How the Arts Standards Support STEM Concepts: A Journey from STEM to STEAM

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Abstract

This issue of the *Journal of STEM Arts, Crafts, and Constructions* is focused on the effects of integrating arts with STEM areas, an important and widely-considered topic in education today. This editorial provides an overview of the current state of the arts and STEM areas integration paradigm, an analysis of the benefits of the arts integration with the STEM subjects, and an overview of the history of the arts anchor standards. Comparison and connections between the National Arts Core anchor arts standards, the scientific method, engineering design process, and the 5E learning cycle are also illuminated. Summaries of the practical and research articles of this issue, highlighting the arts standards addressed, are included in this editorial.

Key Words

STEM education, STEAM education, arts integration, National Core Art Standards, science education

Introduction

Raising the level of student competency in STEM (science, technology, engineering, and mathematics) areas has been considered the most effective approach to helping American school and university graduates become more competitive in the world job market (Colegrove, 2017). Arts education is often regarded as an important factor in the overall economic competitiveness of the country (Bequett & Bequett, 2012).

The results of longitudinal studies of four large databases from the US Department of Education and the US Department of Labor spanning 1998-2010 (Catterall, Dumias, & Hampden-Thompson, 2012) showed that students who were exposed to an abundance of art-related experiences were more likely to attend college despite the fact that 71% of the 18,000 participants were from low socioeconomic backgrounds. One of the findings of a follow up study of 25,000 American secondary school students was an outstanding positive influence of arts-rich school environments on academic success and the likelihood of obtaining a bachelor's and graduate degrees by the English language learners (Catterall, 2009).

All the arts disciplines, such as music, dance, and theater, have been shown to enhance student cognition and attention (Posner & Patione, 2010). Even having music playing in the background can help calm emotions and help students reach a more relaxed state. Certain types of music can even enhance a student's level of concentration (Jensen, 2000). All of these influences of the arts, in turn, resulted in increases of student academic performance and general well-being (Cornett, 2006).

Integration of arts with other subjects is considered one of the most effective tools for increasing student retention of content (Rinne, Gregory, Yarmolinskaya, & Hardiman, 2011). Arts integration also has a strong potential for boosting student overall academic achievement, as shown in a three-year study of 39 schools with arts-focused programs in Oklahoma (Barry, 2011). Because arts integrate so effortlessly with other subjects and foster meaningful connections with various disciplines, knowledge-bases, and skills through solving real-world problems that address important questions, arts integration becomes a key element of holistic education (Cornett, 2015).

The arts provide ample opportunities for multisensory engagement (Booth, 2013). For example, when students are creating a model of the planet Saturn, they touch and manipulate various materials while choosing the one that is sturdy and light enough to hold a round shape and allow the model to hang easily from the ceiling in the classroom. When they mix paints to match the color of the planet, they see how different colors interact and create new shades. Igniting the students' intrinsic motivation to learn is the key to their academic success. Arts education as well as activities that integrate arts are grounded in cultivating intrinsic motivation (Booth, 2013). This intrinsic motivation through arts and arts integrated classes spreads to other subjects and activities and even improves student performance on standardized tests (Deasy & Stephenson, 2005).

Arts Standards History and Organization

Arts education at schools initially occurred at the beginning of the 19th century (Stankiewicz, 2009); however, the standards movement started later in the 20th century. The Goals 2000: Educate America Act that was endorsed in 1994 and the National Standards for Arts Education released the same year are considered the starting points of the arts standards movement in the United States (State Education Agency Directors of Arts Education, 2014). The current National Core Arts Standards published by the National Coalition for Core Arts Standards in 2014 include the most valuable international principles and standards of Arts Education, and are currently being revised and updated. The standards incorporate the following disciplines: Dance, Media Arts, Music, Theatre, and Visual Arts. The Standards are organized into four major categories or processes: Creating, Performing, Responding, and Connecting. Each process includes several anchor standards. The standards are listed in Table 1 adapted from the opening web page overarching standards of the National Core Arts Standards (State Education Agency Directors of Arts Education, 2014).

How Arts Standards Support STEM Education

Over the course of history, arts, humanities, and engineering grew into separate and narrowly focused areas through deepening of the knowledge base of each discipline (Colegrove, 2017). At the end of the 20th century, a different trend of identifying connections between, by that time, very separated and specific disciplines of Science, Technology, Engineering, and Mathematics appeared and gained support of scientists and educators. Later, the strong similarities between processes used by scientists and artists, such as problem solving, inquiry, and integration of multiple solutions were also discovered, resulting in the creation of STEAM, an acronym that stands for Science, Technology, Engineering, Arts, and Mathematics (Bequett & Bequett, 2012).

Any new technological device is a combination of applied advanced knowledge and skills in the STEM disciplines and creative arts. For example, the combination of red, green, and blue pixels of electronic screens, allowing various devices to display numerous colors, is a combination of innovations in technology, engineering, science, mathematics, and artistic techniques such as pointillism (Colegrove, 2017). Among other specific skills, the arts develop the following skills applicable and desirable in other disciplines: creativity, brainstorming, divergent thinking, metaphoric thinking, flexible thinking, empathy, and multisensory engagement (Booth, 2013). Creative thinking and artistic design, not only technology, were the key factors in the successes of such accomplished people as Steve Jobs (Wynn & Harris, 2012). The need for workforce in the STEM areas significantly exceeds the number of qualified graduates (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011). Integrating arts with these subjects will improve student literacy levels in the areas of mathematics, engineering, technology, and science (Wynn & Harris, 2012).

Science and math lessons are often less interesting to students because the lessons lose the real-world applicability once they become more quantitative. This situation can be mitigated through the use of arts integration (Wynn & Harris, 2012). Using the motivational power of the arts can help students stay engaged during STEM lessons and reveal the connections between the content and the real-world in addition to making the math and science lessons less threatening, and, therefore, more enjoyable (Wynn & Harris, 2012). A study (Bieri Buschor, Berweger, Keck Frei, & Kappler, 2014) demonstrated that one of the decisive factors influencing student choice of a STEM career was positive experience in science at a young age. Another study indicated that the level of confidence of the students in their academic abilities in the STEM areas is another central factor in choosing a STEM career (Moakler & Kim, 2014). Art can help rekindle the interest in STEM disciplines of students who are more art-oriented by providing occasions to connect learning with self-expressive pleasure and by providing opportunities for all students to feel successful (Wynn & Harris, 2012).

A very important similarity between the arts and STEM disciplines is the inquiry-based learning and problem-solving at the core. Artistic processes fostering learning skills are also built-in components of the STEM disciplines. These processes include posing questions, identifying problems, experimenting, drawing conclusions based on results, risk-taking, and ongoing reflection, among others (Booth, 2013). Creative problem-solving process embedded in the arts is similar to the scientific method because both employ the following stages: gathering data, experimenting, creating multiple drafts, revising and editing drafts, and some type of sharing or demonstration (Cornett, 2006). The arts standards and related scientific method steps are listed in Table 1. The standards were adapted from the opening web page overarching standards of the National Core Arts Standards (State Education Agency Directors of Arts Education, 2014). The steps of the Engineering Design Process are very similar to the arts design process (Bequett & Bullitt Bequett, 2012). This process also strongly resembles the arts standards. Table 2 presents the connections between the National Core Arts Standards and the Engineering Design Process.

How Articles in this Issue Address the Arts Standards

This issue features three practical and three research articles. All the articles in this issue include example strategies, projects, and activities that effectively integrate arts with STEM disciplines and others, promoting deep content understanding, fostering intrinsic motivation to learn, providing real-world application of knowledge, and encouraging higher order thinking skills. All articles also address multiple arts standards, scientific method steps, the 5E learning cycle steps, and the engineering design process steps. The following section describes connections between these articles and the arts standards.

Practical Articles

This issue contains 3 practical articles. The following section describes how projects and activities involving the integration of arts standards with STEM disciplines enhanced student understanding of the STEM content and concepts, fostered positive attitude to learning, rekindled interest and joy of learning, and provided a real-life application of the student learning.

Middle Level Preservice Teachers Experience a Natural History Arts-Integrated Interdisciplinary Thematic Unit (Weber & Rule, 2017). This article focused on examining the effects of a fully-integrated thematic unit that included the integration of language arts, mathematics, science, social studies and arts on preservice middle school teachers. Educators' attitudes and perspectives have a major impact on the curriculum and instruction students are offered. The first-hand experience of preservice teachers with activities and approaches increases the likelihood of incorporating these approaches in their teaching practice (Wagler & Wagler, 2011). The fully-integrated thematic unit described in this article, according to the reports of the participants, was engaging, enjoyable, and exceptionally informative.

Table 1. *National Core Arts Standards and Related Scientific Method Steps*

Process	Explanation	Anchor Standards	Related Scientific Method Steps
Creating	Conceiving and developing new artistic ideas and work.	#1. Generate and conceptualize artistic ideas and work.	Determine the research question or hypothesis Initial observations Gather data
		#2. Organize and develop artistic ideas and work.	Look for evidence and explanations Conduct experiments
		#3. Refine and complete artistic work.	Refine hypothesis and conduct more experiments
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#4. Analyze, interpret, and select artistic work for presentation.	Write report. Creation of multiple drafts Revision and editing of the drafts
		#5. Develop and refine artistic work for presentation.	Experiments Creation of multiple drafts
		#6. Convey meaning through the presentation of artistic work.	Sharing through publication or demonstration
Responding	Understanding and evaluating how the arts convey meaning.	#7. Perceive and analyze artistic work.	Gathering ideas from reading about the work of others. Make new observations of nature
		#8. Interpret intent and meaning in artistic work.	Data interpretation Weighing the hypothesis
		#9. Apply criteria to evaluate artistic work.	Revision and editing of the drafts Peer review
Connecting	Relating artistic ideas and work with personal meaning and external context.	#10. Synthesize and relate knowledge and personal experiences to make art.	Determine the possible impacts Revise theory or hypotheses
		#11. Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.	Application of science for the public good

Table 2. *National Core Arts Standards and Related Engineering Design Process Steps.*

Process	Explanation	Anchor Standards	Engineering Design Process Steps
Creating	Conceiving and developing new artistic ideas and work.	#1. Generate and conceptualize artistic ideas and work.	Step 1 Identify the need or problem.
Creating	Conceiving and developing new artistic ideas and work.	#1. Generate and conceptualize artistic ideas and work.	Step 2 Research the need or problem. Examine the current state of the issue and current solutions. Explore other options via the Internet, library, interviews, etc.
Creating	Conceiving and developing new artistic ideas and work.	#2. Organize and develop artistic ideas and work.	Step 3 Develop possible solution(s). Brainstorm possible solutions. Draw on mathematics and science. Articulate the possible solution(s) in two and three dimensions.
Creating	Conceiving and developing new artistic ideas and work.	#3. Refine and complete artistic work.	Step 3 Develop possible solution(s). Refine the possible solution(s).
Creating	Conceiving and developing new artistic ideas and work.	#3. Refine and complete artistic work.	Step 5 Construct a prototype. Model selected solution(s) in two and three dimensions.
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#4. Analyze, interpret, and select artistic work for presentation.	Step 4 Select the best possible Solution(s). Determine which solution(s) best meet(s) the original need or solve(s) the original problem.
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#4. Analyze, interpret, and select artistic work for presentation.	Step 6 Test and Evaluate the Solution(s). Does it work? Does it meet the original design constraints?
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#5. Develop and refine artistic work for presentation.	Step 6 Test and Evaluate the Solution(s). Does it work? Does it meet the original design constraints?
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#5. Develop and refine artistic work for presentation.	Step 8 Redesign. Overhaul the solutions based on information gathered during the tests and presentation.
Performing Presenting Producing	Performing (dance, music, theatre): Realizing artistic ideas and work through interpretation and presentation. Presenting (visual arts): Interpreting and sharing artistic work. Producing (media arts): Realizing and presenting artistic ideas and work.	#6. Convey meaning through the presentation of artistic work.	Step 7 Communicate the Solution(s). Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the initial need or the problem.
Responding	Understanding and evaluating how the arts convey meaning.	#7. Perceive and analyze artistic work.	Step 2 Research the need or problem. Examine the current state of the issue and current solutions. Explore other options via the Internet, library, interviews, etc.
Responding	Understanding and evaluating how the arts convey meaning.	#8. Interpret intent and meaning in artistic work.	Step 6 Test and Evaluate the Solution(s). Does it work? Does it meet the original design constraints?
Responding	Understanding and evaluating how the arts convey meaning.	#9. Apply criteria to evaluate artistic work.	Step 6 Test and Evaluate the Solution(s). Does it work? Does it meet the original design constraints?
Connecting	Relating artistic ideas and work with personal meaning and external context.	#10. Synthesize and relate knowledge and personal experiences to make art.	Step 7 Communicate the Solution(s). Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the initial need or the problem. Discuss societal impact and tradeoffs of the solution(s).
Connecting	Relating artistic ideas and work with personal meaning and external context.	#11. Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.	Step 8 Redesign. Overhaul the solutions based on information gathered during the tests and presentation.
Connecting	Relating artistic ideas and work with personal meaning and external context.	#11. Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.	Step 7 Communicate the Solution(s). Discuss societal impact and tradeoffs of the solution(s).

In this middle-level integrated unit, concentrated on natural history and the use of stone tools during the Paleoindian period, the preservice teachers participated in activities that integrated art with four core curriculum areas. Among other language arts and arts integration activities, they engaged in generating descriptive adjectives related to paintings of natural agates they had previously created. The agate paintings featured concentric banding or other characteristics of agates discovered when learning about glacial transport and the volcanic, hot water metamorphism, and agatization processes in the source areas for the glacially-transported materials (rocks and stone tools) they were examining. See Figure 1 for example paintings. In science and art integrated activities, the participants used acrylic polymer clay to create keyring fobs that resembled the concentric, mottled, or crosscut patterns of agates present in the glacial deposits and source area.

In the mathematics and arts integration part of the unit, preservice teachers solved stone tool puzzles by graphing points on a coordinate plane. During the social studies and arts integration portion of the unit, the students examined, classified, and sketched scientific drawings of the stone tools. Finally, an example of an activity that students completed connecting arts and social studies was sorting and tool identification activity. The participants learned about the relationships between the shape of the tools and the use of the tools by people during the Paleoindian period. The participants reported a high level of satisfaction with the activities in the unit; they also indicated that during the unit, they felt they have learned the content and acquired important pedagogical knowledge regarding arts integration. This positive experience may increase the likelihood of the preservice teachers using arts integration in their future work with students.

Figure 1. Agate Paintings showing concentric banding

Cinematherapy in Gifted Education Identity Development: Integrating the Arts through STEM-Themed Movies (Kangas, Cook, & Rule, 2017). This article focuses on the unique and often underserved population of gifted and talented students. The common issue of unmet emotional, social, and affective needs of the students in addition to their advanced academic needs in the areas of STEM are discussed. Cinematography, as one of the forms of the arts, possesses almost limitless possibilities as an educational tool, means of communication, and an instrument that allows the students to create personal meaning.

While viewing a film, students may identify with or find themselves opposed to a character's values, thoughts, and beliefs; and therefore, reach a deeper level of self-understanding (Jones, 1999). One of the main concepts of this study is cinematherapy, an idea parallel to bibliotherapy, except that movies, rather than books are employed. The authors offered a group of identified gifted and talented students a chance to explore and better understand their gifts along with becoming more accepting of themselves through discussion of the challenges and actions of gifted and talented characters in films. This project presented an opportunity for the students to develop their identities as well as realize that there are other likeminded people portrayed in films.

This article included a much greater degree of arts integration than mere viewing of the movies. The participants were involved in arts-based inquiry and critical thinking as they used images related to the themes of the movies to express their ideas about their own identity development. The projects that were developed were personal because all parts of their identities (emotional, physical, and intellectual) were examined in creating these projects. The students were involved in a rigorous inquiry-based learning while analyzing and discussing the characters in the movies, selecting ideas that resonated with them, and generating artistic ways of representing the chosen ideas in an electronically-produced artwork reminiscent of the iconic screen-prints of famous artist Andy Warhol. All steps of the engineering design process, the scientific method steps, and arts anchor standards were addressed in this project. At the culmination of the project, the students created identity statements that included the insights of the participants into their identity in regards to being gifted as a result of comparison to film characters. An example artwork is shown in Figure 2.

Figure 2. Example artwork in the style of Andy Warhol displaying identity elements of a gifted student.

Examining Natural Selection by Sketching and Making Models of the Finches of the Galapagos Islands (Pittman & Teske, 2017). This article describes a project that combined rigorous science learning and the joy of creating artsy models. Through a hands-on activity that involved a variety of media, the students explored such concepts as genetic traits and their influence on the likelihood of survival of the spices. During the lesson, the students investigated the topic of natural selection in relation to finches of the Galapagos Islands. While completing this project, the participants completed all phases of the 5 E's learning cycle. This model is strongly rooted in inquiry-based scientific learning and teaching (Renner & Lawson, 1973). This lesson format is particularly effective for improving student understanding of the laws of nature and the STEM disciplines (Krall, Straley, Shafer, & Osborn, 2009). Table 3 represents the connections between the arts standards, the phases of the 5 E learning cycle, and scientific method steps. The information about the phases of 5 E learning cycle was adopted from a study by Piyayodilokchai, Panjaburee, Laosinchai, Ketpichainarong, and Ruenwongsa (2013). This project addressed all of the anchor arts standards. Students' understandings of the connections between the environmental pressures and changes in genetically controlled attributes, such as the size and shape of the finches' beaks, were addressed in this lesson. The students also demonstrated a significant increase in knowledge and understanding of the birds' habitats and diets during the evaluation phase. Student bird beak products are shown in Figure 3.

Figure 3. Examples of student bird beak products.

Table 3. *National Core Arts Standards and Related 5 E Learning Cycle Phases.*

Process	5 E Learning Cycle Phases	Anchor Standards	Related Scientific Method Steps
Creating	*Engagement Phase* (E1) Activation of the student prior knowledge, making connections to the present knowledge, organizing thoughts about the goals of present learning. *Exploration Phase* (E2) application of the prior and new knowledge, generating new ideas, exploring possibilities, comparing ideas, and initial investigation.	#1. Generate and conceptualize artistic ideas and work.	Determine the research question or hypothesis; Initial observations Gather data
		#2. Organize and develop artistic ideas and work.	Look for evidence and explanations Conduct experiments
		#3. Refine and complete artistic work.	Refine hypothesis and conduct more experiments
Performing Presenting Producing	*Explanation* (E3) focusing on a specific aspect of the exploration, demonstration of understanding, skills, and behaviors, deepening of the conceptual understanding.	#4. Analyze, interpret, and select artistic work for presentation.	Write report. Create multiple drafts Revision and editing of the drafts
		#5. Develop and refine artistic work for presentation.	Experiments Creating multiple drafts
		#6. Convey meaning through the presentation of artistic work.	Sharing through publication or demonstration
Responding	*Elaboration* (E4) extending the learning, deepening and broadening of the understanding through application of the learning, inferences, and hypotheses to various situations. Acquiring additional information.	#7. Perceive and analyze artistic work.	Gathering ideas from reading about the work of others. Make new observations of nature
		#8. Interpret intent and meaning in artistic work.	Data interpretation Weighing the hypothesis
		#9. Apply criteria to evaluate artistic work.	Revision and editing of the drafts Peer review
Connecting	*Evaluation* (E5) assessment of student understanding, progress, and learning	#10. Synthesize and relate knowledge and personal experiences to make art.	Determine the possible impacts Revise theory or hypotheses
		#11. Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.	Application of science for the public good

Research Articles

This issue includes three research articles that describe counterbalanced pretest-posttest repeated measures studies. These investigations present the effects of three projects integrating the STEM disciplines with arts on student STEM knowledge, understanding, and skills as well as on the levels of enjoyment, engagement, and creativity. These studies involved participants from the elementary and middle school levels, and offer possible solutions to the pressing need of the schools to prepare students for an ever more challenging life and work in the 21st century. In their future lives, students will employ critical thinking, creative thinking, problem solving and other skills, along with engagement and intrinsic motivation to be a life-long learner.

Reading Nonfiction Science Literature with and without Arts Integration (McCartney, Mochal, Boyd, Rule, & Montgomery, 2017). The first research article in this issue is focused on investigating the effects of arts integration on comprehension and information retention of nonfiction science-related texts, level of engagement of elementary students during reading, and the student attitudes toward arts integration. In this pretest-posttest-distal posttest counterbalanced research study, the students worked with a new nonfiction science book weekly. Various arts integrated projects concluded the student work with every book when students were in the experimental arts-integrated condition. Figure 4 shows a word art picture that a student created with the text-related vocabulary. The arts-integrated projects varied from creating posters, flip books, to dramatizing ideas through skits and creating landform models. All these projects involved multiple arts standards.

The following standards were addressed in the majority of the projects:

- Standard #1 Generate and conceptualize artistic ideas and work.
- Standard #2 Organize and develop artistic ideas and work.
- Standard #3 Refine and complete artistic work.
- Standard #5 Develop and refine artistic work for presentation.
- Standard #6 Convey meaning through the presentation of artistic work.
- Standard #8 Interpret intent and meaning in artistic work.
- Standard #10 Synthesize and relate knowledge and personal experiences to make art.

The implementation of standards in these lessons were accompanied by the corresponding scientific method steps and engineering design process steps (see Table 1 and Table 2). The study results indicated that, although participants retained content knowledge in both conditions at approximately the same level, the learning of the fifth-grade students was significantly enhanced by the arts-integrated instruction. Arts integration also positively impacted the student level of engagement and enjoyment of the literacy lessons with science content.

Figure 4. Volcano image made with text-related vocabulary

Challenging Elementary Learners with Programmable Robots during Free Play and Direct Instruction (McCoy-Parker, Paull, Rule, & Montgomery, 2017). The innovative and technologically advanced project described in the article involved fifth and first-grade students in programming robots. The study measured not only students' technical skills, but their creative skills. Today, the importance of developing creative skills in students as early as elementary school for the future job success as well as for the benefit of the nation can't be underestimated (Luna Scott, 2015). The students in the current project alternated between the experimental and control conditions. The control condition included more direct instruction and focus on coding skills, while the experimental condition concentrated on giving the students ownership of their learning through letting the participants challenge themselves with robot coding. Curriculum comprised of a combination of inquiry-based and collaborative activities, blended with some direct instruction is considered to be the most beneficial for the development of the 21st century skills such as creativity (Luna Scott, 2015). The results of the robot-coding study presented in this article demonstrated the benefit of the experimental condition for the development of creative and problem-solving skills as well as a positive effect of the experimental condition on the student attitude and greater overall learning. However, the control condition caused increased technical performance scores. The attitudes of the first graders in the study were consistently positive and joyful regardless of the condition, while fifth graders demonstrated higher creativity scores during experimental condition lessons in which they were challenged through inquiry-based learning.

This study had multiple connections to arts-based learning and arts standards as well as to the engineering design process steps and the scientific method steps. The students in the study were given an opportunity to personalize their work, add emotions and humor, and, depending on the grade level, work on creative performances, such as a comedy show, a two-act play, and other fantasy-based presentations. The activities of the experimental condition encouraged students to choose and create challenges with the goal of generating a creative and exhilarating idea for a robot performance, a title for it, and the coding of the robot to enact it. See Figure 5 for the example fifth graders' robot performance of a robot fashion show with a runway for the robot models. Students experienced all the stages of the engineering design process and the scientific method steps.

The following arts standards were the major arts standards addressed in the experimental condition of this study:

- Standard #1 Generate and conceptualize artistic ideas and work.
- Standard #2 Organize and develop artistic ideas and work.
- Standard #3 Refine and complete artistic work.
- Standard #4 Analyze, interpret, and select artistic work for presentation.
- Standard #5 Develop and refine artistic work for presentation.
- Standard #6 Convey meaning through presentation of artistic work.
- Standard #9 Apply criteria to evaluate artistic work.
- Standard #10 Synthesize and relate knowledge and personal experiences to make art.
- Standard #11 Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.

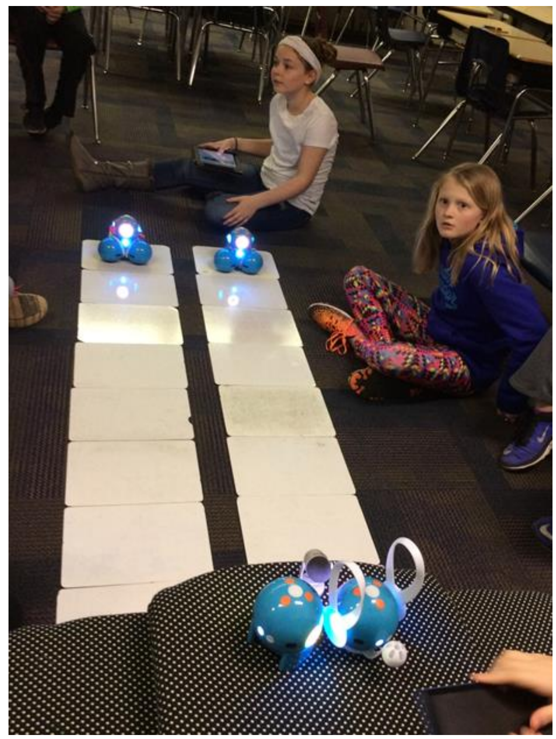

Figure 5. Robots programmed to enact a robot fashion show.

Fifth Graders' Creativity in Inventions with and without Creative Articulation Instruction (Kress & Rule, 2017). This article describes the effects of a multifaceted science and arts integrated project in which fifth grade students were challenged to create an invention for a particular audience while taking into consideration the materials available, time limit, and other constraints. The level of creativity of the product and on the level of sophistication of the creative articulation provided by the students were measured. The participants were learning about animal adaptation strategies and applying the new knowledge while using a set of given craft and recycled materials to create an object or a scene that demonstrated their creative skills and understanding of the concept of adaptation. See Figure 6. The students were also challenged to identify and creatively articulate the creative characteristics of their products. This project addressed the Next Generation Science Engineering Process Standard 3-5-ETS1-2: Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem.

The project also included the following scientific method steps and corresponding anchor arts standards. The participants determined the characteristics of a creative product by analyzing and discussing images of various creative products (Gathering ideas from reading about the work of others. Gather data. Standard #7 Perceive and analyze artistic work. Standard #1 Generate and conceptualize artistic ideas and work). Then, the students were presented with a problem (Determine the research question or hypothesis. Standard #1 Generate and conceptualize artistic ideas and work.). The participants experimented with a set of given materials (Conduct experiments. Data interpretation. Standard #2 Organize and develop artistic ideas and work. Standard #8 Interpret intent and meaning in artistic work.). The students shared their inventions with peers (Peer review. Standard #9 Apply criteria to evaluate artistic work.); received feedback and modified their inventions (Revision and editing of the drafts. Standard #9 Apply criteria to evaluate artistic work.), and created an advertisement of their products that demonstrated their creativity (Determine the possible impacts. Application of science for the public good. Sharing through publication or demonstration. Standard #10 Synthesize and relate knowledge and personal experiences to make art. Standard #11 Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.).

The results of this counterbalanced repeated measures research study supported the notion that challenging real-world applicable, and complex arts-integrated activities help students develop the skills of creativity and creative articulation. The challenge presented by this complex project caused the participants to be fully engaged in the process of creation and problem-solving, which resulted in an increased levels of pleasure and satisfaction with the process itself and reaching the mental state of flow. This state is critical for evoking and sustaining the intrinsic motivation in students (Csikszentmihalyi, 1990). Another advantage of the experimental condition comprised of multiple opportunities to collaborate and receive peer feedback, which resulted in better-quality of the ideas and products.

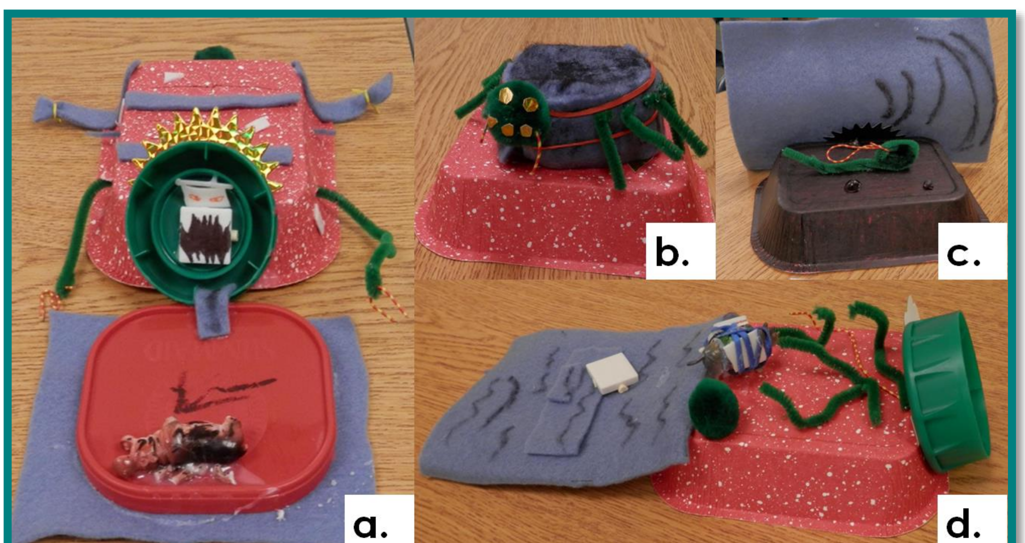

Figure 6. Example student creations made during the experimental condition

Conclusion

Arts integration is a powerful curriculum strategy that can provide multiple, significant benefits when combined with a subject. The arts increase student motivation to learn and produce good-quality work, the arts provide an opportunity to connect and apply learning to real-life problems and situations. Arts engage multiple senses; hence, increasing the level of concentration while providing additional joy and pleasure of creating and unleashing innate creativity which is a necessary skill for a success in the workplace in the 21st century. Integration of the arts can improve student academic achievement in other subjects and on standardized tests. The effects of arts integration can be profound and long-lasting, extending as far as the likelihood of pursuing a graduate degree. The integration of the arts with other subjects is organic and almost effortless, thanks to the versatile nature of the arts and to the natural connections between the arts and the real world. The integration of the arts with STEM areas is particularly compatible due to the inquiry-based nature of the STEM subjects and the arts. The steps of the scientific method, which constitute the foundation of the STEM areas, highly resemble the inquiry-based approach used in all areas of the arts. The scientific method matches the arts processes and the anchor arts standards. Each of the anchor arts standards has corresponding steps in the engineering design process and 5 E learning cycle.

Because of the complex nature of arts-integrated projects, there were many arts standards addressed in the articles of this issue; some projects addressed all of the arts anchor standards. The standards most frequently used in this issue included the following:

- Standard #1 Generate and conceptualize artistic ideas and work;
- Standard #3 Refine and complete artistic work;
- Standard #4 Analyze, interpret, and select artistic work for presentation;
- Standard #6 Convey meaning through presentation of artistic work;
- Standard #7 Perceive and analyze artistic work; and
- Standard #11 Relate artistic ideas and works with societal, cultural and historical context to deepen understanding.

These standards have the most resemblance with the scientific method steps, and therefore, occurred commonly in the arts-integrated STEM projects.

The integration of the anchor arts standards and the STEM disciplines allows the development of students' critical thinking and problem-solving skills, while highlighting interdisciplinary and real-world connections through building student knowledge and understanding of concepts central to learning in-general and subject-specific concepts and ideas. Integration of the arts standards with STEM subjects permitted students to learn through applying their preexisting and newly-acquired knowledge to the real-life problems and issues, which is vital for success in the 21st century job market. Anchor arts standards also provided a fertile ground for the student creativity skill development, which is another highly desirable skill for any future employee. Another conclusion that can be drawn from the results of the majority of the projects described in this issue is that integrating arts with STEM subjects made the learning process more joyful for the students. The projects that resulted from integration of the STEM subjects with the arts provided an increased level of challenge and complexity, which helped develop student critical and creative thinking skills. The outcomes of STEM and arts integration included vigorous learning alongside a pleasurable experience.

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