Editorial: Developing Creativity through STEM Subjects Integrated with the Arts

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Abstract

This issue of the *Journal of STEM Arts, Crafts, and Constructions* is focused on creativity - one of the most highly-desirable 21st Century skills on personal and global levels. Time, pedagogical knowledge, and resource constraints limit the number of opportunities for teachers to develop creativity in students. In this editorial, creativity development steps and strategies are illuminated along with specific roles of STEM subjects and the arts in development of student creativity. The processes of creativity development used in STEM and the arts are compared to each other and to the non-subject-specific creative process model of Root-Bernstein and Root-Bernstein; correlating steps are highlighted. The role of integration of the arts and STEM subjects for creativity development is also analyzed in this editorial, followed by the summaries and key findings of three practical and three research articles, which introduce arts-integrated projects fostering creativity development.

Key Words

STEM education, creativity development, arts integration, STEAM, crafts

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Introduction

Creativity is a highly-desired skill in our world of rapid change and ever-increasing social, emotional, and intellectual demands. Content knowledge is not enough to be successful today; one also needs to determine how to use knowledge in novel and efficient ways. This notion made the phrase "Work smart, not hard" very popular. Creativity is considered to be a solution to many pressing global issues (National Educational Association, n.d.). What we already know and can do is not enough to solve these issues because if it were, we would have addressed them already. These problems require completely new approaches. Educators have recognized the value of creativity and, consequently, have included it in the 21st century skills list.

Similar to the learning of many other skills, creativity development needs to begin early in life. Early childhood education, in fact, is largely focused on creativity development (Fazylova & Rusol, 2016). However, already in elementary school, teachers face obstacles to creativity development such as time, budget, pedagogical knowledge, and other constraints such as scripted curricula and mandated testing (Stylianidou, Glauert, Rossis, Compton, Cremin, Craft, & Havu-Nuutinen, 2018). Subject integration is often regarded as the way to overcome these constraints (Jacobs, 1989) and an effective approach to creativity development (Watkins, 1990). This editorial is focused on the individual role of the Arts and STEM subjects in creativity development and on the effects of integration of STEM and the Arts on student creativity.

Creativity

According to one definition, creativity includes everything (e.g. a process, product, idea) that can be assessed (Sternberg & Lubart, 1999) and meets two criteria: (1) novelty or originality; (2) usefulness or value within a particular field (Beghetto, 2013). Crazy or random ideas that have no connection, function, or value to the problem, although possibly unique, are not considered to be creative.

Why is Creativity Important and Can it be Taught?

Creativity is important on two levels: personal, and societal. On the personal level, creativity is a part of a problem-solving process used to address challenges of daily life; on a more global level, it benefits humanity by catalyzing many scientific breakthroughs (Sternberg & Lubart, 1999). Therefore, developing creativity in students is beneficial for their personal success and for the wellbeing of society. In today's world of rapid change and globalization, the success and, often, even existence of an organization largely depends on the creativity of its employees (Shalley, Zhou, & Oldham, 2004). Additionally, creativity is considered one of the driving forces of local and global economic development (Atkinson & Easthope, 2009). Creative thinking is one of the three most important skills that students need to acquire to ensure future career success along with development of critical thinking and problem-solving abilities (Kubat & Guray, 2018).

If people are asked to be creative, usually they have a general sense of what is expected. Some people believe they are creative, and others believe that they are not. Can those who believe that they are not creative be taught to be creative? There is a notion that creativity can be developed and taught through the use of creative strategies or by following the steps of a creative process.

There are multiple definitions of creativity and many creative process models (e.g. Wallas's (1926) model, Root-Bernstein and Root-Bernstein's (1999) model, and Torrance's (Torrance & Safter, 1990) model). One similarity between the majority of these models is their interdisciplinarity. The steps or components of these models are not exclusive to any particular subject. On the contrary, they can be effectively applied within any area and require going outside the discipline by connecting with other disciplines. This supports the idea that any school subject can develop creativity in students through interdisciplinary connections as one of the key components in developing creativity (Kubat & Guray, 2018). The following three sections explore the ways STEM (Science, Technology, Engineering, Mathematics) and Arts develop creativity independently and in concert with each other.

How STEM Subjects Integrated with the Arts Develop Creativity

Although creativity is typically viewed as a feature of the arts and arts-related disciplines, it is not discipline-specific (Root-Bernstein & Root-Bernstein, 1999). STEM subjects develop creativity as well (Stylianidou et al., 2018).

The Role of STEM. The acronym STEM was created after many strong similarities and connections between science, technology, engineering, and mathematics were acknowledged (Bequette & Bequette, 2012) and became the base for the interdisciplinary approach to teaching STEM subjects (Kubat & Guray, 2018). Interdisciplinary approaches allow teachers to create learning opportunities that mimic real life situations that are often complex and ill-defined. This pedagogical tactic has been shown to foster creativity in students (Kubat & Guray, 2018; Roberts, 2015). An interdisciplinary approach to teaching STEM subjects also provides students with increased motivation because authentic learning opportunities are meaningful and have a clear purpose to which students can relate. Interdisciplinary projects promote the use of problem finding, problem solving, analysis, synthesis, and other 21st century skills including creativity (Kubat & Guray, 2018) in addition to engaging multiple intelligences and multiple senses, which also foster creativity (Clarke & Cripps, 2012).

For example, if middle schoolers want to build a greenhouse, they need to identify items needed (e.g. wood, soil, shovels, plastic sheeting). This creates an opportunity to practice problem-finding and problem-solving, the two major components of creative process (Craft, 2002). Teaching students how to use a list of Excel formulae (Technology) to keep track of items available and items needed, to compare costs of items, to calculate the total cost, and others would be much more engaging than a lecture about the formulae. This project also requires knowledge of the local climate, soil, properties of various materials, and others to ensure the greenhouse lasts (Science). Students need to know how to measure the land, to approximate the size of the greenhouse, and to calculate whether additional amounts of soil are needed, which can be accomplished in a Mathematics lesson (Mathematics and Engineering).

STEM activities, such as the one mentioned above are based on experiential learning and experimenting, which are effective ways of developing student creativity (Stylianidou et al., 2018). A study of policies and a survey of STEM teachers' opinions across several European countries demonstrated that the positive impact of problem solving and agency in STEM subjects on student creativity and development of inquiry skills is widely recognized (Stylianidou et al., 2018). This study demonstrated that teachers link the number of opportunities for students to practice questioning and being curious (parts of problem-finding process employed by the STEM disciplines), to increased levels of student creativity. Another finding was a connection between the learning opportunities in STEM subjects that promote generation and evaluation of ideas with creativity and inquiry development. This same study demonstrated that activities, during which children were observed to exhibit creativity and those requiring the use of inquiry were almost always the same (Stylianidou et al., 2018). This finding supports the idea that the two concepts are strongly connected and inquiry-based STEM activities also develop student creativity.

The Role of the Arts. It has long been established that Arts develop creativity (Lee, Kohn, & Young, 2012; Isbell & Raines, 2012). In fact, creativity development is one of the goals of the Arts. A comparative study of Arts curricula of 21 countries demonstrated that these curricula are formed with the purpose of addressing, among others, the objective of creativity development (European Commission, as cited by Craith (2009)). How do the Arts develop creativity? Simply put, the creative process or creative inquiry is entwined with all areas of the Arts (Isbell & Raines, 2012; Cornett, 2015). Creative process relies on observation, finding patterns, creating mental images, and making conclusions (Cornett, 2015). Results of engaging in creative inquiry during the Arts lessons are long-lasting. The degree of immersion in the Arts during early childhood positively affects student creativity levels even later in life even if the following years did not include much Arts education (Isbell, 2008).

The Arts provide a pleasurable and gratifying medium of self-expression. For example, creating any artwork, be it a musical piece or a clay sculpture, develops children's creativity (Craith, 2009) and is one of the reasons why students are drawn to art lessons, during which they are more willing to take risks, pursue new projects, and exhibit greater motivation to work on challenging and ill-structured assignments. Such ill-defined problems and projects develop creativity along with intelligence (Welter, Jaarsveld, & Lachmann, 2017). Projects within the Arts disciplines are not overstructured, allow great flexibility and welcome self-expression. Arts involvement teaches students to take healthy risks (Cornett, 2015) and to tolerate anxiety related to the unknown; this skill is a necessary part of creative practice (Carabine, 2013).

Much is said about the importance of the environment for creativity development (Craith, 2009). During art lessons, students feel safe to try new and different activities, approaches, ideas because "new" and "different"- not "correct", are the highly desired attributes in all areas of the Arts (Isbell & Raines, 2012). Additionally, the Arts involve studying works of artists whose creativity is internationally acknowledged, which creates the necessary exposure to examples of creative work and an environment saturated with creative ideas. Such an environment is conducive to the development of creativity and imagination (Fazylova & Rusol, 2016).

Arts projects provide students with an embodiment of their thinking, ideas, and selves through literally *making* art, which is in essence experiential learning. This type of learning permeates all areas of the Arts and develops creativity (Livingstone & Lynch, 2002). Students see that by using ordinary parts or elements, they can bring into existence something new and unique. For example, during a week-long arts-integrated project of making models of creatures from the Cambrian Period, the participants discovered an increase in their levels of creativity (Anderson, Zhbanova, Gray, Teske, & Rule, 2017).

In addition to developing creativity through engaging students in creative inquiry, Arts help overcome other issues that can be impeding student creativity. According to Fazylova and Rusol (2016), Arts help dissolve aggression in students, aid in addressing emotional problems, develop fine motor skills, and improve social skills. The Arts provide a medium to express the feelings and thoughts that cannot be expressed verbally resulting in this therapeutic effect (Fazylova & Rusol, 2016). One other unique feature of the Arts that is particularly important in our increasingly diversifying society, is overcoming the language barrier (Fazylova & Rusol, 2016), which makes developing creativity of the English Language Learners (ELLs) much easier. Arts involvement facilitates an intrinsic motivation to create, which is a key component of any creative endeavor and one of the most desirable aspects of learning for every subject. A study of 233 high schoolers advanced in visual arts and creative writing demonstrated that the participants were greatly motivated by the opportunities that these areas of the Arts provided. The most commonly listed motivating aspects were freedom to use imagination, express themselves, and deepen their self-understanding (Harrington & Chin-Newman, 2017).

Integrating STEM with the Arts. Because STEM subjects and the Arts foster creativity, integration of these subjects allows participants to reap the benefits of them all. Integration of STEM and the Arts is also warranted. One of the common obstacles to creativity and inquiry development frequently reported by teachers of science and mathematics is the reduced number of opportunities to develop creativity because of time, space, and curriculum restrictions (Stylianidou et al., 2018). Integration of the Arts with STEM subjects, because of its seamlessness and gifts of the arts, such as creative inquiry, authentic real-world applicable projects, intrinsic motivation, and others, can help overcome this obstacle (Cornett, 2015).

The Arts and STEM areas have a significant number of similarities promoting organic integration of these subjects. Hands-on activities that involve the use of various materials are native to the Arts and STEM areas fostering development of problem-solving skills and creativity in students (Cornett, 2015; Carabine, 2013; Cunningham, 2009). The creative design process is another major similarity between engineering and Arts (Bequette & Bequette, 2012).

Interdisciplinary approaches to teaching have been shown to improve student problem-solving and creativity skills (Boix Mansilla, Miller, Gardner, 2000). This is one of the reasons why STEAM (Science, Technology, Engineering, Arts, and Mathematics) education is so successful in developing creativity across multiple disciplines (Wynn & Harris, 2012).

According to Clarke and Cripps (2012, p. 114), who analyzed multiple definitions of creativity and generated a definition reflecting most common features of all, creativity is "… a transformative process of knowing, thinking and doing that embodies elements such as risk taking, envisaging, engaging, persisting, observing, experimenting, attending to relationships, taking a benign attitude to error and critically reflecting." This definition includes skills and qualities that are developed and considered valuable in all the STEM and Arts areas.

The list of features of the creative process by Robert and Michele Root-Bernstein (1999) includes components that are also part of the scientific method and of artistic inquiry, a problem-solving process that is the foundation of all the Arts (Cornett, 2015). This shared core of all STEM and Arts subjects supports the notion that creativity is an interdisciplinary concept best developed in an interdisciplinary setting, such as STEAM (Root-Bernstein & Root-Bernstein, 1999). Table 1 includes a comparison of the Creative process components (Cornett, 2015) and related artistic and scientific method steps (Bequette & Bequette, 2012).

Table 1. *Comparison of the Creative process components, Artistic, and Scientific methods' steps*

Creative Process Components Root-Bernstein & Root-Bernstein's (1999) model	Scientific Method Component	Artistic Inquiry
Observing Imagining (creation of mental images) Abstracting (selecting the core/most essential features) Recognizing patterns (observation and analysis)	Problem finding Asking questions and gathering additional information Hypothesizing Conducting observations	Gathering data
Forming Patterns (combining and re-combining the essential elements) Analogizing (finding associations with things that are unrelated) Body thinking (using an innate intelligence of the body to address the problem) Empathizing (adopting the view of the subject/object under study to get an "insider perspective") Dimensional Thinking (changing dimensions of the object) Playing (exploring, learning without constraints, building new understanding)	Experimenting	Experimenting Creating multiple drafts
Modeling (involves using information from observations, selecting the most important features, rescaling, and giving form: physical/mathematical/artistic/verbal) Transforming (transformation of ideas from one domain to another e.g. a novel is transformed into a movie)	Data analysis, possible revision and editing of the hypothesis Reproduction of the experiment	Revision and editing drafts
Synthesizing (final product, culmination of all previous steps; harmonious unity of the results pf previous steps)	Sharing findings/conclusions; confirming and/or rejecting the hypothesis	Sharing or demonstration

STEAM is one of the effective paradigms that involves strong and frequent interdisciplinary connections between subjects for the purpose of creativity development (Mishra, Henriksen, and Deep-Play Research group, 2012). The STEAM approach to teaching also provides strong content knowledge in the areas of science, technology, engineering and mathematics. At the same time, deep content knowledge of a discipline in which the creative process is happening is another major component of effective creativity development (Mishra et al., 2012; Roberts, 2015). During STEAM lessons, thorough learning of content occurs if one of the main principles of Arts integration is applied. This principle is called teaching "through the Arts" (Cornett, 2015), i.e. Arts are used as a tool to teach other subjects, not as an end goal. Results of a study by Jacobson, Seavey, and Mueller (2016) demonstrated a positive effect of integrated Arts and a climate change science project on creative thinking among students. Similar results were obtained by Kaimal, Drescher, Fairbank, Gonzaga, and White (2014). All research and practical articles in this issue describe projects that focus on development of student creativity through integration of the Arts with STEM subjects.

How Projects described in the Articles of this Issue are Fostering Creativity

This issue of the *Journal* is analyzed for student creativity development through arts integration with one or more STEM subjects. All practical and research articles describe STEM and Arts- integrated projects that can be instrumental in developing creativity in students. The following section includes summaries of three practical articles and benefits of the projects described in these articles in regards to creativity development and STEM education; integration of arts and crafts with STEM and other subjects is also highlighted.

Practical Articles

The practical articles included in this issue present three arts-integrated projects that were conducted in school and university settings. These projects can be instrumental in teaching STEM content and develop student creativity. The activities and learning tools employed in these projects engage all creative process components (See Table 1). Authors of the articles provide a detailed description of the projects, their benefits for creativity development as well as STEM subject areas based on a thorough analysis of the project implementation experience and student results.

Practical Art Projects Related to Children's Picture Books about Ecology (Hageman, Martin, Montgomery, & Rule, 2019). It has been established that arts integration is beneficial for student academic success; it even improves standardized test scores (Deasy & Stephenson, 2005). However, arts integration is not a magic wand; it needs to be meaningful and purposeful. Teachers need to think critically when selecting arts-integrated activities to achieve the best results. This article presents high-quality art projects that are intended to improve literature-based science instruction. Hageman et al. (2019) also present the analysis of teacher observations, student works, and student attitudinal survey. Results demonstrated a positive impact of the arts-integrated activities on student scientific knowledge, a deepened understanding of the interconnectedness of all components of nature, including humans, and an awareness of student personal roles in protecting nature. Students were highly motivated and engaged during the lessons in part thanks to the outlet for creativity provided by integration of the Arts. Participants of this study included a diverse group of elementary students. One of them was an English Language Learner (ELL). The number of ELLs in American schools is constantly increasing (National Center for Education Statistics, 2017), which makes arts-integrated activities and approaches even more important for teachers because arts integration has been shown to be an effective approach to teaching ELLs (Casey, Mireles, & Viloria, 2018). The ELL participant of this study demonstrated similar results to the non-ELL participants, which further supports the notion of effectiveness of arts integration.

Activities in this study met several Next Generation Science Standards (NGSS) and Common Core Literacy Standards. Furthermore, all creative process components were included in arts-integrated activities in this study. The study results demonstrate that participants not only gained academic knowledge and improved their motivation to learn science, but had an opportunity to and were encouraged to creatively express themselves and the newly gained knowledge. These opportunities for creative expression are vital for development and sustaining student creativity (Koster, 2012). The arts-integrated projects in the study of Hageman et al. (2019) also fostered creative use of materials by the participants to demonstrate their learning. For example, after listening to the book *One Well: The Story of Water on Earth* (Strauss, 2007), participants engaged in creating a three-dimensional artwork demonstrating the impact of pollution on the seas and sea inhabitants (See Figure 1).

Figure 1. Water pollution project. This completed project demonstrates the following creative strengths: movement or action, elaboration, and artistic richness and sensory appeal (Hageman et al., 2019, Figure 32)

Slime Bash Social: A Tactile Manipulative for Child and Youth Play (Levingston, Adebiyi, Hadley, Al-Hassan, Back, Cook, & Edginton, 2019). This article is devoted to the multiple beneficial ways slime may be used as a learning tool. The authors describe the experience of using slime in teaching STEM concepts to elementary and middle school students in "Slime Bash Social" event conducted by the University of Northern Iowa's Institute for Youth Leaders. They also provide a review of other program examples that successfully use slime-based or similar activities in the STEM and arts-integrated setting with the effects of those on student creativity.

Slime, due to its unusual physical properties, can be used to simultaneously develop student creativity through play and teach STEM subjects through hands-on, active process of problem solving by doing. For example, the mere process of creating slime involves learning about the physical properties of various materials (science) and measuring different components (mathematics). Multiple other benefits of using this learning tool to teach and to develop creativity exist. For instance, such tactile manipulatives offer a wide range of opportunities for experimenting and play, which are both conducive to creativity development and constitute components of the creative process, scientific method, and artistic inquiry (See Table 1). Moreover, after analyzing several programs employing slime-based activities, the authors discovered that these activities can be used to meet STEM and Art Standards.

During the "Slime Bash Social" program, over a hundred participants between the ages of 7 and 15 were involved in an engaging sequence of organized creative play activities resulting in a creative artistic performance for parents. Slime-based activities were implemented more than any other activities during this program and helped meet different goals, such as developing leadership skills, learning science concepts (e.g. experimenting with slime ingredients and following steps of creating slime outlined in recipes), and developing creativity during an arts-integrated activity involving slime. The participants exhibited high levels of joy and enthusiasm when participating in this program and gave many unsolicited positive comments. Based on the program analysis, the authors of this article concluded that such programs in general, and slime-based or similar activities in particular, can be instrumental for engaging school students in learning through experimenting and, consequently, ignite their curiosity and desire to learn more. The photograph below shows students enjoying the learning process through experimentation with slime and its components (see Figure 2).

Figure 2. Participants experimenting and playing with slime ingredients while applying the new knowledge regarding physical properties of matter (Levingston et al., 2019, Figure 8)

Ocean Underwater Scene Dioramas of First Graders with Submarine Porthole Views (Zhbanova, Rule, & Tallakson, 2019). This article is devoted to the topic of ecology education and describes an arts-integrated project that can be used to teach about ocean reef life while simultaneously developing student creativity. The Arts and crafts are often neglected in our schools (Spohn, 2008) although they have been proven to have a positive impact on student academics and creativity (Lee et al., 2012; Isbell & Raines, 2012). Other countries, such as Finland, that utilize arts and crafts in public more extensively, are not only ranked best regarding the overall quality of education (World Top 20 Project, 2019), but reap the benefits of art-based environmental education. Finland is currently taking one of the top positions regarding environmental conditions in the country (Yale Center for Environmental Law and Policy, 2018).

Zhbanova et al. (2019) illuminate the importance of craft activities for students, include an analysis of the skills applicable and desired in other subjects, and in development of student creativity. This article also provides a reasoning behind environmental education at schools and offers an effective way to integrate ecology education and crafts through making dioramas.

This project was conducted with first graders; however, it can also be successfully implemented in older grades with minor adjustments to the level of complexity of the information. As first graders were learning about coral reefs, their inhabitants and relationships between components of this ecosystem, they were integrating the new knowledge into their previous knowledge base through creating a diorama. This arts-integrated project is a wonderful example of the use of craft and dioramas as an effective educational tool with all benefits, such as improvement of spatial skills (Uttal & Kohen, 2012), development of critical thinking skills and inquiry (Tunnicliffe & Scheersoi, 2010), development of creativity (Klein, Gray, Zhbanova, & Rule, 2015) to name a few.

Dioramas constitute an artform (Metzler, 2007). The process of creation of a diorama involves all creative process components from observing to synthesizing. Student works displayed not only a thorough understanding of such science concepts as food chain and interconnectedness of all components of an ecosystem, but creative characteristics such as elaboration, artistic richness and sensory appeal, unusual visualization, and others (Torrance, Ball, & Safter, 1992). Figure 3 provides examples of student works that possess these creative traits.

Figure 3. Creative characteristics in student dioramas. Photo on the left is an example of unusual visualization through creative use of materials (bottle cap, fuzzy ball, and paints); Photo on the right represents artistic richness and sensory appeal (Zhbanova et al., 2019, Figure 2.

Research Articles

Three research articles in this issue focus on science and arts integration. An added benefit of this integration and the projects described in these articles was heightened level of creativity of student works.

A Content Analysis of Thirty Children's Picture Books about Ecology (Martín, Hageman, Montgomery, & Rule, 2019). The first study is a content analysis of 30 ecology-themed bilingual picture books. Martín et al. (2019) examined these books according to several criteria such as realistic ecology problem, appropriate illustrations, and others. The researchers concluded that most of these picture books are an effective tool for raising children's awareness of ecological issues. A companion-article in the practical section of this issue includes arts-integrated activities used with the books from the current article that resulted in highly-creative student products.

Books were used in teaching for ages; after the benefits of interdisciplinary teaching were discovered, the popularity of literature-based lessons began to grow. The current article includes a thorough analysis of thirty ecology-related children's picture books for science lessons in both English and Spanish. This book analysis is accompanied by examples of art projects to use with these books that are included in a practical article Practical Art Projects Related to Children's Picture Books about Ecology by Hageman et al. (2019). This article addresses the issue of lack of high-quality peer-reviewed articles connecting the NGSS with literature and provide practical information that can be used by teachers right away. Another issue that this article in combination with the practical companion article in this issue addresses is involuntary marginalization of the topic of ecology by teachers that stems from the lack of instructional time and large volume of content. Subject integration has long been recognized as an effective educational tool that helps teachers optimize the use of instructional time and meet standards from different content areas (Jacobs, 1989).

Information on several aspects of the book analysis by Martín et al. (2019), (e.g. realistic ecology problem, differing perspectives, imagining, reflection and responsibility, and appropriate illustrations) can be used by teachers to determine the book value in regards to creativity development. Creativity is developed through problem-solving, asking questions, evaluation of ideas, and others (Stylianidou et al., 2018). Not only problem solving but problem-finding skill is related to creativity development (Craft, 2002). An ecology-themed book can serve as a model for problem-finding and problem-solving processes and help students learn to detect and solve other ecology-related problems (creative process component – observing; creative process component – analogizing (finding associations with things that are unrelated)). Literature fosters use of imagination and abstract thinking because when listening or reading a book, students are not physically relocated to an ocean bank but are experiencing it vicariously (Martín et al., 2019) (creative process component – imagining (creation of mental images)). A book that offers a different perspective on the issue can help students see how the same situation can be perceived differently by different parties (creative process component - empathizing (adopting the view of the subject/object under study to get an "insider perspective")). Good books foster reflection. Based on the new information from books on ecology and their own thoughts and feelings, students can produce a new idea to improve ecological situation and realize their personal role in solving an ecological problem (creative process component - synthesizing (final product, culmination of all previous steps; harmonious unity of the results of previous steps).

Book illustrations can be a valuable component for creating an arts-saturated classroom environment, which is conducive to developing creativity in students (Fazylova & Rusol, 2016). An example of a final product created by an elementary student based on the book *Nuestro Planeta en Peligro/Our Planet in Danger* (Grant, 2008) is included in Figure 4.

Figure 4. Student with his diorama of the Amazon Rainforest. Unusual visualization, attention to detail and elaboration (Hageman et al., 2019, Figure 8)

Exploring Preservice Teachers' Still-Life Paintings of Crystals with Artist-Focused Compared to Science-Focused Introductions (Hussain, Stoycheva, Rule, & Tallakson, 2019). This research article is an experimental study focused on the effects of science and arts integration on student creativity and retention of scientific details. Both science and the arts improve student creativity (Wynn & Harris, 2012). This research article investigated the potential for creativity development and increase of frequency of incorporation of scientific details by the means of integrating science into the arts. This quasi-experimental pretest-posttest- study included two conditions: a lesson conducted with a science-focused lesson introduction compared to a lesson conducted with an art-focused lesson introduction. The study involved two basically equivalent groups of preservice teachers. Participants of the arts-focused group studied famous artists and their works depicting crystals. Those in science-focused group studied the scientific paintings with information about geology and features of crystals. Both groups received instruction on the use of gouache, a water-based paint that was used to create still-life paintings of crystals. Student works were assessed using a rubric. The assessment concentrated on the strength of creative traits and frequency of inclusion of science information.

The activity that participants of this study were involved in addressed three National Core Art Standards and three Next Generation Science Standards. The lesson included all creative process components in both conditions. When completing homework, participants viewed several videos about using gouache. During the lesson introduction, participants watched a power point presentation about artists who painted crystals or a science-focused informational presentation with realistic paintings of crystals, depending upon the condition. During this part of the experiment, participants completed the following components: imagining, abstracting, and pattern recognition. At the beginning of class, when condition-appropriate information was reviewed, the participants worked on forming patterns, analogizing, and empathizing. During the work time in class, when students were engaged in painting crystals, they completed the following creative process components: body thinking, dimensional thinking, modeling, playing, transforming, and synthesizing. Figure 5 includes an example of a student-made painting that was created during the synthesizing creative process component.

Results of the study demonstrated the benefits of science integration for both groups of participants. The benefits included an increase in creativity in the arts-focused group, and an improved understanding of science concepts in the science-focused condition. Participants in both groups reported an increase in the level of motivation and joy due to the pleasure of self-expression in both conditions. These results further validate the notion that arts and STEM subjects foster creativity development and integration of these subjects with each other is beneficial for students' creativity and academic development.

Figure 5. A student envisioned the crystal specimen as a boat in a sea, which demonstrates such creative traits as breaking boundaries, movement, and parody (Hussain et al., 2019, Figure 2)

Fossil Mobiles: Exploring the Process of Art as Science Inquiry for Elementary Students through a Grounded Theory Study (Teske, Clausen, Parpucu, Gray, & Rule, 2019). The last research article represents the grounded theory of how artmaking stimulates geoscience inquiry. This article also illuminates the influence of arts and science integration on student creativity. Both arts and STEM subjects develop creativity, inquiry (Stylianidou et al., 2018) and enhance the positive effects of each other (Wynn & Harris, 2012). Moreover, according to Stylianidou et al. (2018), activities that develop inquiry and creativity are often the same.

In the current study by Teske et al. (2019), the researchers used grounded theory to investigate the potential of an arts-integrated activity of mobile-making for facilitation of scientific inquiry. The data were collected over a period of the five days of the children's summer camp project and analyzed using the constant comparison method that yielded nine interconnected themes or categories. These categories comprised a model illuminating connections between the categories and the influence art had on science learning and science on art learning.

Results of this study demonstrated a profound positive impact of arts-integration on science learning. Other studies also support the notion that arts integration benefits science learning (e.g. Hendrix, Eick, & Shannon, 2012; Webb & Rule, 2012). Arts learning was also enhanced by the integration with science. Similar results were achieved in the study of effects of integration of science into arts by Guyotte, Sochacka, Constantino, Kellam, and Walther (2015). In the current study, researchers also found that because the integration of the arts made the project student-centered, both art learning and science learning were enhanced.

Some other ways art enhanced science learning in the current study included motivating participants to acquire more knowledge about fossils to complete the art project, providing a positive and engaging atmosphere, improving student attention to details, enhancing the desire for deeper knowledge of fossils in order to make the artwork more realistic, among others. This arts-integrated project included numerous opportunities for self-expression and provided fertile soil for creativity because the connections between the activities and student personal experiences or preexisting knowledge were encouraged. This led to a greater student involvement and investment in holistic learning, which along with other art-influenced gains, created a cyclic reaction in which the more knowledge of the fossils the students acquired, the stronger their interest in learning about fossils became.

Science learning enhanced art through providing strong content knowledge, a necessity for creativity development (Mishra et al., 2012; Roberts, 2015). The participants learned about numerous functional details and features of fossils which constituted the scientific knowledge necessary for creating their own art-enhanced, yet realistic models of fossils. Participants retrieved ideas for making their works aesthetically appealing to the viewer and for accurate representation of the scientific learning from the newly-gained knowledge of the environment and other factors influencing fossils as well as the knowledge of details and features of the fossils' appearance. Many participants indicated that they were driven by the desire to make something creative, yet educational.

This project included all creative process components, which resulted in student works being highly-creative. Attention to detail and elaboration are two of the indicators of creativity (Schlichter & Palmer, 2002). Other creative characteristics included in student mobiles based on ideas addressed in the Torrance Test of Creative Thinking (Torrance, et al., 1992) were resistance to premature closure, i.e. participants were motivated to spend time learning about the fossils and not stop the idea-generation process prematurely, emotional expressiveness, breaking boundaries, and three-dimensional visualization. Besides, student works included unusual visualization, artistic richness and sensory appeal that are also creative characteristics recognized by Torrance (Torrance et al., 1992).

The study identified seven types of interactions between arts, science, and students, which led to the development of a model of these interactions. Results of this grounded theory study support the notion that science- and arts-integrated projects develop creativity. Another idea supported by the study results is the power of the arts to enhance science learning and vice versa. The project yielded highly-creative student products which signifies a successful implementation of arts and science integration. Figure 6 includes an example of such highly-creative student work. The horn coral includes horizontal lines that demonstrate the interior structure of the coral; same coral is also an example of sensory appeal. The lines on the edge, sides, and inside the coral represent small ribs and crevices that cover the coral. The blastoid in this mobile is an example of attention to detail and artistic richness creative traits.

Figure 6. Student-made fossil mobile example demonstrating the creative traits of internal visualization, attention to detail, artistic richness, and sensory appeal (Teske et al., 2019, Figure 2)

Conclusion

Three practical articles in this issue introduce several successful arts- and crafts- integrated STEM projects focused on age-appropriate ecology education and helping students realize how they can contribute to saving the environment. The research articles are also related to ecology education. They include a content analysis of ecology-themed bilingual books that can be used by practicing teachers as a guide for selecting a good quality book for a science lesson. Based on this analysis, authors illuminate a global issue of the lack of ecology-themed bilingual picture books. Another experimental study discovered the strong positive effects of arts-integrated science projects on student creativity and retention of scientific details. The third study resulted in development of a grounded theory of how artmaking stimulated geoscoence inquiry and creating a model of the relationships between a student, art, and science as well as their influences on each other. When analyzing the articles, the editor discovered another common added benefit of all of the projects in this editorial. The benefit constituted in high levels of student engagement in the activities and creativity of their works.

All of the articles in this issue support the premise of effectiveness of arts and crafts integration for academic knowledge of STEM subjects, inquiry and creativity development. Many of them also demonstrate the motivational power of arts- and crafts- integrated activities. The editors of the journal are encouraging teachers to utilize projects such as the ones described in this issue to address the lack of instructional time to devote to ecology education, while simultaneously providing students with an outlet for self-expression and creativity.

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