Using Creativity from Art and Engineering to Engage Students in Science

Mason Kuhn, Scott Greenhalgh
University of Northern Iowa
and
Mark McDermott
The University of Iowa

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Abstract

STEAM education, referring to integrated Science, Technology, Engineering, Art, and Mathematics, is a contemporary buzzword that is popular in many schools. In particular, many elementary school teachers who have been tasked to incorporate STEM teaching, because of the requirements of the Next Generation Science Standards, attempt to apply the arts in their science curriculum because they feel more comfortable using instructional approaches that incorporate creative activities such as crafts, drawing, and model construction than the core practices of STEM disciplines. Teachers can use the creative arts activities in two ways to enhance the STEM learning environment: 1) Using creative processes as a way to gain access to students' ideas before science content is taught, to help guide further instruction; and 2) Using creativity as a means for students to express their understanding of science content. In this editorial, we explore how the arts can help students generate "Big Ideas" about science, construct questions, and share their understanding of the topic with authentic audiences. We will also discuss the scope and nature of discipline of specific STEM fields and how the arts could be incorporated into these practices.

Key Words

Arts-integration, STEM education, STEAM education, Creativity, Conceptual Change

Introduction

Science can be challenging for children to understand. In particular, it is difficult for children to change, through observation, the misconceptions and beliefs that they have developed, even when presented with concrete scientific evidence (Hewson & Hewson, 1984). For example, a heliocentric model of our solar system was first introduced in the late 16th century, yet a recent poll conducted by the National Science Foundation (NSF; 2014), found that one out of four Americans think that the Sun revolves around the Earth. With so many issues of the 21st Century being science and STEM based (i.e., climate change, sustainability, biotechnologies, food additives, health-care choices) it is imperative that teachers focus on creating a scientifically and STEM- literate public through teaching practices that engage students in thinking critically about science. This editorial focuses on ways teachers can use creative aspects of art, technology, and engineering design as an instructional practice to gain access to student ideas, and to allow students to creatively express their learning, while simultaneously strengthening students' conceptual understandings of science and STEM subjects.

How Creativity Fits in STEM

STEM education has been described as:

> An interdisciplinary approach to learning where challenging academic concepts are joined with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Gerlach, 2012, para. 2).

Educators have begun to look specifically at the integrative nature of STEM and STEM instruction. Wells described *integrative* STEM, apart from STEM specifically as

> The application of technological/engineering-design-based approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology and engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels. The term integraTIVE (sic) implies an ongoing, dynamic, learner-centered process of teaching and learning distinct from the integraTED (sic), which connotes a static, completed teacher-centered process (Wells, 2013, p. 29).

Wells further explains that integrative STEM encourages the natural intersections with other subjects including social studies, literacy, art, and physical education. This intentional integration of engineering design and art in a student-centered learning environment is what we wish to explore through this article.

Each individual component of STEM has a distinct purpose and underlying philosophical position, and a well-designed STEM program has student activity in which natural subject intersections flow throughout the units. The nature of science involves seeking an understanding of the natural world by developing descriptions of how nature works based on sensory information (National Research Council; NRC; 2012), and is the underpinning of technology. Technology is the modification of the natural world to meet human wants and needs. Art has the ability to engage students in the humanistic, social, and cultural contexts of science and technology. Technology enhances our senses and assists in describing nature (International Technology Education Association; ITEA; 2000). Mathematics is the study of patterns, properties, and relationships (National Council of Teachers of Mathematics; NCTM; 2000, p. 20), while engineering is a systematic practice of design to achieve solutions to particular human problems (NRC, 2012; p. 11). Table 1 compares the characteristics of the individual STEM components. Components from diverse subject areas are necessary to fully comprehend many of the important skills learners are developing as 21st Century learners including evaluating claims based on evidence, designing models, deriving meaning to individuals and groups, and collaborating with others. Utilizing the creativity found in technological inventions and in engineering problems in a science class are especially important in establishing cross-cutting concepts found in STEM in addition to promoting an engaging learning environment.

Each of these components has a clear and complementary connection with others in scope, goal, techniques and methods (Hotek & Greenhalgh, 2013). This interconnectedness makes placing art in STEM as STEAM philosophically challenging, especially given the breadth in the scope and nature of art, which can vary through media, style, and movement. Additionally, while art educators are worried about the lack of effective art instruction in schools, art must also exist as content in its own right beyond service as a medium to learning science, STEM, or other school subjects.

The STEM/STEAM philosophical debate can be avoided by acknowledging that art can enhance STEM as an instructional aid clearly described as STEM + Art. This designation also allows the goals of art to exist in the forefront, and ensures it does not play a secondary role to another subject. Furthermore, it is likely that teachers are less concerned about theoretical models and more interested in how art can be featured in the curriculum in addition to being used as an instructional tool to enhance STEM lessons in a practical manner.

The creativity exercised in art, engineering design, and development of technology can enhance many aspects of a science lesson, but in this editorial we will focus on two ways teachers can use it to enhance the learning environment that they create in their classrooms:1) Using creative processes as a way to gain access to students' ideas before science content is taught, to help guide further instruction; and 2) Using creativity as a means for students to express their understanding of science content.

Table 1: *Scope and Nature of Discipline Specific STEM Fields*

Category	STEM Field			
	Science	Technology	Engineering	Mathematics
Definition	The study of the natural world (American Association for the Advancement of Science; AAAS, 1993; p. 1) (NRC, 2012; p. 251)	The study of modifications to the natural world. (ITEA, 2000, p. 2) All human-made systems and processes. (NRC, 2012; p. 11)	Systematic practice of design to achieve solutions to particular human problems (NRC, 2012; p. 11)	The study of patterns, properties and relationships (NCTM, 2000, p. 20)
Goals of Student Learning	To cultivate students' scientific habits of mind; capability to engage in scientific inquiry, discovery, and reasoning in a scientific context (NRC, 2012; p. 41)	To understand the use, management, and assessment of technology. (ITEA, 2000, p. 9)	To systematically create new technologies through design with emphasis on mathematical and scientific modeling. (Katehi, Pearson, & Feder, 2009, p. 17)	The understanding and application of quantitative patterns, properties and relationships in reasoning and problem solving (Katehi, Pearson, & Feder, 2009, p. 17)
Methods	Scientific inquiry and discovery (AAAS, 1993; p. 2) (NRC, 2012; p. 30)	Design, production, maintenance, and assessment of technological components and systems. (ITEA, 2000, p. 4)	Engineering design (ITEA, 2000, p99) (Katehi, Pearson, & Feder, 2009, p. 4)	Quantitative representations and reasoning in problem solving. (NCTM, 2000, p. 16)
Predominant Cognitive Domain (Bloom, 1956)	Knowledge, comprehension, analysis, and evaluation (NRC, 2012; p. 41-46)	Knowledge, comprehension, application, synthesis, and evaluation (ITEA, 2000, p. 4)	Application, synthesis, and evaluation (ITEA, 2000, p. 99)	Knowledge, comprehension, application, and evaluation (NCTM, 2000, p. 17-18)
Nature	Tentative but durable: the actual laws of nature do not change, but our understanding of the laws change over time dramatically.	Dynamic: new technologies are developed and modified along with society	Dynamic: iterations and continual improvement are elements of the engineering design process	Static: quantitative properties, relationships, and patterns do not change

Gaining Access to Student Ideas

Using creative processes as a catalyst to make student ideas public at the beginning of a lesson allows teachers to access critical knowledge about their students that will make future lessons more meaningful. The drawing out of ideas from students' expressions can frame the lesson or unit in a more student-centered way. Once teachers have this knowledge, they can address specific misconceptions and build upon students' current knowledge. Simply asking students "What do you think?" is an inefficient way to access student information because many times students will not respond unless they have the "right" answer they perceive the teacher wants. However, asking students to perform an art or design based activity (like the examples in Table 2), reduces the stress of being "correct" by allowing the possibility of multiple appropriate perspectives. A creative activity might allow students to present a more authentic version of their ideas to the teacher and still support Next Generation Science Standards (NGSS; NGSS Lead States, 2013)

If accurate information about student beliefs of the targeted science concepts is not available, the teacher will have great difficulty forming an accurate judgment of the students' understanding and providing lessons to support students' needs. This background information of students' current understandings is important for development of learning experiences that engage students at an appropriate level.

Once a teacher has access to student ideas, he or she can plan future activity in which misconceptions are challenged, or initial ideas are built upon so students develop a deeper understanding of the science concepts engaged within the unit. Students can conduct experiments to test ideas, gather data that can serve as evidence, and challenge each other through negotiation. Once the teacher determines that students have a solid understanding of the science concepts, she or he can return to the activities to ask students to creatively express their understanding of what they learned in the unit. A second specific use of creativity in a science lesson will be discussed in greater detail in the following section.

Table 2. *K-4 Examples of Creative Activities to Gain Access to Student Ideas* (Table continues over next page).

Grade Level	Disciplinary Core Idea (DCI) NGSS Performance Standard	Creative Medium	Activity
K	DCI - LS1C - Organization for Matter and Energy Flow in Organisms	Painting or modeling	Paint a "Pet Rock" with all of the structures an animal would need to survive. Likewise, students may create a model in clay with all of the structures an animal would need to survive. Ask students to explain why they chose to paint the rock the way they did.
	K LS1-1 - Use observations to describe patterns of what plants and animals (including humans) need to survive.	Engineering Design	Students can design a farm that would include both plants and animals. Students can draw the farm, or model the farm with objects in the classroom. Students can explain what the farm needs in order to be successful. Ask students how energy from one part of the farm can become energy in another part of the farm.
1	DCI - The Universe and its stars ESS1-1 - Use observation of the sun, moon, and stars to describe patterns that can be predicted.	Dance	Put students into groups and assign roles of Earth, Moon, and Sun. Ask them to create an interpretive dance that explains why we have night and day

	DCI – Waves: Light and Sound 1-PS4-3 Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light. 1- PS4-4 Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.	Engineering Design	Allow students to form a small group that builds a fort, cave, tent, or hut. Let the students find the problem of darkness in the structure. Have student plan a way to bring light from the classroom into the structure. Now, challenge the students to find a way to communicate with another group outside of the structure without yelling or leaving the structure.
2	DCI - PS1A Structure and Properties of Matter 2 PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties	Photography (art and technology)	Take students outside and ask them to capture pictures of solids, liquids, and gasses on the playground (this will require an iPad or digital camera). Print the photos and have the students make a collage, then describe why they placed the photos into each group.
3	DCI - PS2.A - Force and motion 3-PS2-1 - Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	Music and Engineering	Have students sing the children's nursery rhyme “Humpty Dumpty” song. Next, have the students describe, in great detail, why Humpty Dumpty fell off the wall. Finally, have the students design a device that would balance Humpty Dumpty with a description of how the device solves the problem of an egg balancing on the wall.
4	DCI - PS3.A - Definitions of Energy.	Drama	Put the students into groups and ask them to write, and act out, a short play about a baseball or softball player who hits the game winning homerun. After they act out the play ask them to describe the energy of the ball upon the bat in the play.
	4-PS3-3 - Ask questions and predict outcomes about the changes in energy that occur when objects collide.	Engineering Design	Put a breakable object such as an egg in a toy car and allow it to run into the wall. Allow students to design a device or system that would protect the object in a collision. Have students explain how and why their safety system works and connect it to the safety systems found in their lives.

Using Creative Processes to Express Understanding of Science Concepts

Traditional science units typically assess student understanding through tests, quizzes, or laboratory reports. One issue with these assessment practices is they do not allow students to personally explain how their learning has evolved. Even worksheets that ask students how their ideas have changed typically do not ask students to explain their understanding in any real world context, which many times results in uninspired responses.

Science teaching approaches, like the Science Writing Heuristic (SWH) and the Five E’s Learning Cycle, place a premium on students expressing their understanding of science concepts through developing an explanation that can be communicated to an outside audience (Bybee, 1997; Hand, 2007). The SWH approach, in particular, asks students to write to an authentic audience that is not the teacher. This approach encourages a process in which students translate the science content they learned into writings that make sense to a non-expert audience (i.e., not the teacher who is an expert on what is being taught). One suggestion to help students more accurately and thoroughly convey their understanding would be to take the SWH writing approach a step further by expanding the opportunities for student communication to include non-text modalities.

Table 3 provides examples of technology, art, and engineering based assessment opportunities in which students expressed their understandings in a creative way. For evaluation purposes, teachers may create rubrics to score their students' writing or performance, or use traditional assessment practices (i.e., quizzes and tests) after the alternative assessment option described is utilized.

Table 3. *Creativity-based Activities in which Students Express their Knowledge of the Science Content in Alternative Ways*

Grade	Disciplinary Core Idea / NGSS Performance Standard	Activity
K	DCI - LS1C - Organization for Matter and Energy Flow in Organisms K LS1-1 - Use observations to describe patterns of what plants and animals (including humans) need to survive.	Students form small groups and the teacher records the students' short "commercial" for a store selling pet rocks or showcasing their farm (activity requires an iPad or video camera) The students will be asked to emphasize why their "pet" is a smart choice because it doesn't require water or food (and other resources living things require.) students can also describe how different parts of the farm, plants and animals transfer energy to sustain the farm. The Kindergarten students will show their videos to another Kindergarten or Pre-school class and ask them if they think the rock is living and if it would make a good pet. Students can also decide if the farm has everything it needs for the people and animals to survive.
1	DCI - The Universe and its stars ESS1-1 - Use observation of the sun, moon, and stars to describe patterns that can be predicted.	Students paint a picture that includes the Earth, Moon, and Sun. The painting will include arrows or streaks of paint to demonstrate the movement of each celestial object. Students will visit a Kindergarten classroom and explain their paintings. After they explain the movement in their paintings they will give markers and a blank paper to the Kindergarten students and ask them to make their own drawing of the movement of the Earth, Moon, and Sun.
2	DCI - PS1A Structure and Properties of Matter 2 PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties	Students will make objects out of clay or play-dough (some objects must be solids, liquids, and gasses) and they will write down a description of the object on a note card. The object will be put in a shoebox and students will play a "Guess the Object" game with a group of 1st graders. The 2nd grade students will read the description on the card, and 1st graders will guess what the object is.
3	DCI - PS2.A - Force and motion 3-PS2-1 - Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	Students will make a cartoon of their choice that describes balanced and unbalanced forces. The cartoons will be sent to a group of 2nd graders followed by a short quiz about balanced and unbalanced forces that the 2nd graders will take.

Summary and Conclusion

The use of creativity in STEM lessons has grown in popularity recently (Mote, Strelecki, & Johnson, 2014). Many teachers agree that students are more engaged in lessons that include one or more creative modalities (Eisner, 1998; Gullatt, 2007), yet a definitive model of how to use art or engineering as an effective and efficient teaching tool in science and STEM is not clear. The authors suggest that various types of creativity can be utilized in STEM learning environments. Creative products can be used initially in units to gain access to student ideas about targeted science concepts, which will eventually be used as a guide to plan future lessons addressing misconceptions and building upon their knowledge. At the conclusion of a STEM unit, creative products can provide a way for students to express their knowledge in a creative way that encourages students to self-reflect about their conceptual knowledge related to the science concepts addressed within the unit. Using student creativity as an instructional tool will likely increase engagement of all students in science lessons, thereby improving student understandings of science.

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