Exploring Preservice Teachers' Still-Life Paintings of Crystals with Artist-Focused Compared to Science-Focused Introductions

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Abstract

This experimental study was undertaken with preservice teachers to test whether the use of science integration into arts education increases demonstration of science details and creative features in artwork. Two conditions were created: arts-focused and science-focused; gouache still-life paintings were produced and analyzed, and an attitude survey was completed. The results suggested that science integration into visual arts classes increased creativity for the arts-focused condition and increased science concepts in the science-focused condition. Participants in both conditions reported positive attitudes, specifically, high levels of enjoyment, alluded to lack of experience with arts and creative projects, and expressed desire for more exposure because of emotional benefits.

Key Words

Arts-integration, crystals, art, still-life painting, science integration into art, science, preservice teachers

Introduction

In the early 1990s, Torrance proposed that the United States create a national climate for creativity and invention. A glance at the historical origins of creativity and invention reveals the "pioneer spirit":

> From the outset, we valued adventurousness, willingness to try difficult tasks, independence in thinking and judgment, courageousness of convictions, industriousness, high energy level, determination, persistence, self-confidence, sense of humor, versatility, willingness to take a risk, and curiosity (Torrance, 1992, p. 14).

The proposition was to re-emphasize and value these characteristics highly for a creative climate to prevail. Though emphasis on creativity has been a worldwide educational goal since the 20th century (Cho, Chung, Choi, Seo, & Baek, 2013), nurturing students' creative potential has been increasingly recognized as a "valuable, yet often unrealized, educational goal" (Beghetto & Kaufman, 2014, p. 53). This lack of creative education progress can be attributed to intractable issues that plague the education system at large. In American school classrooms, an age-old structure from the Industrial Age prevails in the curriculum (Kress & Rule, 2017) along with a "pervasive ethic of individualism" hindering teachers from sharing innovations (Brouillette, Grove, & Hinga, 2015, p,9). Therefore, teachers are often ill-equipped to promote creativity among students as they cannot clearly define or recognize creativity and neither can they appreciate creative behavior (Aljughaiman & Mowrer-Reynolds, 2005). Educational settings are governed by issues of accountability and time, with the bulk of curricular content driven by the demands of high stakes testing (Chessin & Zander, 2006). More importantly, creativity education has been separated from or merely added to the curriculum and class activities in general rather than being integrated with them (Cho et al., 2013). Wicklein and Schell (1995, p. 59) argued that the segregated approach applied to the school curricula inadequately address the "reassemblage of topics into a coherent body of knowledge" for students to be able to use. These challenges impact the development of the creativity process. For effective facilitation, creativity cannot be considered as domain-specific. Rather, the value of integrating interdisciplinary subject matter must be recognized in its potential to engage the mind in a complex process, conducive for creative growth: "Implementing integrated cross curricular content in the classroom facilitates the process of synthesizing ideas from disparate sources, which is a key component in the development of creative thought" (Letts & Richmond, 2012, p. 39).

Learning depends solely on the learners: they may or may not engage in learning. Yager (2000) suggested that because traditional instruction does not lead to 'real' learning, science instructors must take the initiative to promote student engagement. He further argued that science programs have been treated more as a source of information rather than as a way to develop learners' imagination and creative thinking. As instructors are being asked to support creative thinking to prepare students for increasingly complex life and work environments in the 21st century (P21, no date), instructional strategies have changed and instructors are seeking new ways and more hands-on approaches (Swift & Watkins, 2004). In addition to the challenges that the school environment poses, teachers themselves have certain limitations. They often do not have science background (Swift & Watkins, 2004), or lack pedagogical skills requiring understanding of arts integration as it had not been a part of their educational experience (Kress & Rule, 2017; LaJevic, 2013). Yet, the drive to improve science teaching goes on. Curriculum integration is one way to spur the creative potentials of 21st century students. To establish a creativity-supportive classroom environment, instructors need to make informed decision rather than simply adopt creativity techniques that promise to yield rapid-fire solutions to boosting creative potentials of students. Breaking the traditional segmented arts teaching/learning practices and promoting dynamic pathways of interdisciplinary teaching/learning as well as understanding the experiences students have in such conditions are necessary. Although many benefits of art-science partnership are anecdotal and compelling project reports suggest transformative effects when art and science are combined, the blurry boundaries between science and art ought to be investigated through further studies (Gurnon, Voss-Andreae, & Stanley, 2013).

In science education, students have been generally believed to be influenced by the notion that science learning is nothing but hard, and has very little use and relevance to daily life (Ursyn & Sung, 2007). To promote STEAM (STEM + Arts) education, the advantages of integrating Arts for STEM students have been emphasized in relevant literature. While the primary focus in current research has been what the arts bring to the STEM conversation, research studies supporting science learning through artistic expression are limited in number (Ursyn, 1997; Ursyn, Scott, Hobgood, & Mill, 1997; Ursyn & Sung, 2007). Research needs to demonstrate what STEM might bring to the arts as well as reciprocal gains between all disciplines (Guyotte, Sochacka, Constantino, Kellam, & Walther, 2015). In this investigation, we explored the use of science integration into art to determine if increased incorporation of science detail in artwork (elaboration) and types of other creativity are demonstrated. The study placed two groups of students in two different ways of learning information and of exploring different perspectives through visual art. The differences in the treatment of the groups occurred in the lesson introduction with a focus on artists and their artwork that featured crystals versus scientific paintings of crystals and science information about crystals. Students in both the groups were exposed to a video about gouache painting techniques as homework.

Literature Review

With the growing emphasis on creating strong foundational knowledge in science, researchers have explored the impact of science education on student learning and revealed the effectiveness of integrated science education. This study was guided by the hypothesis that providing opportunities for art activities that pre-expose preservice teachers to the science of the art subject in their Expressive Arts classes would improve the education of the preservice teacher participants. Literature about demonstrated and potential benefits of arts integrations as well as science integration in arts provide a basis for this hypothesis. In the next section, we first situated curriculum integration against a backdrop of the benefits of arts integration into science as well as benefits of science integration into art. Studies contributing to the literature on art-integration and science-integration have been highlighted to appreciate the usefulness of interdisciplinary teaching/learning. Csikszentmihalyi's (1990) flow theory is then considered to understand the experiences of the students in the context of the study.

Identified Benefits of Arts integration into Science

Art plays a central role in educating students in basic skills as these skills facilitate the development of higher mental processes (Ursyn, 1997). The transformation of the arts into an important subject with potential benefits for assisting in concept acquisition in other subjects occurs as documented by research studies highlighting student learning gains (LaJevic, 2013; Hardiman, Rinne, & Yarmolinskaya, 2014). The arts assist in several ways: supporting teachers to master arts-based instructional strategies to address the oral language development needs of English language learners (Brouillette et al., 2015); promoting long-term retention as arts naturally takes advantage of these strategies to interact with academic content (Hardiman, Rinne, & Yarmolinskaya, 2014); providing opportunity to students with disabilities to participate in decisions about what is created that enhance their learning (Alberts, 2008); strengthening STEM skills in interdisciplinary contexts (Bequette & Bequette, 2012); providing motivation and a new pathway to learning and personal meaning making (Land, 2013; Weber & Rule, 2017) without being obstructed by the abstract symbols of written language (Letts & Richmond, 2012); and encouraging students to become independent and engaged learners (Pittman & Teske, 2017). Most importantly, arts research has revealed literacy learning to be multimodal (Soundy & Drucker, 2010).

Arts integration supports all kinds of learners and makes academic content accessible. Arts integration allows learners to express their perspectives and understandings of academic subject matter, which the culture of standardized high-stakes testing and set curriculum does not do. In fact, in an arts integrated classroom, the decision-making process allows students to make their own interpretations while exploring numerous possibilities (Land, 2103). Land found that integration of arts into content area encouraged students to probe deeper as well as exploit various learning modes so that more access points are created. This process essentially involves the whole person, so that students immerse themselves intellectually, emotionally, and physically thereby participating rigorously in the learning experience. In the classroom curriculum, arts integration enhances learning opportunities and academic success for all learners. Rinne, Gregory, Yarmolinskaya, and Hardiman (2011) suggested that for mastering skills, content, and concepts, long-term retention is required which arts integration can assist teachers in guiding students towards this goal. The authors reviewed eight well-documented arts factors that that include elaboration, enactment, generation, oral production, rehearsal, pictorial presentation, effort after meaning, and emotional arousal to demonstrate how artistic activities effectively enhance long-term retention of content.

Studies Exploring Arts-Integration Instruction

According to Beghetto and Kaufman (2014), classroom context is the most crucial aspect of a learning environment because of its potential to nurture creativity. Practical projects (e.g., Hardiman et al., 2014; Kress & Rule, 2017; Pittman & Teske, 2017; Weber & Rule, 2017) are resourceful for practitioners as classroom-tested activities can help them make informed decisions when identifying arts-integrated learning initiatives their students can take. Hardiman et al. (2014) examined effects of arts integration on long-term retention of content on fifth graders. Although there were no differences in initial learning, a delayed posttest revealed retention of what was learned among students, especially with low proficiency levels, was significantly better when taught through arts integrated instruction. In Kress and Rule's (2017) creative invention project with fifth graders addressing the NGSS Engineering standard 3-5-ETS1-2, concepts of plant and animal adaptations were applied. Inventions made by fifth graders were meant to fit a specific audience; then student evaluation of inventions of fifth graders of another school followed.

While the challenging, complex activities facilitated a state of flow (Csikszentmihalyi, 1990) among the students, multiple invention opportunities as opposed to a single activity, helped to develop their skills as well as creativity. Pittman and Teske (2017) described a modeling activity involving students in creating models of birds' beaks based on online and text research and investigating the relationship between each type of bird beak to its diet. Students displayed clearer understandings of genetic variation and the way environmental pressures influence natural selection. Preservice teachers in Weber and Rule's (2017) project who engaged in exploring all subject areas with arts-integrated projects attributed the utility of integrating science and art to visualization and creativity. They concluded that visualizing through art would trigger better understanding of science and allow students to make use of their creativity meaningfully.

Identified Benefits of Science Integration into Art

Art and science are believed to be intrinsically linked with the primary essence being discovery (Alberts, 2008; Morrison, 2012); their boundaries can "meld fluidly together" and lead to a "synergistic relationship" (Bequette & Bequette, p. 40, 2012). Common features shared by both the disciplines include important skills such as observation, experimentation, problem solving, and openness to change (Chessin & Zander, 2006). Although science education reports insist on the necessity of providing solid foundational knowledge to all students, traditional classroom settings are not conducive to creating that lasting foundation (Gurnon et al., 2013). To enable students to reap the benefits of a classroom incorporating science into arts, it is important to ensure that students' experiences are diverse and worthwhile. To help students gain foundational knowledge in science, students need to be motivated to engage in the act of discovering, conceptualizing, and internalizing scientific concepts through activities that involve integrating science into arts. Morrison (2012, p.38) observed that early childhood science education can help children "refine their creativity and discover different perspectives" that can become a strong foundation for science education. Moreover, in a classroom of students with different skill levels, science-art integration offers students the freedom to think, discover, and make connections. As students' understandings of scientific concepts develop, their curiosity will grow (Alberts, 2008). Dambekalns and Medina-Jerez (2012), observed while conducting a practical class project, that science-art integration leads to learning beyond scientific conceptualization to include curiosity about physical properties of objects used in their project. They pointed out that novel experiences trigger excitement and engagement among marginally interested students.

Practical studies and projects that have focused on science integration into the arts have highlighted this in their findings. Preservice teachers in Weber and Rules' (2017) project engaged in exploring all subject areas with arts-integrated projects attributed the utility of integrating science and art to visualization and creativity. They suggested visualizing through art triggers better understanding of science and allows students to make use of their creativity meaningfully. Similar responses were identified in Thompson and Balschweid's (2000) study investigating the attitudes of Agricultural Science and Technology teachers who completed a science-incorporated agricultural education course. Teachers believed that students would be able to conceive the connectivity between scientific principles and agriculture, becoming better equipped in science and the application of science principles to agriculture.

Challenge is conducive to fostering creative thinking and is necessary for idea generation (Hussain & Carignan, 2016). This was exemplified in Kress and Rule's (2017) project involving 13 fifth graders. Incorporation of science concepts through a combination of 21st Century Skill of meta knowledge into a complex project prompted the students to practice skills relevant to their future lives while reinforcing science content knowledge. Interestingly, multiple challenging activities initiated skill development and a state of flow that contributed to their creativity. Gurnon et al. (2013) investigated whether incorporating the visual arts into a science curriculum supports scientific imagination and engages nonscientists. Artists and scientists collaborated to create a series of science-inspired sculptures. Sculpting provided motivation, inspiring them to think differently while combining aesthetic design with scientific knowledge. Similar experiences were encountered by art and science teachers' collaborating in classroom settings in Chessin and Zander's (2006) classroom project. Teachers realized students' knowledge could be further extended through combining and expanding the two disciplines, art and science, as it allowed a different way of thinking.

Flow Theory

Conscious action requires two types of motivation: intrinsic and extrinsic. While extrinsic motivation involves a person's success being controlled externally, intrinsic motivation is within the control of the person that drives the person to do something because he or she enjoys doing it. Csikszentmihalyi was drawn by the way an artist worked: immersed in the work of his painting, the artist ignored hunger or discomfort of any kind, but then drastically lost interest in his creation upon completion (Nakamura & Csikszentmihalyi, 2009). This phenomenon of intrinsic motivation is what underlies flow research and theory.

According to Csikszentmihalyi's (1990) flow theory, the highest intrinsic motivation is a state of "flow" where a person loses self-consciousness, surrendering himself/herself entirely to the moment with time becoming irrelevant. This state of flow, he claimed, can be experienced in any kind of activity and is an important contributor to creativity and well-being. Furthermore, an experience of flow occurs when a person's skill level and a given challenge are equal. In this study, the participants' experiences in each condition could be understood when viewed through the experiential lens of flow: "It is the subjective challenges and subjective skills, not objective ones that influence the quality of a person's experience" (Nakamura & Csikszentmihalyi, 2009, p. 91). Flow can be experienced by an individual in any kind of activity; however, under certain circumstances and depending on an individual's past experience with the activity, any pursuit can alternatively create boredom or anxiety. Similarly, when analyzing participants' responses to open-ended questions in the attitude survey in the current study, the quality of their experience varied depending on the environment, state of mind, attitude towards the painting task, and prior experience. The following section explains the experimental study that was conducted with preservice teachers in Expressive Art classes.

Methodology

This experimental study was undertaken with preservice teachers to test whether the use of science integration into art increases incorporation of science detail in artwork (elaboration) and types of other creativity demonstrated. The study provided students a different way of learning information and of exploring different perspectives through visual art.

Research Questions

The following research questions guided this study:

1. Does an introduction featuring science concepts before the lesson activity of painting a science-themed still-life increase the overall creativity, individual creative traits of the artwork, and science concepts present in each participant's artwork?
2. Does an introduction featuring examples of artists and their artwork with a given science theme before the lesson activity of painting a science-themed still-life increase the overall creativity, individual creative traits of the artwork, and science concepts present in each participant's artwork?
3. How do students in each condition describe their experiences during the lesson?

Participants and Context

The study took place at a mid-sized public university in the Midwest. The experiment was conducted during the 75-minute class periods of two different sections of an expressive arts course taught by the same professor. The researchers were guest teachers during this time because the content of the experiment supported the course curriculum. The artist-focused condition had 29 adult students (2 male, 27 female) with a mean age of 21.1 years while the science-focused condition had 26 adult students (4 male, 22 female) with a mean age of 21.5 years. Almost all students of both conditions were education majors as this class fulfilled an arts education requirement in the degree.

This study was approved by the Human Subjects Committee of the Internal Review Board of the overseeing university. A week before the experiment, the teacher distributed a letter and consent form to each student. The consent form also contained brief pretest questions to determine participant age along with prior experience with gouache paint and the subject matter of the lesson activities. All participants whose data were included in the study gave signed, informed consent to participate. Participants gave signed consent for exhibition of the art works included in this paper. All students participated in the crystal still life painting class taught by the guest researchers because it supported the course curriculum; data were only used for those participants who provided signed consent.

Experimental Design

The study was a quasi-experiment with controlled variables (as shown in Table 1) and application of pre- and posttest design (Creswell & Creswell, 2017). The pretest aimed to determine whether the participants in the two conditions had similar prior knowledge whereas the posttest measured their attitude and experience following the painting challenge they were given. The variable in the design was the treatment during the lesson introduction of a focus on artists and their artwork that featured crystals versus scientific paintings of crystals and science information about crystals. The diffusion of treatments for the control and experimental groups was addressed by having seventy-five minute Expressive Art classes for the art-focused group and the science-focused group on the same day consecutively.

The study compared the still life gouache paintings of twenty-nine preservice teachers in an Expressive Art class who were exposed to slide shows on still life paintings by professional artists with information about the artists' lives (condition 1, the control condition as shown in Table 1) to twenty-six preservice teachers in another Expressive Art class who viewed slide shows on scientific paintings and information about the science of crystals (condition 2, the experimental condition as shown in Table 2). Participants of both conditions were required to view a video about gouache painting techniques. Taking responsibility of their role included understanding what they are required to do (Weber & Rule, 2017). During the seventy-five minute class, for each of the art-focused section and the science-focused section, eight groups of two to four preservice teachers seated at each table had still life displays of crystals with cloth backdrops and painting materials for their creative activity. To validate the conceptual process, assure student engagement, and authenticate the image of crystal as an artistic practice, the class was introduced to a number of artists' works (Letts & Richmond, 2012) before they were challenged to create still life painting using gouache technique.

Lesson Procedures

Homework. Students in the class were provided access to two short videos on gouache painting titled, "How to paint with gouache: Beginner's tips and walkthrough" (Small, 2015) to view as homework several days before the class, along with a PowerPoint slide presentation of artists who made crystal paintings or science information about crystals illustrated with realistic crystal paintings, depending upon experimental condition. Gouache paint is an opaque water-based paint that is more-dense in pigment than watercolor and can be layered to produce intensely-colored areas or diluted with water to form washes.

Beginning of class. As they entered the classroom, students were asked to choose a seat at a table with crystals in a still life arrangement with background draped cloth that appealed to them. They were allowed to select two brushes and a cardboard tray with their choice of four or more colors of gouache paint, along with white and black. Water was available at all tables for cleaning brushes and diluting paint.

The condition-appropriate slide show was reviewed for about ten minutes at the start of the class period. See Table 2 for major components of the slide shows for each condition. The last slide (identical in each presentation) encouraged students to be creative in their work and was read to the student participants in both conditions. See Table 3 for the suggestions given to students in both conditions.

Table 1. *Comparison of Two Condition Showing Controlled Aspects*

Design Aspect	Condition 1: Artist-Focused	Condition 2: Science-Focused	
Lesson Introduction	Slide show featuring artists, their lives, and their realistic or abstract paintings that contained images of crystals	Slide show featuring realistic paintings with crystals and information about the science of crystals	Variable
Length of slide show	30 slides; 10 minutes	30 slides, 10 minutes	Controlled
Artwork shown in Slide show	Paintings with images of crystals	Paintings with images of crystals	Controlled
Sample Population	Preservice elementary education teachers, mean age = 21.1	Preservice elementary education teachers, mean age = 21.1	Controlled
Class Period Length	75 minutes	75 minutes	Controlled
Still life items	Set of 24 mineral specimens showing large crystals of quarts, amethyst, smoky quartz, citrine, calcite, fluorite, barite rose, and celestite	Set of 24 mineral specimens showing large crystals of quarts, amethyst, smoky quartz, citrine, calcite, fluorite, barite rose, and celestite	Controlled
Cloth backdrops for displays	All well-draped cloth of these colors: light blue, velvety dark blue light pink, fuchsia, yellow, brown, turquoise	All well-draped cloth of these colors: light blue, velvety dark blue light pink, fuchsia, yellow, brown, turquoise	Controlled
Painting materials	Selection of brushes, gouache paints, clear water in tub, cardboard paint palettes, and watercolor art paper	Selection of brushes, gouache paints, clear water in tub, cardboard paint palettes, and watercolor art paper	Controlled

Table 2. *Major Components of the Slide Presentations for Each Condition Shown at the Beginning of the Lesson*

Condition	Content
Art-focused condition featuring artists who painted crystals and information about their motivations, techniques, and their lives	Wilhelmina Barns-Graham, British Artist: Paintings of ice crystals of glaciers highlighting shapes, light, and contrast between solidity and transparency Jaime Rovenstine, American Artist based in Kansas City, Kansas: Intuitive and meditative process. Paints crystal forms with vertices highlighted in dreamlike landscapes with pastel colors Angie Crabtree, American Artist from Northern California: mesmerized with geometry of cut diamonds. Paints shimmering close-ups of diamonds showing internal reflections Karina Eibatova, Austrian Artist, born in Russia, based in Tokyo, Japan: Paints mineral crystals in watercolors Jackie M. Graham, American, San Francisco-based artist: Paints still life paintings of faceted diamonds Many color paintings featuring crystals from the above-listed artists
Science-focused condition featuring realistic paintings of crystals and explanations of the science of crystals	Crystals form in geometric crystal shapes because of the pattern of the atoms inside Gems are cut to mimic the natural, flat, shiny crystal faces of minerals Quartz forms many gems because it is hard, scratch-resistant, and is colored by impurities. Purple quartz is amethyst; pink quarts is rose quarts, yellow or amber quartz is citrine, gray to black or brown quartz is smoky quartz Quartz: forms six-sided crystals with six-sided pointed pyramids on top. The pyramid faces are often different sizes. Celestite forms blue orthorhombic (blocky) crystals. Barite forms rose-shaped clusters of blade-shaped crystals. A geode is a crystal-lined former bubble in volcanic rocks or an empty space in limestone rock. It often has bands of colored minerals and has larger crystals in the middle. The rock matrix is sometimes dark mafic rock Many realistic color paintings of mineral crystals.

Class work time. With approximately an hour remaining in the class period, students were asked to create a gouache painting of one or more crystal specimens on watercolor paper. Students were allowed to talk and to acquire additional paints, brushes or water as they worked. Near the end of the class period, students were advised that they could stay up to 15 additional minutes, but no students stayed for this extended time. Everyone completed their work during the scheduled class period. Work was collected as students completed it.

Table 3. *Suggestions for Creativity on Last Slide of Presentation*

Creativity Suggestions
Think of many ideas before you start painting;
Think of different ways to make your painting [Perspectives, sizes, colors, brush techniques];
Be original [Make your painting unique];
Add details [use many colors];
Make it three-dimensional;
Consider showing the interior of the objects;
Take an unusual perspective;
Break unspoken rules or conventions [Make something upside down or re-arrange the objects
Show motion in your painting by arrangements or motion lines;
Express emotions through facial expressions or comments;
Tell a story by showing what has happened or is about to happen;
Incorporate fantasy;
Incorporate sound through callouts or symbols;
Use sensory appeal with shining, sharp, fuzzy, glowing parts or shine lines;
Make your painting aesthetically appealing;
Incorporate humor;
Make it a parody of something famous;
Show abstract or invisible ideas;
Give your painting a descriptive and interesting title.

National Standards Addressed by the Lessons of the Experiment

Science standards. The lessons in this study address science standards of the Next Generation Science Standards (NGSS Lead States, 2013). These standards have just been adopted by the State of Iowa for public school children and it benefited preservice teachers to see how they were applied. These standards included engineering components that have not been in previous sets of standards and which sometimes pose problems for teachers trying to implement them because of unfamiliarity. In particular, the science-integrated lessons focused on the 1) crosscutting concept of structure and function; 2) the science practice (process skill) of obtaining, evaluating, and communicating information; and 3) the disciplinary core ideas of PS1A structure and properties of matter (why crystals have crystal shapes).

Art standards. The project required students to work with the new medium of gouache paints on watercolor paper to conceptualize, plan, develop, and refine a still life painting composed of one or more crystal specimens from a still life model of several mineral crystals at different elevations on a draped cloth background. The lessons of the experiment supported three National Core Art Standards (State Education Agency Directors of Arts Education, 2014) related to creating art: 1) Anchor Standard #1, generate and conceptualize artistic ideas and work; 2) Anchor Standard #2, organize and develop artistic ideas and work; and 3) Anchor Standard #3, refine and complete artistic work.

Data Analysis

All paintings were photographed and labeled with codes for the students and the conditions. Spreadsheets were prepared to organize the analyzed data and to perform statistical tests. Table 4 and Table 5 show the rubrics used in analyzing the paintings for creativity and science information respectively. Inter-rater reliability (Creswell & Creswell, 2017) was achieved by obtaining scores from two of the researchers who evaluated the strength of creative traits of the gouache paintings of the preservice teachers using an adapted creative thinking tool (Rule, Zhbanova, Hileman Webb, Evans, Schneider, Parpucu, Logan, Van Meeteren, Alkouri, & Ruan, 2011).

The interrater reliability of the rubrics used in analyzing the paintings was investigated with the consensus estimates (Stemler, 2004) involving two raters. In their review of 75 empirical research studies of scoring rubric Jonsson and Svingby (2007) reported, "two raters are, under restrained conditions, enough to produce acceptable levels of inter-rater agreement” (p.136). In this study the “restrained conditions”, referenced by these authors, were met by using raters with similar educational backgrounds, implementing a strict scoring protocol, and conducting training before embarking on rating the paintings.

Two of the researchers were raters; both were female doctoral candidates in their third year, having teaching experience in diverse settings and experience in working on STEM research projects. In addition to similar demographics, the raters scored 100% of the student work samples and followed a consistent scoring protocol for each set of paintings, twenty-nine in artist-focused condition and twenty-six in science-focused condition: (1) Each rater independently rated a set of seven paintings done in a particular condition at a time working in the same environment (i.e., in the raters’ own office spaces), exchanged the same set they had scored for rating and immediately recorded the average score of the two sets of scores of each of the seven paintings; (2) each rater studied and scored a painting in a consistent order, sequentially following the creative traits in the rubric, following the operational definition, and counting the number of instances a trait was visible (see Table 4 and Table 5); (3) each rater followed weight of evidence when a work sample did not neatly fall into a certain score on a rubric category. This strict protocol provided an additional restraint to the conditions under which scoring took place.

A third researcher, a professor with a doctorate in mineralogy, additional master degrees in education, and both preK-8 and college teaching experience, who also had extensive experience in both science and arts integration research projects and in using the rating scale, trained the two researcher-raters on the rating scales prior to the scoring of the paintings. The training included practical demonstrations of different aspects of mineral specimens, discussions on the different components of the scoring rubric, instructions for how the rating process would be carried out, exemplification of different levels of performance using paintings, and finally rating of four student paintings. A companion document containing rubric notes was created during the training and served as supplemental material to aid the raters in maintaining consistency. The training of the raters not only served the purpose of how to interpret a scoring rubric and consistently apply the rubric, it also imposed some level of objectivity into the rating scale (Stemler, 2004). As a method of increasing interrater reliability, the training of raters is well recognized in literature (Jonsson & Svinby, 2007; Stemler, 2004). Thus the scoring system as outlined above created the “restrained conditions” recommended by Jonsson and Svingby (2007).

The expert with a doctorate in mineralogy scored the crystal paintings for science content using the rubric shown in Table 5, marking each characteristic as present (1 point) or not present (0 points).

Instrumentation

To determine whether the art-focused and science-focused students had similar prior experience with and knowledge about gouache paint and the subject matter of the lesson activities, the preservice teachers were required to answer a brief set of pretest questions: (1) How many times in the past five years have you used watercolors or gouache paints (not oil, tempera, or acrylic paints) to make a painting? (2) How many of the following crystal shapes could you sketch - tetrahedron, octahedron, trigonal pyramid, hexagonal prism, and rhombohedron? A simple attitude survey was administered at the end of the class to identify how the participants rated themselves in their level of creativeness in their paintings; enjoyment; satisfaction; and motivation on a scale of 1 – 10. Participants had to explain why they had rated themselves thus. An open-ended question was asked to determine their overall experience of participating in the project: What is the most important thing or things you gained from participating in this project? They also had to give a title for their creative gouache painting and explain the meaning of their artwork. The following demographic information had to be provided by the participants in the survey: age, gender, major, race/ethnicity. Another instrument used was a rubric for evaluating students’ still life paintings adapted from Rule et al. (2011) to analyze the paintings for creativity. This instrument is shown in Table 4.

Table 4. Creative Traits Scored in the Creativity Analysis*: Each Trait was scored from 0 to 4.

Creative Trait	Operational Definition
Originality	Showing features or components or approaches no one else in the class shows
Elaboration	Adding extra details not needed for one to identify the item
Fluency	Generation of many ideas = Number of crystal or skull objects in painting _______
Variety of Colors	Count the number of colors and put here________
Flexibility	Ideas from different categories that solve the same problem = Number of different types of added objects
Internal visualization	Showing the interior or contents of an item
Unusual visualization	Showing the item from a perspective or view that is uncommon. Close-up or only part counts here
Three-dimensionality	Showing two or more sides of an object or shading / shadows*
Breaking boundaries	Breaking of unspoken rules or conventions
Adding extra components	Adding extra scenery, flowers, shapes, stripes not shown in display
Colors different from Display	A type of boundary breaking by imagining new colors instead of colors shown in display
Movement or action	Suggestion of motion by pose, position, motion lines or blurring
Emotional expressiveness	Expressing emotion through facial expression, pose, or words in title
Story-telling articulateness	Conveying what happened before or what is about to happen through position or title or background
Fantasy	Containing imaginary characters, lands, events
Sound	Containing call-outs or words/ symbols indicating sound
Sensory Appeal (Sharp)	Containing sharp parts or curly that can be perceived through the senses
Sensory Appeal (Shiny or glowing)	Containing shiny or glowing parts that can be perceived through the senses
Richness of imagery	Artistic/ aesthetic appeal of the painting
Blending of colors	Colors blended with the water and paint
Humor	Exaggerated scene, puns, wordplay
Parody	Recreation of a well-known item or scene in a new way
Abstract ideas	An idea that is not directly observable or visually physical such as an odor, feeling, electricity, or ghost
Effective title	Descriptive words or abstract ideas in title

*Adapted from Rule, A. C., Zhbanova, K., Hileman Webb, A., Evans, J., Schneider, J. S., Parpucu, H., Logan, S., Van Meeteren, B., Alkouri, Z., and Ruan B. (2011).

Table 5. *Demonstrated Science Facts Scored in the Science Analysis*

Generalized Category	Specific Fact Demonstrated
Color	Color variation of crystals
	Accurate color of mineral
	Translucency shown with color variation
Crystal form	Orthorhombic - boxlike or rectangular
	Accurate angles and shapes of non-rectangular crystal faces
	Cube
	Hexagonal prism
	Pyramid shaped terminations
	Irregular pinacoids on crystal terminations - differing growth rates
	Two or more different crystal forms shown
	Showing geometric faces
	Vertices between faces highlighted
Crystal Habit	Banding of mineral layers
	Two or more different crystal habits shown
	Crystals emanating from a nucleation point to form a sphere of crystals
	Crystals lining wall or aligned in bands
	Geode sphere or partial sphere
	Multiple crystals in a cluster
	Petal-like or bladed habit
	Twin striations shown
	Twinning - mirror symmetry or interpenetration of crystals
	Domains shown
Luster	Glassy shown with highlights
	Pearly sheen (diffuse bright spots)
	Internal reflections shown
Rock Matrix	Matrix - Dark rock encasement of geode
	Matrix - Rock layers in matrix
	Matrix - Rock matrix shown
Other Properties	Translucency with back vertices showing through
	Fractures or cracks shown in crystals or matrix
	Impurities or inclusions shown in crystals
	Phosphorescence or blacklight glow of minerals
Mean for Paintings in Condition	Mean of the specific fact means
	Mean of total facts demonstrated

Results

Overall, students approached the task of making a crystal painting featuring the mineral specimens seriously. They appeared relaxed and seemed to enjoy the work as they examined the specimens, thought about their paintings' compositions, and began painting. Most students took their time, remained focused, and continued to work through most of the hour remaining after the slide show, with everyone completing work by the end of the hour.

Results of Pretest

The pretest results for the arts-focused condition indicated that the average times participants have used watercolors in the past 5 years was 3.93 times and number of crystal shapes identified was 0.86 (out of five listed). The results for the science condition revealed that the average times watercolor was used was 1.38 and the number of crystal shapes identified was 1.04 (out of five listed). This suggests that neither one of the groups had significant prior experience with watercolor or knowledge of crystals to impact the results of the current study.

Results of Creativity Analysis of Paintings

The results (Table 6) revealed a statistically significant difference between the scores for total creative traits demonstrated (p = .03; d = .50), favoring the arts condition. Also favoring the arts condition was the significantly different mean score for specific creative traits (p = .001; d = 1.44). Additionally, statistically significant differences were found for four specific creative traits, all favoring the art condition: adding extra component (p = .009; d = .61), colors different from display (p = .002; d = .85), fantasy (p = .003; d = .68), parody (p = .03; d = .51). These results suggested that the students in the arts-focused group acquired greater benefits in terms of creativity.

Figures 1 through 4 provide example creative traits that appeared in paintings that scored high in creativity from the artist-focused condition. These creative traits are explained next.

Table 6. *Results of Creativity Analysis of Paintings*

Creative Trait	Science Condition Mean (SD)	Art Condition Mean (SD)	*p*-Value of t-test	Cohen's *d* Effect Size
Originality	2.24 (1.2)	2.62 (1.1)	-	-
Elaboration	2.35 (1.2)	2.43 (1.2)	-	-
Fluency	2.04 (0.6)	2.20 (0.6)	-	-
Variety of colors	2.46 (0.6)	2.67 (0.7)	-	-
Flexibility	0.54 (1.2)	0.77 (1.2)	-	-
Internal visualization	2.57 (1.1)	2.68 (1.2)	-	-
Unusual visualization	2.30 (1.0)	2.40 (1.1)	-	-
Three-dimensionality	2.78 (0.9)	2.88 (1.0)	-	-
Breaking boundaries	1.74 (1.3)	2.32 (1.4)	-	-
Adding extra components	1.02 (1.6)	2.08 (1.7)	p = 0.009 (not paired)	d = 0.61 medium effect
Colors different from display	2.43 (1.1)	3.32 (1.0)	p = 0.002 (not paired)	d = 0.85 large effect
Movement or action	0.96 (1.3)	1.17 (1.4)	-	-
Emotional expressiveness	1.35 (1.3)	1.87 (1.3)	-	-
Story-telling articulateness	1.26 (1.3)	1.60 (1.1)	-	-
Fantasy	0.81 (1.4)	1.83 (1.6)	p = 0.003 (not paired)	d = 0.68 medium effect
Sound	0.30 (1.1)	0.27 (0.8)	-	-
Sensory appeal (sharp)	2.26 (1.2)	2.15 (1.3)	-	-
Sensory appeal (shiny or glowing)	2.48 (1.1)	2.67 (1.1)	-	-
Richness of imagery	2.41 (1.0)	2.48 (0.9)	-	-
Blending of colors	2.28 (1.2)	2.33 (1.3)	-	-
Humor	2.52 (1.7)	2.73 (1.0)	-	-
Parody	2.11 (1.40	2.78 (1.2)	p = 0.03 (not paired)	d = 0.51 medium effect size
Abstract ideas	2.30 (1.5)	2.75 (1.3)	-	-
Effective title	3.02 (1.1)	3.38 (1.0)	-	-
Mean of the mean scores for specific creative traits	1.18 (0.8)	2.26 (0.7)	p= 0.001; (paired)	d = 1.44 very large effect
Mean of total creative traits demonstrated	46.52 (16.1)	54.28 (14.7)	p= 0.03 (not paired)	d = 0.50 medium effect size

The painting in Figure 1 shows many creative traits; some outstanding ones are discussed here. This painting exhibits a lot of originality in that the painter portrayed the crystals as ice cubes in a drink; no one else in this study did anything like this. The painter added extra scenery and objects not shown in the mineral displays. The image of the cool drink on a sunny day shows fantasy and some humor.

Figure 1. A painting that scored high in creativity traits.

Again, the painting in Figure 2 shows many creative traits, a few of which will be discussed here. The transformation of the crystal specimen into a boat afloat on a crystalline sea shows breaking of boundaries. The painter broke the unspoken rule that the crystal specimen must be presented in a realistic manner. This image shows movement through the fluttering sail and the shifting ocean waves. This painting is a parody of the well-known image of a sailboat on the water.

Figure 2. Another painting scoring high in creativity.

The painter of the image shown in Figure 3 painted the image from a perspective or view that is uncommon, therefore showing the creative trait of unusual perspective. The painter showed some of the internal features of the crystals, perhaps crystal domains. There is sensory appeal in the sharpness of the crystals and the glowing halo around them.

Figure 3. Painting scoring high in creative traits.

The painting in Figure 4 scored high in these creative traits, among others: originality, breaking boundaries, added components, colors different from the mineral display, fantasy, motion, and parody.

Figure 4. Another painting that showed many creative traits.

The following four figures (Figure 5 through Figure 8) portray paintings from preservice teachers painted during the science-focused condition. These are paintings that scored high in creative traits when compared to other paintings from the science-focused condition. The painting in Figure 5 shows originality and elaboration in the large amount of detail presented. The painting shows unusual visualization and breaks the unspoken rule of making a realistic mineral display painting. This painting shows movement through the flowing river and raining clouds.

Figure 5. Creative painting from the science-focused condition.

The painting in Figure 6 displays three-dimensionality by showing multiple sides of the crystals and the underside of the cluster. Boundaries are being broken by portraying the crystal cluster as floating in the clouds. The painting conveys what happened before or what is about to happen through position and background. This trait is called storytelling articulateness.

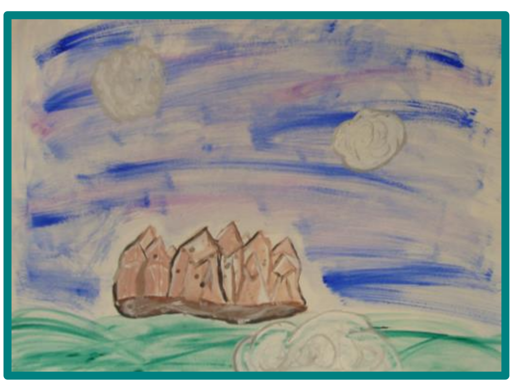

Figure 6. Another creative painting from the science-focused condition.

The painting in Figure 7 shows originality, emotional expression, and parody. It breaks boundaries by filling the crystal with stars and stripes.

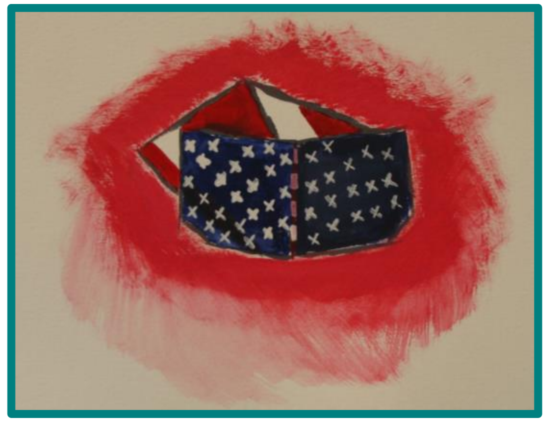

Figure 7. A creative painting from the science-focused condition.

Figure 8 shows a realistic crystal painting from the science-focused condition. This painting shows detail (elaboration) and shine (sensory appeal).

Figure 8. A realistic crystal painting from the science-focused condition.

Results of Analysis of Science Content

A significant difference was found regarding total scores of demonstrated science facts between student crystal paintings made in the science condition and in the art condition favoring the science condition with a large effect size (p < 0.001; Cohen's d = 0.92). See Table 7. The science condition mean overall score was 10.41 (s.d. = 4.1) demonstrated science facts per painting; the art condition mean overall score was 7.00 (s.d. = 3.3) demonstrated science facts per painting. When the mean scores in each science fact area were compared in a paired manner between the two conditions, a significant difference was found favoring the science condition with a small to medium effect size ($p <$ 0.001; Cohen's d = 0.47). The overall mean score for the science fact areas for the science condition was 0.32 (s.d. = 0.3) facts demonstrated per area and 0.21 (s.d. = 0.2) for the art condition. These two significant differences in overall mean scores for 1) total scores of demonstrated science facts and for 2) mean scores of individual science facts areas indicate that students in the science condition tended to demonstrate more science facts in their crystal paintings.

Differences between the crystal paintings of students in the art condition and the science condition regarding demonstration of specific science facts occurred in ten fact areas with mostly medium effect sizes all favoring the science condition. See Table 7 for more details. These ten areas were: 1) accurate angles and shape of non-rectangular crystal faces (p = 0.04; Cohen's d = 0.51; medium effect size); 2) the presence of hexagonal prisms (p = 0.01; Cohen's d = 0.56; medium effect size); 3) irregular pinacoidal faces (faces on the crystal's pointy terminus) depicted on crystal terminations (p = 0.001; Cohen's d = 0.92; large effect size); 4) the presence of banded mineral layers (p = 0.02; Cohen's d = 0.56; medium effect size); 5) two or more different crystal habits shown (p = 0.04; Cohen's d = 0.48; medium effect size); 6) crystals lining wall (p = 0.05; Cohen's d = 0.44; small effect size); 7) multiple crystal in a cluster shown (p = 0.003; Cohen's d = 0.73; medium effect size); 8) glassy luster shown with white highlights of light (p = 0.04; Cohen's d = 0.51; medium effect size); 9) layers shown in rock matrix (p = 0.05; Cohen's d = 0.44; small effect size); and 10) impurities or inclusions shown in crystals (p = 0.01; Cohen's d = 0.63; medium effect size). These findings, along with observations of the paintings during scoring, indicate that students in the science condition tended to produce more realistic, detailed paintings of crystal clusters or geodes that incorporated accurate crystal features.

Figures 9 through 18 show crystal paintings of students in the art condition and in the science condition demonstrating prominence of science facts. Each row in Figures 9 through 18 shows two still-life paintings made by two students; the painting on the left was made under the art-focused condition, while the painting on the right was made under the science-focused condition. Compared to the art-focused paintings, the science-focused ones display evidences of better understanding of crystal features.

Figure 9. Paintings (left: art focused condition; right: science-focused condition) displaying accurate angles and shapes of non-rectangular crystal faces.

Table 7. *Results of the Science Analysis of the Crystal Paintings Created under Both Conditions*

Generalized Category	Specific Fact Demonstrated	Science Condition Mean	Art Condition Mean	*p*-Value of t-test	Cohen's *d* Effect Size
Color	Color variation of crystals	0.81 (0.4)	0.76 (0.4)	-	-
	Accurate color of mineral	0.67 (0.5)	0.59 (0.5)	-	-
	Translucency shown with color variation	0.70 (0.5)	0.69 (0.5)	-	-
Crystal form	Orthorhombic - boxlike or rectangular	0.22 (0.4)	0.31 (0.5)	-	-
	Accurate angles and shapes of non-rectangular crystal faces	0.19 (0.4)	0.03 (0.2)	$p = 0.04$ (not paired)	$d = 0.51$ medium
	Cube	0.04 (0.2)	0.07 (0.3)	-	-
	Hexagonal prism	0.30 (0.5)	0.07 (0.3)	$p = 0.01$ (not paired)	$d = 0.56$ medium
	Pyramid shaped terminations	0.41 (0.5)	0.38 (0.5)	-	-
	Irregular pinacoids on crystal terminations - differing growth rates	0.26 (0.4)	0.00 (0.0)	$p = 0.001$ (not paired)	$d = 0.92$ large
	Two or more different crystal forms shown	0.15 (0.4)	0.07 (0.3)	-	-
	Showing geometric faces	0.78 (0.4)	0.69 (0.5)	-	-
	Vertices between faces highlighted	0.56 (0.5)	0.38 (0.5)	-	-
Crystal Habit	Banding of mineral layers	0.56 (0.5)	0.28 (0.5)	$p = 0.02$ (not paired)	$d = 0.56$ medium
	Two or more different crystal habits shown	0.30 (0.5)	0.10 (0.3)	$p = 0.04$ (not paired)	$d = 0.48$ medium
	Crystals emanating from a nucleation point to form a sphere of crystals	0.07 (0.3)	0.00 (0.0)	-	-
	Crystals lining wall or aligned in bands	0.41 (0.5)	0.21 (0.4)	$p = 0.05$ (not paired)	$d = 0.44$ small
	Geode sphere or partial sphere	0.44 (0.5)	0.28 (0.5)	-	-
	Multiple crystals in a cluster	0.37 (0.5)	0.07 (0.3)	$p = 0.003$ (not paired)	$d = 0.73$ medium
	Petal-like or bladed habit	0.15 (0.4)	0.14 (0.4)	-	-
	Twin striations shown	0.07 (0.3)	0.00 (0.0)	-	-
	Twinning - mirror symmetry or interpenetration of crystals	0.07 (0.3)	0.14 (0.4)	-	-
	Domains shown	0.00 (0.0)	0.03 (0.2)	-	-
Luster	Glassy shown with highlights	0.78 (0.4)	0.55 (0.5)	$p = 0.04$ (not paired)	$d = 0.51$ medium
	Pearly sheen (diffuse bright spots)	0.04 (0.2)	0.10 (0.3)	-	-
	Internal reflections shown	0.22 (0.4)	0.10 (0.3)	-	-
Rock Matrix	Matrix - Dark rock encasement of geode	0.44 (0.5)	0.28 (0.5)	-	-
	Matrix - Rock layers in matrix	0.41 (0.5)	0.21 (0.4)	$p = 0.05$ (not paired)	$d = 0.44$ small
	Matrix - Rock matrix shown	0.52 (0.5)	0.34 (0.5)	-	-
Other Properties	Translucency with back vertices showing through	0.04 (0.2)	0.00 (0.0)	-	-
	Fractures or cracks shown in crystals or matrix	0.07 (0.3)	0.07 (0.3)	-	-
	Impurities or inclusions shown in crystals	0.33 (0.5)	0.07 (0.3)	$p = 0.01$ (not paired)	$d = 0.63$ medium
	Phosphorescence or blacklight glow of minerals	0.04 (0.2)	0.00 (0.0)	-	-
Mean for Paintings in Condition	Mean of the specific fact means	0.32 (0.3)	0.21 (0.2)	$p < 0.001$; (paired)	$d = 0.47$ small to medium
	Mean of total facts demonstrated	10.41 (4.3)	7.00 (3.3)	$p < 0.001$ (not paired)	$d = 0.92$ large

Figure 10. Paintings (left: art focused condition; right: science-focused condition) displaying presence of hexagonal prisms.

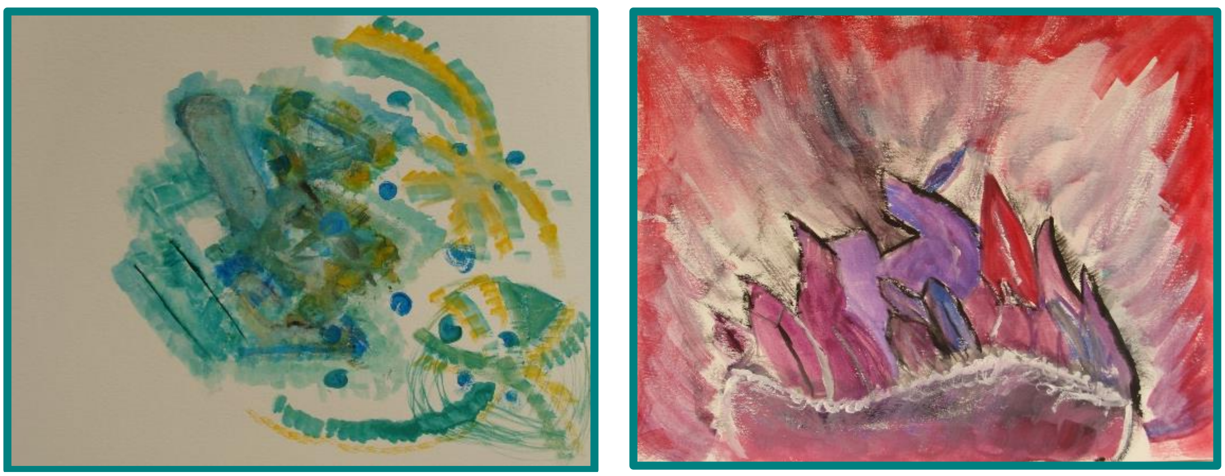

Figure 11. Paintings (left: art focused condition; right: science-focused condition) displaying irregular pinacoidal faces depicted on crystal terminations.

Figure 12. Paintings (left: art focused condition; right: science-focused condition) displaying presence of banded mineral layers.


Figure 13. Paintings (left: art focused condition; right: science-focused condition) displaying two or more different crystal habits


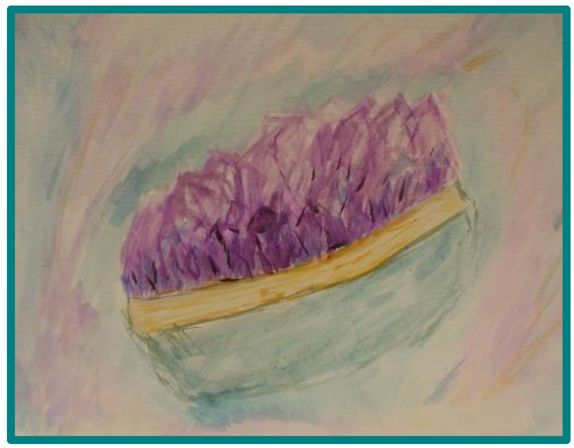

Figure 14. Paintings (left: art focused condition; right: science-focused condition) displaying crystals lining wall


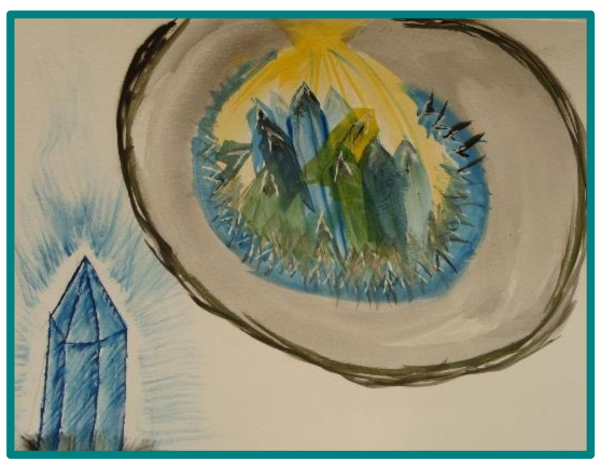

Figure 15. Paintings (left: art focused condition; right: science-focused condition) displaying multiple crystals in a cluster

Figure 16. Paintings (left: art focused condition; right: science-focused condition) displaying glassy luster with white highlights of light

Figure 17. Paintings (left: art focused condition; right: science-focused condition) displaying layers in rock matrix

Figure 18. Paintings (left: art focused condition; right: science-focused condition) displaying impurities or inclusions in crystals

Results of Attitude Survey

The participants filled out an attitude survey right after the experiment took place. They self-reported levels of creativity, enjoyment, motivation, and satisfaction on a ten-point, ascending Likert-type scale, and provided short answers for the reasons behind their ranking. For the art condition, the mean creativity score was 6.33, the enjoyment score was 7.76, the motivation score was 6.72, and satisfaction score was 6.08. For the science condition, the mean creativity score was 5.4, the enjoyment score was 8.46, the motivation score was 6.75, and satisfaction score was 5.58. The differences between the conditions' means are not statistically significant; however, both conditions yielded good scores > 5 (i.e., poor = 0-4; neutral = 5; good = 6-10). These results suggested that the experiment evoked overall positive attitudes in the participants of both conditions. The levels of enjoyment were the highest of all indicators in both conditions which alludes that painting as an exercise is well-accepted by the participants.

A further theme analysis (Creswell & Creswell, 2017) was conducted on the short answers from the surveys in both the art and science conditions. These short answers revealed the reasons behind the numeric scores for creativity, enjoyment, motivation, and satisfaction, as well as summarized the most important thing the participants gained from the experiment. All short answers were analyzed and categorized into the most common themes included in Table 8. The highest frequency reason for creativity ranking was "I'm not creative", followed by "Painting didn't turn out like I wanted". The participants also mentioned imagining the crystal displays as something else, coming up with their own way of accomplishing the task, and surprising use of colors. Therefore, some interpretations that can be made about creativity are that preservice teachers lack experience with creativity and skill in painting which may have led to this prevalently negative self-assessment.

The most common reason for enjoyment was that the painting task was fun, followed by the fact that participants liked painting and trying new things they don't often get to do in college. The third most common answer deemed the exercise as relaxing. There were some participants admitting that they were not in a mood for various reasons or that the rules of the experiment were limiting (i.e, time limit, must draw crystals, limited colors, no music, etc.). However, overall the short answers addressing reasons for enjoyments confirmed that drawing tasks are fun, enjoyable, and relaxing which can make them appropriate for educational purposes.

In terms of motivation, most common reasons for lower motivation levels were that the participants didn't like their painting, didn't think they were good artists, or had some personal and environmental reasons (i.e, "it was a Monday", "don't like rocks", etc.). The participants who rated their motivation higher credited their desire to see good finished product and the excitement of doing something different than the regular classes. This alludes that there isn't sufficient emphasis on the arts in higher education and as a result some students may become alienated from the arts while others who would still like to practice them, may not find time and place to do so.

Overall, most students thought their paintings turned out well, listing this as the most common reason for the satisfaction rating. The second most common reason indicating low satisfaction was that the paintings didn't turn out the way imagined, followed by issues with colors/shapes, details. This again suggested that the lack of skill in painting may lead to lower satisfaction with the experience and the product. It was not surprising, then, that the most important thing gained from the experiment was reported to be knowledge about creativity and uniqueness. Some participants shared that the more they learned about it and practiced the painting technique, the more motivated and satisfied they felt. They also reported gaining understanding that it is beneficial to try new things and practice painting as a means for relaxation. Three participants from the science condition claimed they gained more knowledge about crystals through this painting activity. This alludes for the fruitfulness of art tasks in science education or that an activity like the one in this experiment can teach about the arts as well as about the science of crystals.

Table 8. *Results of Theme Analysis of Short Answers on Attitude Survey*

Reasons for creativity rating		Reasons for enjoyment rating		Reasons for motivation rating		Reasons for satisfaction rating		Most important thing gained from the exercise	
I'm not creative	10	It was fun/ enjoyable	22	Don't like painting/not good at painting	12	The painting turned out well (colors, abstract)	23	Learned about creativity/uniqueness (doesn't have to be perfect, finding inspiration, thinking outside the box)	20
Painting didn't turn out like I wanted	9	I like trying new things/break from regular classes	9	The conditions (no music, don't like rocks, wasn't prepared, was Mon)	11	The painting didn't turn out well	12	Learned a new art technique	12
Imagined it to look like something else (space, ice cubes, boat, etc.)	7	I like painting	9	To see good finished work	9	Issues with shapes/colors/details	8	It's good to try new things/plan	6
Because of the use of colors	7	It was relaxing	8	Excited for the exercise	9	Tried my best	5	Painting as relaxation/ enjoyment	5
Came up with own way of accomplishing the task	6	I was not in a mood/don't like painting	7	It was something different	4	I'm not creative/artistic	5	Learned more about crystals	3
Looks like the crystals/ literal representation	4	Didn't like the exercise's theme/rules	6	Gained more confidence going through it	4	Not enough time	4	I'm not good at painting	2
This exercise was something new	3	I was able to express myself	3	No strong feelings either way	2	Good experience (fun, relaxing)	3	I'm good at painting	2
The painting could not be replicated/unique	3			The painting didn't look good	2	Wanted to mimic other artists	1	Need time to do well	1
Because of the painting's name/ meaning	2								

Discussion

This study explored the use of science integration into art to determine whether increased incorporation of science detail in artwork and types of other creativity is demonstrated, measured by noting strengths of creative traits in an adapted creative thinking rubric (Rule et al., 2011) and evaluating science content using a checklist. The next section discusses the findings of the study. First, comparison with a similar study is made. Then, necessity of reinforcement of science concepts and making connections across disciplines is emphasized as the study indicates. Next, necessity of translating flow principles into science-centered art activities is explained based on the study results. Finally, implications for practice are stated followed by conclusion and suggestions for future research.

Comparison to a Study on Animal Skull Paintings

A similar study was conducted by Stoycheva, Hussain, Rule, and Tallakson (2019) where still life painting of animal skulls were produced in art-focused and science-focused conditions. When compared to the current study, both had greater mean scores of overall creativity in the art conditions. The current crystals study found statistically significant differences in the means for specific creative traits and for overall creativity scores, while in the skulls study the art condition scored higher but the difference was not statistically significant.

Additionally, in both studies, the significant differences in creative aspects favored the art-focused introduction conditions. In the skulls study, statistically significant differences were found for four specific creative traits: elaboration (p = 0.03; Cohen's d = 0.52), internal visualization (p = 0.05; Cohen's d = 0.48), unusual visualization (p = 0.05; Cohen's d = 0.47), and humor (p = 0.05; Cohen's d = 0.46) (Stoycheva et al., 2019). In the current crystals study, other four creative traits statistically significantly favored the art condition: adding extra component (p= .009; d = .61), colors different from display (p = .002; d = .85), fantasy (p = .003; d = .68), parody (p = .03; d = .51). It is possible that the experiments' specific PowerPoint introductions (images and facts) and the topic itself (crystals vs. skulls) have triggered the higher scores on different creative traits; yet in both studies those benefited the art condition.

When comparing the science content in the paintings from the current study and Stoycheva et al. (2019), the results in both indicate significant differences in total scores (crystals: p < 0.001; Cohen's d = 0.92 and skulls: p = 0.01; Cohen's d = 0.69) and also significant differences in averages scores of individual science facts (crystals: p < 0.001; Cohen's d = 0.47 and skulls: p = 0.04; Cohen's d = 0.42), all favoring the science-focused condition. Therefore, both studies suggest that students in arts-focused conditions demonstrate greater creative traits in their paintings while students in science-focused condition- greater scientific traits.

When considering the attitude surveys in these two experiments, another similarity is that both indicated highest self-reported scores for enjoyment. This suggested that regardless of the topic for still-life, the participants enjoyed the painting task. Many common themes exist across the two studies: 1) for reasons for creative scores: "I'm not creative", "The use of color/position/detail"; 2) for enjoyment scores: "Painting was enjoyable/fun/relaxing", "I like painting/creativity"; 3) for motivation scores: "I'm not good at or I don't like painting"; 4) for satisfaction scores: "The painting did or didn't turn out as imagined"; 5) for most important thing gained from the experience: "Learning about creativity and gouache". These findings from the thematic analyses suggest that regardless of the topic for still-life, the participants in the Hussain et al. (2018) and Stoycheva et al. (2019) had similar experiences and attitudes towards the STEAM exercises.

Necessity of Reinforcement of Science Concepts and Making Connections across Disciplines

Pretest results indicated that this study was not impacted by prior experience or knowledge about gouache painting or crystals as neither one of the groups, i.e., art-focused condition or the science-focused condition had significant prior experience or knowledge. Interestingly, creativity analysis of paintings revealed students in the arts-focused group acquired greater benefits in terms of creativity; statistically significant differences were found for four specific creative traits, namely, adding extra component, colors different form display, fantasy, and parody, all favoring the art condition. On the other hand, analysis of science content in paintings, along with observations of the paintings during scoring showed students in science condition were inclined to produce more realistic, detailed paintings of crystal clusters or geodes that incorporated accurate crystal features. The findings suggest possibility of reinforcement of scientific concepts through scientific illustration. Scientific illustration has two advantages for students: Introduction to the idea of depiction that allows rendering a subject from observation is possible and the conceptual and aesthetic quality can be inspirational (Marshall, 2010). In fact, science process skills can be integrated into a developmentally appropriate early childhood environment through the arts (Morrison, 2012). Fundamental science process skills at the curriculum level is likely to have positive outcome for students.

In other studies and practical projects, too, understanding of science content has been found to be enhanced when combination of creative techniques (e.g., Rule, Baldwin, & Schell, 2009; Rule & Rust, 2001; Ursyn & Sung, 2007), integrative instruction (e.g., Ursyn, 1997; Luna & Rye, 2015), integration of science and art concepts (Dambekalns & William, 2012; Gurnon et al., 2013; Stoycheva et al., 2018) are in use. This study further indicates that art should be emphasized for both aesthetic reasons and enhancing knowledge of other disciplines. Literature supports encouraging students to utilize process skills that are commonly shared by the science and art disciplines (e.g., Chessin & Zander 2006; Marshall, 2010; Morrison, 2012) and examine artists who integrate science in their artwork (Alberts, 2008; Bequette & Bequette, 2012; Güney & Şeker, 2017; Letts & Richmond, 2012; Marshall, 2010).

Necessity of Translating Flow Principles into Science-integrated Art Activities

The self-reported levels of creativity, enjoyment, motivation, and satisfaction expressed in the attitude survey indicated an overall positive experience of the participants in both the art-focused and the science-focused conditions. Levels of enjoyment were found to be the highest of all indicators in both conditions. Most participants accepted the painting activity as worthwhile, which implies that the experience of the painting activity had been intrinsically rewarding, a subjective state that Csikszentmihalyi (1990) identified as a characteristic of being “in flow”. However, a few students voiced anxiety as their experiences had not been enjoyable e.g., not being in the mood or feeling restricted by the painting theme and rules. Negative attitude had barred these students from experiencing a deep sense of enjoyment or gain optimal experience. According to Csikszentmihalyi’s (1990) flow theory, “optimal experience” occurs when a person is able to control what happens in consciousness and this requires a person to exert individual efforts and creativity. Physiological states or emotional arousal such as stress, anxiety, fear, etc. can affect people’s performance (Bandura, 1977) and these students’ experiences in terms of enjoyment indicate that physiological as well as environmental conditions act as obstacles or facilitators to optimal experience and flow experience (Nakamura & Csikszentmihalyi, 2009).

Positive experiences were reported by some students too. For task achievement some students expressed having extended their own imagination as far they could in depicting the still-life in vibrant colors and unusual shapes. These students were addressing the challenging activity by seeing things in new contexts so as to help understand them differently and find new meaning in them. In other words, they were using “reformatting”, a conceptual strategy contemporary artists develop, to manipulate ideas and imagery to make meaning (Marshall, 2010). They were able to “reenter flow” by avoiding an unpleasant state that Nakamura and Csikszentmihalyi (2009) explained is achieved by adjusting a level of skill or challenge. The issue of lower self-efficacy on the one hand, and the willingness to re-contextualize on the other suggests that alienation from the arts can suppress exploration of tools of creativity and eagerness to involve in risk-taking. Environments that inspire risk-taking actually nurture creative behavior (Rule et al., 2011) and the students exhibited that through their paintings.

The development of creative potential is dependent on various factors and is not limited to individual differences but the kinds of personal experiences and opportunities students have. Students attributed lower motivation levels to not liking their own artwork, not thinking of themselves as good artists, and a personal or environmental obstacle. The acknowledgement of the participants suggest that recognition of high or low skill set, how prepped they were, and contextual factors impact whether they can find themselves in a state of intense focus, confidence, and extreme motivation. According to Shernoff, Csikszentmihalyi, Schneider, and Steele (2003) students' engagement can be enhanced by supporting their sense of competency and autonomy. From the perspective of flow theory, their study, too, demonstrated that subjective perceptions of challenge and relevance influence quality of student's experience. In this study, although the painting activity afforded opportunity for creativity, effective engagement in the activity depended on their possession of relevant capacities for action (Nakamura & Csikszentmihalyi, 2002). This means that introducing a variety of art forms to choose from and connecting to students' personal goals, and provide opportunities for success can increase student engagement (Shernoff et al., 2003). Providing opportunities in the classroom context should be teachers' priority. Most importantly, when incorporating science into arts, students may have very low levels of confidence in their artistic ability that is based on their drawing ability. It is necessary to demystify the concept that talent in art is a gift that one has or does not. Trial and error, planning, problem solving, interpretation, invention, and synthesis of ideas are some skills used in creating art forms but they are not exclusive to the domain of drawing (Letts & Richmond, 2012).

Implications for Practice

A number of implications for science integration in arts emerge from this study. First, it can be emphasized that it is necessary to engage students' cognitive processes earlier in their school years. A lot of developmentally appropriate learning explorations in the arts include basic science process skills (i.e., observe, communicate, compare, measure, and organize) (Morrison, 2012). According to Morrison, since children are naturally curious about their world and how it works, linking science and art explorations is meaningful in early childhood curriculum. Integrating science and the arts into the curriculum should be the goal for every classroom teacher. Second, teachers need to be cognizant of the necessity of strengthening STEM skills and explore ways of how to support students in developing them. When nurturing creativity, the importance lies in identifying what is conducive to as well as suppressing to its growth in a classroom context (Beghetto & Kaufman, 2014). In the present study, participants' physiological as well as environmental conditions acted as obstacles or facilitators to flow experience. This implies the importance of encouraging student engagement by considering factors that obstruct and enhance conducive environment.

To nurture creative education and excitement about science among students so that their learning goals are achieved, creative classroom activities need to be incorporated (Hussain & Carignan, 2016). Practitioners can make informed-decisions when using classroom-tested creative science activities according to grade levels. They can avoid rote memorization by doing so and select age-appropriate techniques (Park & Seung, 2008). To help retain students' attention and optimal engagement, the challenge for teachers would be to identify moderately difficult tasks for a student's current skill level that can be mastered with the acquisition of new skills (Nakamura & Csikszentmihalyi, 2009). Therefore, an understanding of flow experience (Csikszentmihalyi, 1990; Nakamura & Csikszentmihalyi, 2009) is necessary among teachers to help enhance students' level of enjoyment, satisfaction, and motivation when they are engaged in science-integrated art activities that appear challenging to them.

Above all, to initiate the conceptual process, two steps are important: (1) validation of the conceptual process (e.g., providing information about the science concepts being focused and examples of artists and their science-focused artwork of those concepts), and (2) authenticity of the image of the object as an artistic practice. This will support idea-generation as well as inspire imaginative use of science concepts in student creation. Students are likely to project diversity in their own creation if teachers devote themselves to building visual awareness through exposure to a variety of examples. Also, students are generally accustomed to writing texts to communicate and they do not realize that art can be a mode of expressing their understanding. The fact that human beings view and respond to visual information from birth needs to be emphasized. Art as a form of visual communication can be facilitated through other modes including collage that has less impediments to acquiring necessary skills, and map or graph construction to demonstrate knowledge of location, climate, environment that encourages synthesis and prior knowledge typical in science learning (Letts & Richmond, 2012).

Conclusion

Neither of the arts- or science- focused groups in this study had significant prior experience of watercolor or knowledge of crystals to impact the study. Although students in the art-focused group gained more benefits in terms of creativity, two significant differences in overall mean scores revealed students in the science-focused group were more likely to demonstrate science concepts in their crystal paintings: total scores of demonstrated science facts and mean scores of individual science facts areas. Additionally, overall experiences expressed by students in both the groups were mostly positive: unique, self-inspirational, spontaneous, stimulating, increased conceptual understanding, knowledge about creativity, flexible (atmosphere), and relaxing. Students expressed the need for new experiences and a desire for more arts exposure because of emotional benefits, but some voiced lack of confidence in trying something new and unfamiliar as well as time constraints as a limitation. In other words, challenges, if manageable, could motivate them to be in flow. This experience of skill adjustment was encountered by some and they successfully re-entered a state of flow.

Suggestions for Future Research

Development of projects that explore the blurred boundaries between science and art is necessary. Whereas other studies have indicated science and art integration can lead to transformative effects (e.g., Ursyn & Sung, 2007; Eick, 2011; Gurnom, 2013; Luna & Rye, 2015), this study found evidences of the utility of science integration into art and vice versa. While the arts-focused group acquired greater benefits in terms of creativity, the seventy-five-minute class period possibly set a time constraint on the students' creative potential and skill level adjustment in the science-focused group. Although more science facts were demonstrated in the crystal paintings of students in the science condition, larger sample size and longer class timing may provide a clearer picture of the nature and specificity of differences between conditions. Since classroom teachers potentially influence student exposure to the sciences and arts, and their actions influence the future of arts and science education, it is imperative that teaching and learning with Science Integration and Arts Integration be further explored. Although efforts are being made to rework teacher education to support interdisciplinary scholarship (LaJevic, 2013), more small-scale initiatives to conduct experimentation are needed. Exploring both Arts Integration and Science Integration into Arts can provide understanding of the dynamic processes of merging art with other disciplines and merging science with arts. This is likely to encourage a better conception of the possibilities of such integrations across the school curriculum and the boundaries of school subjects. The authors hope that this study will promote discussion and inquiry in the under-explored space of Science and Arts Integration.

References

Alberts, R. (2008). Discovering science through art-based activities. Retrieved from http://beyondpenguins.ehe.osu.edu/issue/earths-changing-surface/discovering-science-through-art-based-activities

Aljughaiman, A., & Mowrer-Reynolds, E. (2005). Teachers' conceptions of creativity and creative students. *The Journal of Creative Behavior, 39,* 17–34.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215. doi: 10.1037/0033-295X.84.2.191

Beghetto, R., & Kaufman, J. (2014). Classroom contexts for creativity. *High Ability Studies, 25*(1), 53-69. doi: 10.1080/13598139.2014.905247

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education*, *65*(2), 40-47. doi: 10.1080/00043125.2012.11519167

Brouillette, L., Grove, D., & Hinga, B. (2015). How arts integration has helped K-2 teachers to boost the language development of ELLs. *Journal of School Leadership, 25*(2), 286-312.

Chessin, D., & Zander, M. J. (2006). The nature of science and art. *Science Scope, 29*(8): 42-46.

Cho, Y., Chung, H. Y., Choi, K., Seo, C., & Baek, E. (2013). The emergence of student creativity in classroom settings: A case study of elementary schools in Korea. *Journal of Creative Behavior, 47*(2), 152-169. doi: 10.1002/jocb.29

Creswell, J. W., & Creswell, J. D. (2017). *Research Design: Qualitative, quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA: Sage publications.

Csikszentmihalyi, M. (1990). Flow: The Psychology of Optimal Experience. New York, NY: Harper and Row.

Dambekalns, L., & Medina-Jerez, W. (2012). Cell organelles and silk batik: A model for integrating art and science. *Science Scope*, *36*(2), 44-51.

Eick, C. J. (2012). Use of the outdoor classroom and nature-study to support science and literacy learning: A narrative case study of a third-grade classroom. *Journal of Science Teacher Education, 23*, 789-803. doi: 10.1007/s10972-011-9236-1

Güney, B., & Şeker, G. (2017). Discovering socio-cultural aspects of science through artworks. *Science & Education, 26*(7), 867-887. doi: 10.1007/s11191-017-9924-0

Gurnon, D., Voss-Andreae, J., & Stanley, J. (2013). Integrating art and science in undergraduate education. *PLoS Biology, 11*(2). doi: 10. 1371./journal.pbio.1001491

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Kellam, N., Kellam, N. N., & Walther, J. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. *International Journal of Education & the Arts*, *16*(15), 1-38. Retrieved from http://www.ijea.org/v16n15/

Hardiman, M., Rinne, L., & Yarmolinskaya, J. (2014). The effects of arts integration on long-term retention of academic content. *Mind, Brain, and Education*, *8*(3), 144-148. doi: 10.1111/mbe.12053

Hussain, M. & Carignan, A. (2016). Fourth graders make inventions using SCAMPER and animal adaptation ideas. *Journal of STEM Arts, Crafts, and Constructions, 1*(2), 48-66. Retrieved from https://scholarworks.uni.edu/journal-stem-arts/vol1/iss2/

Jonsson, A., & Svingby, G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review*, *2*(2), 130-144. doi: 10.1016/j.edurev.2007.05.002

Kress, D. K., & Rule, A. C. (2017). Fifth graders' creativity in inventions with and without creative articulation instruction. *Journal of STEM Arts, Crafts, and Constructions,* *2*(2), 130-154. Retrieved from https://scholarworks.uni.edu/journal-stem-arts/vol2/iss2/

LaJevic, L. (2013). Arts integration: What is really happening in the elementary classroom? *Journal for Learning through the Arts,* *9*(1), 1-28. Retrieved from https://escholarship.org/uc/item/9qt3n8xt

Land, M. (2013). Full STEAM ahead: The benefits of integrating the arts into STEM. *Procedia Computer Science, 20*, 547-552. doi: 10.1016/j.procs.2013.09.317

Letts, M., & Richmond, K. (2012). Imagining insects: Integrating the fine arts into writing, literature, and science through project-based learning activities. *Language Arts Journal of Michigan, 28*(1), 39-45. doi: 10.9707/2168-149X.1930

Luna, M. J. & Rye, J. A. (2015). Gardening for homonyms: Integrating science and Language Arts to support children's creative use of multiple meaning words. *Science Activities, 52,* 92-105. doi: 10.1080/00368121.2015.1102698

Marshall, J. (2010). Five ways to integrate: Using strategies from contemporary art. *Art Education*, *63*(3), 13-19. doi: 10.1080/00043125.2010.11519065

Morrison, K. (2012). Integrate science and arts process skills in the early childhood curriculum. *Dimensions of Early Childhood, 40*(1), 31-38. Retrieved from https://www.southernearlychildhood.org/upload/pdf/DEC401201231.pdf

Nakamura, J., & Csikszentmihalyi, M. (2009). The concept of flow. In C. R. Snyder & S. J. Lopez (Eds.), Handbook of Positive Psychology (pp. 89-105). Oxford, USA: Oxford University Press.

NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: The National Academies Press.

Park, S., & Seung, E. (2008). Creativity in the science classroom: Four strategies to help students think outside the box. *The Science Teacher*, *75*(6), 45–48.

Partnership for 21st Century Schools [P21]. (no date). *Framework for 21st century learning.* Retrieved from http://www.p21.org/our-work/p21-framework

Pittman, P. J. Z., & Teske, J. K. (2017). Examining natural selection by sketching and making models of the finches of the Galapagos Islands. *Journal of STEM Arts, Crafts, and Constructions,* 2(2), 66-73. Retrieved from https://scholarworks.uni.edu/journal-stem-arts/vol2/iss2/4/

Rinne, L., Gregory, E., Yarmolinskaya, J., & Hardiman, M. (2011). Why arts integration improves long-term retention of content. *Mind, Brain, and Education, 5*(2), 89-96. doi: 10.1111/j.1751-228X.2011.01114.x

Rule, A. C., Baldwin, S., & Schell, R. (2009). Trick-or-Treat Candy-Getters and Hornet Scare Devices: Second Graders Make Creative Inventions Related to Animal Adaptations. *The Journal of Creative Behavior*, *43*(3), 149-168.

Rule, A. C. & C. Rust. (2001). A bat is like a…. *Science and Children*, *39*, 26-31.

Rule, A. C., Zhbanova, K., Hileman Webb, A., Evans, J., Schneider, J. S., Parpucu, H., Logan, S., Van Meeteren, B., Alkouri, Z., & Ruan B. (2011). Creative product problem-solving game: Exploring Torrance's creative strengths by making an object from a set of given materials. ERIC Document Reproduction Service No. ED527045.

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly, 18*(2), 158-176. doi: 10.1521/scpq.18.2.158.21860

Small, M. (2015). How to paint with gouache: Beginner's tips and walkthrough. Retrieved from https://www.youtube.com/watch?v=mb2_rqkenPE

Soundy, C. S. & Drucker, M. F. (2010). Picture partners: A co-creative journey into visual literacy. *Early Childhood Education Journal, 37*(6), 447-460. doi: 10.1007/s10643-010-0374-4

State Education Agency Directors of Arts Education. (2014). *National core arts standards: A conceptual framework for arts learning.* Retrieved from http://www.nationalartsstandards.org/content/conceptual-framework

Stemler. S. E. (2004). A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. *Practical Assessment, Research and Evaluation, 9*(4), 1-11.

Stoycheva, D., Hussain, M., Rule, A., & Tallakson, D. (2019). Exploring creative and scientific aspects in preservice teachers' still-life paintings of animal skulls. Unpublished manuscript.

Swift, T. M., & Watkins, S. E. (2004). An engineering primer for outreach to K-4 education. *Journal of STEM Education: Innovations and Research, 5*(3/4), 67-76.

Thompson, G. W., & Balschweid, M. M. (2000). Integrating science into agriculture programs: Implications for addressing state standards and teacher preparation programs. *Journal of Agricultural Education*, *41*(2), 73-80. doi: 10.5032/jae.2000.02073

Torrance, E. P. (1992). A national climate for creativity and invention. *Gifted Child Today Magazine, 15*(1), 10-14. https://doi.org/10.1177/107621759201500103

Ursyn, A. (1997). Computer art graphics integration of art and science. *Learning and Instruction*, *7*(1), 65–86. doi: 10.1016/S0959-4752(96)00011-4

Ursyn, A., Scott, T., Hobgood, B., & Mill, L. (1997). Combining art skills with programming in teaching computer art graphics. *ACM SIGGRAPH Computer Graphics, 31*(3), 60-61. doi: 10.1145/262171.262210

Ursyn, A., & Sung, R. (2007). Learning science with art. *ACM SIGGRAPH Educators Program*,. 8-es. doi: 10.1145/1282040.1282049

Weber, C. A., & Rule, A. C. (2017). Middle level preservice teachers experience a natural history arts-integrated interdisciplinary thematic unit. *Journal of STEM Arts, Crafts, and Constructions, 2*(2), 15-44.

Wicklein, R. C. & Schell, J. W. (1995). Case studies of multidisciplinary approaches to integrating Mathematics, Science and Technology Education. *Journal of Technology Education, 6*(2). 59-76.

Yager, R. E. (2000). A new vision for what science education should be like for the first 25 years of a new millennium. *School Science and Mathematics, 100*(6), 327-41.