really familiar with the technique at the onset of the project, it created a level playing field between art and science students. Batik pieces were painted on silk, since silk yardage is reasonable in cost and lends itself well to group or individual projects. However, lightweight cotton cloth also works. In batik, lines of resist (resin) are applied to fabrics which then dry before coloured dyes go onto the cloth. Wherever there is a resist line, the colour stops flowing. The results can turn out to be a nice mix of detailed and abstract shapes. Instructors encouraged their prospective teachers to think about the scientific concepts they wanted to express artistically. Samples of each stage of the process were displayed in the room so that participants could refer to them if they needed. During this stage, each student was given a frame with a piece of silk attached to it (approximately 77 square centimetres).

Next, each team chose an image depicting geological, human body systems, or nature features, and drew it using charcoal, with pattern marks to follow when

Figure 1. Prospective teachers work on the sampler piece.

applying the painting (Figure 2). Prospective teachers also explored the texture effects of salt, alcohol, formaldehyde, and vinegar when mixed with the colours. The use of these materials allowed the students to produce different shades and colours.

Since these prospective teachers were not at all sure of what these substances would do to the painted silk, it became a good practical example of an inquiry-oriented activity. In each group, a series of hypotheses were proposed in an attempt to explain, from a scientific point of view, the shades, tones, and colours produced with the mix of chemicals such as alcohol and the dyes. As pointed out by Rosenberg (2008, 468), for the participating prospective teachers, their designs and 'diagrams offered them a quick way of making a hypothesis'. Samplers were washed and hung to dry.

Session 3: viewing science through the lenses of art

The next step for the prospective teachers was to create a final group piece on a larger scale, using the same procedural steps as practised in the sampler piece (Figure 3). Before handling brushes, dyes and chemicals, each group actively explored the meaning of concepts such as colour and spectrum both in art and sci-

Figure 2. A sampler.

Figure 3. Creating a group piece.

ence; they also brainstormed on the use of colour by both artists and scientists. Themes represented in the final batik pieces included: states of matter, cellular division, marine environments, adaptation strategies in reptile species, seasons, and the solar system. This time, the dimensions of the frame (approximately 0.4 square metres) allowed all the members to participate in each stage of the process: demarcation of the pattern, resist (gutta) application, and painting.

Session 4: presentation of art projects

In the final session, each team had an opportunity to present its artistic piece along with their conceptualisation and instructional application in a high school science classroom. On this presentation day, art teachers from neighbouring schools visited the class and became active participants in the group discussions of how the implementation of this approach would actually look like in public school. In the exhibition hall of the education building, each art piece was accompanied by a placard indicating the title of the artwork, the science and art principles represented in the painting, and a potential use in science and art classrooms. Before the end of the final session, prospective teachers completed the post-study survey. Table 3 offers a sample of participants' reported connections between the two disciplines that could be implemented in a secondary school art/science classroom.

Data analysis

Paired sample *t*-tests were performed to determine how the integrated art and science instructional approach influenced prospective teachers' attitudes about collaborative practices. Correlational analyses for the first 11 survey items were also conducted to address the reliability of respondents' answers. Data were also gathered from the four final survey items (Questions 12–15), as open-ended questions, that allowed prospective teachers to respond freely to items about content ability and knowledge of interdisciplinary teaching. Open-ended responses were coded and described by percentages of total valid surveys (34 at pre-test and 30 at post-test) in specific categories from pre- to post-project surveys.

All data were analysed for descriptive and inferential purposes to reflect pre- and post-study attitudes, knowledge and usability of an integrated art and science

Table 3. A sample of cross-curricular applications identified by prospective teachers.

Concept	Objective	What students will do
Aquatic ecosystems	Students will be able to identify and describe the major impacts of agricultural practices on aquatic ecosystems.	Students create an aerial representation that captures the depletion of an aquatic ecosystem.
Properties of specific materials (e.g., dyes, fabrics)	Students will be able to explain why certain fabrics absorb different dyes at different rates.	Students design their own experiments to test the absorption rate of dyes that produce the most desirable artistic outcomes.

activity with students in a secondary education programme. Open-ended questions targeted knowledge, benefits and challenges of interdisciplinary teaching in the content areas of art and science.

Results

Participants responded to the first 11 survey items using a 10-point rating scale. The calculated overall response was 69.8% (37 students out of 53 completed both pre- and post-surveys). Due to the small sample sizes, tests for normality were done on the data from each year, and the data were found to be normal therefore parametric *t*-tests were used in the data analyses. In 2006, there was a significant difference between pre- and post-test scores on the 11 items ($t(11) = -4.72$, $p = .001$). The negative value is indicative of the prospective teachers having more knowledge after the study than before the study. The correlation between pre- and post-test scores was also significant ($r(12) = .80$, $p = .002$). This is indicative of the survey producing reliable results. In 2007, there was also a significant difference between pre- and post-test scores on the 11 items ($t(13) = -6.76$, $p < .001$). The correlation between pre- and post-test scores was significant as well ($r(14) = .76$, $p = .002$). Likewise, the 2008 data produced a significant difference between pre- and post-test scores on the 11 items ($t(10) = -4.04$, $p = .002$). The correlation between pre- and post-test scores was non-significant ($r(11) = .42$, $p = .20$), meaning that for the 2008 sample, the respondents' answers were not largely consistent across administration times.

Section I: content ability items

In 2006, there was a significant difference between pre- and post-test scores on the seven content items ($t(11) = -4.57$, $p = .001$. The negative value indicates prospective teachers scored higher on the post-test than on the pre-test which means participants expressed that they had more content ability after the study. The correlation between pre- and post-test scores was significant with $r(12) = .78$, $p = .003$ which speaks to the reliability of the instrument. In 2007, there was a significant difference between pre- and post-test scores on the seven content items ($t(13) = -5.66$, $p < .001$). The correlation between pre- and post-test scores was significant with $r(14) = .72$, $p = .004$. In 2008, there was a significant difference between pre- and post-test scores on the seven content items ($t(10) = -3.36$, $p = .007$). The correlation between pre- and post-test scores was non-significant with $r(11) = .43$, $p = .18$. See Table 4 for individual item descriptive statistics related to the content items.

Section II: interdisciplinary teaching

In this section of the survey, standard deviation values and the ratings for these items showed significant changes from pre-survey to post-survey (Table 4). In 2006, there was a significant difference between pre-test and post-test scores among the four interdisciplinary items ($t(11) = -2.98$, $p = .01$). Prospective teachers scored higher on interdisciplinary teaching knowledge and ability after the study. The correlation between pre- and post-test scores was significant at the .05 level with $r(12) = .68$, $p = .01$ which indicates the results were reliable across time. In 2007, there was a significant difference between pre- and post-test scores on the four interdisciplinary items ($t(13) = -6.51$, $p < .001$). The correlation between pre- and post-test scores was significant with $r(14) = .77$, $p = .001$. In 2008, there was a significant difference between pre- and post-test scores on the four interdisciplinary items ($t(10) = -4.45$, $p = .001$). The correlation between pre- and post-test scores was non-significant with $r(11) = .30$, $p = .38$. See Table 5 for individual item descriptive statistics related to the interdisciplinary items.

Section III: open-ended items

This portion of the survey contained four items that allowed prospective teachers to express their views on (1) their previous experience with artistic mediums; (2) the outcomes and benefits of an art and science integrated activity; (3) the challenges of an art and science integrated activity, and (4) the ways in which artists and scientists practice similar skills. Regarding the first question, and at pre-survey, 44.1% of the participants reported 'no previous experience' in the use of or having seen artistic mediums in their classrooms. As expected, those in art education indicated their familiarity with different artistic mediums (i.e., ceramic, clay, sculpture, drawing, and printmaking). As for the science education students, they indicated having practised art-related tasks in their college (i.e., remote sensing, presentation visuals) and secondary school courses (i.e., skeletal systems using pipes, sculptures of the DNA and sketching as a means of observation while using microscopes). A third group of students identified this integrated activity as their first experience with artistic mediums.

In the second item, which addresses the outcomes of this combined learning approach, prospective teachers described the benefits of this integrated activity with a positive change as 'engaging and useful for visual or hands-on learning' and 'collaborative and interdisciplinary in nature'. Some participants highlighted that secondary school students with an inclination for arts will feel fully involved during a combined activity of this sort, and that those into science will develop an appreciation for arts. Yet other students addressed the pedagogical value of this activity in that it 'promotes analogies' which fosters higher-order thinking skills.

Nevertheless, there were also challenges in trying to connect the two disciplines. As highlighted by the participating prospective teachers, some circumstances that may keep teachers from engaging in interdisciplinary projects of this sort include lack of teachers' artistic skills, time, resources, and support from administrators. It is also possible, in the view of the participating prospective teachers, that students

Table 4. Descriptive statistics for content items.

2006			2007			2008		
Item	Pre-test Mean (SD)	Post-test Mean (SD)	Item	Pre-test Mean (SD)	Post-test Mean (SD)	Item	Pre-test Mean (SD)	Post-test Mean (SD)
2	5.67 (2.02)	7.0 (2.83)	2	5.61 (2.25)	8.79 (.89)	2	5.35 (1.98)	7.82 (1.54)
5	7.27 (1.83)	8.25 (1.6)	5	7.78 (1.56)	8.43 (1.34)	5	7.55 (1.76)	8.64 (.92)
6	7.07 (1.79)	7.42 (2.11)	6	6.5 (2.57)	7.21 (2.55)	6	6.75 (2.0)	7.64 (2.29)
7	5.93 (2.15)	7.25 (2.49)	7	5.89 (1.94)	8.36 (1.08)	7	6.3 (1.53)	8.45 (1.04)
8	6.0 (2.07)	7.83 (2.04)	8	6.94 (2.18)	8.29 (1.27)	8	6.65 (2.06)	7.64 (2.25)
9	5.47 (2.85)	7.58 (1.98)	9	5.11 (3.61)	6.79 (3.12)	9	6.95 (2.19)	8.18 (1.17)
10	5.87 (2.88)	7.33 (2.06)	10	5.61 (3.36)	6.71 (3.02)	10	6.55 (2.48)	8.09 (1.51)

Table 5. Interdisciplinary teaching items.

2006			2007			2008		
Item	Pre-test Mean (SD)	Post-test Mean (SD)	Item	Pre-test Mean (SD)	Post-test Mean (SD)	Item	Pre-test Mean (SD)	Post-test Mean (SD)
1	6.60 (1.68)	7.92 (1.88)	1	6.06 (2.31)	8.36 (.75)	1	6.0 (1.72)	8.0 (1.1)
3	7.0 (1.77)	8.08 (1.78)	3	6.83 (1.92)	8.21 (1.48)	3	6.0 (1.75)	8.45 (.93)
4	6.13 (2.0)	8.0 (1.65)	4	5.11 (1.97)	8.07 (1.07)	4	5.4 (2.46)	8.55 (.52)
11	4.93 (2.84)	6.5 (2.39)	11	5.56 (2.53)	7.36 (2.31)	11	5.95 (2.01)	8.45 (.82)

may misunderstand the purpose of the activity. For art education prospective teachers, their concerns were that they do not have enough content knowledge in science to be able to make the adequate cross curricular connections. Another art education participant pointed out that this weakness could be solved by establishing positive connections with the science education colleague in the school building. A few participants commented on the difficulties they might have addressing the required academic standards.

In the case of the last question, which refers to the skills shared by practitioners of these disciplines, participants identified that both artists and scientists use and manipulate materials, practise visual observation skills, document, depict, and communicate a phenomenon or idea, and make available their creations in public forums. It was also pointed out that calculation, measuring, and preparation of materials/solutions are common in art and science, and that as people go through these processes, they get to explore, investigate and interpret. All but one student explicitly indicated the lack of connections between art and science.

Discussion

Regarding the research question in this study, we submit that in general, prospective teachers' responses on survey items addressing content skills and previous experience of art or geological/biological images in the classroom were affected by their major area. Art education participants were likely to report higher ability and understanding of artistic skills and mediums in the classroom. Likewise, their science education counterparts reported greater confidence in science content. Overall, prospective teachers in science education reported less experience using artistic mediums in the classroom.

The mean of interdisciplinary teaching ratings increased on all four target survey items according to the 10-point rating scale. Based on the results, the integrated art and science instructional approach significantly influenced prospective teachers' attitudes about collaborative practices. This was seen by the significant increase in means between the pre-test and post-test scores. The same can be said about the seven target survey items related to content ability as those scores increased after the study as well. Data from the open-ended responses allow us to see that there was also a reversal of descriptions about the benefits of an integrated art and science activity from being primarily 'engaging' at pre-survey to 'interdisciplinary' at post-survey. Interestingly, concerns for a lack of 'content skills' decreased from pre- to post-study, while 'time and resources' became the primary challenge as seen by participants. Our experience suggests that an integrated learning experience is an effective way to improve prospective teachers' self-ratings of knowledge and ability to develop and engage secondary students with interdisciplinary connections. We also noted that a small amount of mentoring during the semester of residency is necessary for prospective teachers to realise the possibilities for collaboration with colleagues from other disciplines in the school building.

An example of the utility of this combined approach was observed in a science classroom during a semester of residency. Two of our prospective teachers, along with their mentor teachers, carried out a two-session class focused on the conceptualisation of both plant and animal cells by eighth grade students in a biology class. The art and science connections were evidenced as students voiced their opinions on how art and science intersect, in particular in the work produced by Leonardo

Da Vinci on physiology, and Robert Hook on the visualisation and illustration of microorganisms, a topic that had been previously discussed in their biology class. Additionally, students' renditions of cell structures were produced and judged based on the shape, composition and conceptualisation elements included in the final piece. This was a unique opportunity for students to tie the links between the two subjects that they had previously studied in isolation. They could also see their art teacher's work focused on hybrid sculptures of insect and fish species. This segment of the lesson served as an attention-grabbing activity that led students into topics such as ecosystems, taxonomy, and evolution.

Conclusions

Science and visual arts form a natural partnership based on the content and processes involved in each discipline. Current educational practices among many countries around the globe now encourage the use of interdisciplinary modeling. In that vein, it is hoped that if university faculty can model the practices to their prospective teachers, these same students may then take a more pro-active role in reaching out to their colleagues once they are out in the public school systems. The research experience described in this article sought to model just such a joint activity for prospective teachers. As they worked together in teams using science content and artistic mediums to better understand geological and biological phenomena, comparison of pre- and post-activity surveys suggests that indeed some attitudinal change registered with the university prospective teachers. It is hoped that continued attempts to prepare students to work thematically in viewing data through artistic and scientific lenses will encourage more meaningful interdisciplinary experiences for future students in the public school system as university prospective teachers enter the workforce more willing and more prepared to collaborate across disciplinary boundaries.

Acknowledgements

The authors wish to thank the University of Wyoming Photo Service Department for assisting us during this project and allowing us to use the images included in this paper.

References

Bagget, P.V., and E.L. Shaw. 2004. The art and science of Gyotaku: There's something fishy goin' here. *Science Activities* 45, no. 1: 3–7.

Baldwin, L., and I. Crawford. 2010. Art instruction in the botany lab: A collaborative approach. *Journal of College Science Teaching* 40, no. 2: 26–31.

Campbell, B., and L. Fulton. 2003. *Science notebooks: Writing about inquiry.* Portsmouth, NH: Heinemann.

Chessin, D., and M.J. Zander. 2006. The nature of science and art. *Science Scope* 29, no. 8: 42–6.

Clary, R.M., and J.H. Wandersee. 2010. Scientific caricatures in the earth science classroom: An alternative assessment for meaningful science learning. *Science and Education* 19, no. 1: 21–37.

Coleman, J.M., E.M. McTigue, and L.B. Smolkin. 2011. Elementary teachers' use of graphical representations in science teaching. *Journal of Science Teacher Education* 22: 613–43.

Coskie, T.L., and K.J. Davis. 2008. Encouraging visual literacy. *Science and Children* 46, no. 3: 56–8.

Dempsey, B.C., and B.J. Betz. 2001. Biological drawing: A scientific tool for learning. *The American Biology Teacher* 63, no. 4: 271–81.

Eisner, E., and K. Powell. 2002. Art in science? *Curriculum Inquiry* 32, no. 2: 122–59.

Eisenkraft, A., C. Heltzel, D. Johnson, and B. Radcliffe. 2006. Artist as chemist. *Science Scope* 73, no. 8: 33–7.

Flannery, M.C. 1991. Science and aesthetics: A partnership for science education. *Science education* 75, no. 5: 577–93.

Girod, M., T. Twyman, and S. Wojcikiewicz. 2010. Teaching and learning science for transformative, aesthetic experience. *Journal of Science Teacher Education* 21: 801–24.

Girod, M., and D. Wong. 2001. The view from aesthetic understanding: A Deweyan perspective on science learning. *The Elementary School Journal* 102: 199–224.

McComas, W. 2008. Back to the future. *The Science Teacher* 75, no. 2: 24–8.

McTigue, E., and A. Croix. 2010. Visual literacy in science. *Science Scope* 33, no. 9: 17–22.

MIT News: Picturing to learn makes science visual. 2006. http://web.mit.edu/newsoffice/2006/picturing.html.

National Art Education Association (NAEA). 1994. *The national visual arts standards*. Reston, VA: NAEA.

National Research Council. 1996. *National science education standards*. Washington, DC: National Academy Press.

National Research Council. 2007. *Taking science to school: Learning and teaching science in Grades K-8*. Washington, DC: National Academies Press.

Needle, A., C. Corbo, D. Wong, et al. 2007. Combining art and science in 'arts and sciences' education. *College Teaching* 55, no. 3: 114–9.

Oppenheimer, F. 1972. The exploratorium: A playful museum combines perception and art in science education. *American Journal of Physics* 40, no. 7: 1–7.

Pugh, K., and M. Girod. 2007. Science, art and experience. Constructing a science pedagogy from Dewey's aesthetics. *Journal of Science Teacher Education* 18, no. 1: 9–27.

Rosenberg, T. 2008. Science sketched out. *Nature* 455, no. 25: 468.

Shaw, E.L., P.V. Baggett, L.R. Daughenbaugh, and S. Santoli. 2005. From boxed lunch to learning boxes: An interdisciplinary approach. *Science Activities* 42, no. 3: 16–24.

Subramanian, K. 2006. Six rules for integrating the arts. *Science Scope* 26, no. 5: 61–2.

Uffelman, E.S. 2007. Technical examination of seventeenth-century Dutch painting as interdisciplinary coursework for science majors and nonmajors. *Journal of Chemical Education* 84, no. 10: 1617–24.