Editorial:

The *Journal of STEM Arts, Crafts, and Constructions* as an Ideal Venue for Showcasing Application of the Next Generation Science Standards

Dana Atwood-Blaine,
University of Northern Iowa

Journal of STEM Arts, Crafts, and Constructions
Volume 2, Number 1, Pages 1-7.

The Journal's Website:
http://scholarworks.uni.edu/journal-stem-arts/

Abstract

The Journal of STEM Arts, Crafts, and Constructions is an ideal venue for disseminating new ideas, lessons, and research developed in response to the Next Generation Science Standards (NGSS). This editorial explains how arts integration is well-suited to addressing the Science and Engineering Practices and the Cross-cutting Concepts. The research articles in this issue provide evidence that arts integration is also effective at improving student retention of disciplinary content over time. Using specific examples from the articles in this issue, this editorial elaborates on the three-dimensional nature of NGSS and how the integration of arts, crafts, and constructions into science instruction is a good fit for addressing these new science and engineering standards.

Key Words

Next Generation Science Standards (NGSS), STEAM, STEM, constructions, science education, engineering education, arts-integration.

Introduction

The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) represent a significant improvement in the way teachers who adhere to these standards approach science instruction. The standards themselves are written in a manner that demands the integration of three distinct dimensions of science education: disciplinary content, cross-cutting concepts (a.k.a. the "big ideas" in science), and science and engineering practices. The three dimensions work together to support inquiry-based construction of accurate science knowledge and an understanding of the nature of science. Furthermore, the inclusion of "engineering" as both content and practice is a particularly noteworthy change from previous science standards.

Not only is engineering included as its own disciplinary content area with practices given equal weight to those of science, but engineering is also explicitly integrated into the other disciplinary content areas of life science, physical science, and earth/space science. The inclusion of engineering clearly presents not only the opportunity, but the obligation for teachers to engage students in designing and constructing solutions to problems in all disciplinary core areas. The focus on "constructions" makes the *Journal of STEM Arts, Crafts, and Constructions* an ideal venue for sharing the new ideas, lessons, and pedagogy research that develops in response to the engineering component of the Next Generation Science Standards in particular.

The Three Dimensions of the Next Generation Science Standards

Each Performance Expectation in the Next Generation Science Standards is comprised of three dimensions of science literacy: Disciplinary Core Ideas (DCI), Science and Engineering Practices (SEP), and Cross-cutting Concepts (CCC). The intention is that all science instruction be three-dimensional; every lesson including at least one component from each dimension. Although the foundation boxes provide DCIs, SEPs, and CCCs that connect well with each Performance Expectation, teachers should feel free to choose any combination of the three-dimensions that fits well with the curriculum they have designed for their students (Workosky & Willard, 2015).

The Dimension of Disciplinary Core Ideas. Disciplinary Core Ideas (DCIs) include science content in the four areas of life science, physical science, earth/space science, and engineering. Within these broad disciplinary domains are more specific and recurring themes throughout the DCIs. These themes and their corresponding elementary grade levels are listed below:

Physical Science

- Motion and Stability: Forces and Interactions (K, 3, 5)
- Energy (K, 4, 5)
- Waves and their Applications in Technologies for Information Transfer (1, 4)
- Matter and its Interactions (2, 5)

Life Science

- From Molecules to Organisms: Structures and Processes (K, 1, 3, 4, 5)
- Heredity: Inheritance and Variation of Traits (1, 3)
- Ecosystems: Interactions, Energy, and Dynamics (2, 3, 5)
- Biological Evolution: Unity and Diversity (2, 3)

Earth/Space Science

- Earth's Systems (K, 2, 3, 4, 5)
- Earth and Human Activity (K, 3, 4, 5)
- Earth's Place in the Universe (1, 2, 4, 5)

A fourth Disciplinary Core Idea is the combination of **engineering, technology, and the applications of science**. The NGSS define technology as "any modification of the natural world made to fulfill human needs or desires." Engineering is defined as "a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants." The application of science is "any use of scientific knowledge for a specific purpose, whether to do more science; to design a product, process, or medical treatment; to develop a new technology; or to predict the impacts of human actions (NGSS Lead States, 2013)."

Engineering, Technology, and Applications of Science

- The Engineering Design Process
- Links among Engineering, Technology, Science, and Society

The Dimension of Science and Engineering Practices. Science and Engineering Practices (SEPs) are a redux of what have been called "science process skills" or "science inquiry skills" in earlier versions of science standards (National Research Council, 1996). NGSS includes eight SEPs:

1. Asking Questions and Defining Problems;
2. Developing and Using Models;
3. Planning and Carrying Out Investigations;
4. Analyzing and Interpreting Data;
5. Using Mathematics and Computational Thinking;
6. Constructing Explanations and Designing Solutions;
7. Engaging in Argument from Evidence; and
8. Obtaining, Evaluating, and Communicating Information.

Of these eight, "Defining Problems" and "Designing Solutions" are specifically associated with engineering.

The Dimension of Crosscutting Concepts. The Crosscutting Concepts are the "big ideas" that span across all domains of science. There are seven Crosscutting Concepts included in NGSS:

1. Patterns
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter
6. Structure and Function
7. Stability and Change

In the earlier standards, these ideas were part of what was called the “Unifying Concepts and Processes in Science” that transcended disciplinary boundaries. In the *National Science Education Standards*, the five unifying concepts were listed as: systems, order, and organization; evidence, models, and explanation; change, constancy, and measurement; evolution and equilibrium; and form and function (National Research Council, 1996). In the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), these concepts were called “Common Themes” and included systems; models; constancy and change; and scale.

Theoretical Alignment

A strong theoretical alignment exists between this new *Journal of STEM Arts, Crafts, and Constructions* and the Next Generation Science Standards. Both enterprises embrace and espouse the practical and pedagogical necessity of cross-curricular integration. The NGSS already provides explicit connections to the English Language Arts (ELA) and Mathematics standards in the Common Core (NGSS; NGSS Lead States, 2013). The message is that a more effective approach to science education is one that integrates science instruction with other disciplinary areas such as engineering, mathematics, and language arts.

Indeed, with many states mandating the amount of time K-5 teachers must spend every day on reading and mathematics instruction, there is no longer enough time in the school day to teach every subject separately (Griffin & Scharmann, 2008). Integrating the disciplines is one way to engage more students and to help all students connect with the concepts in ways that are most meaningful to them and that make sense in the real world (Fogarty & Stoehr, 2008). From creating detailed scientific drawings of natural specimens through close observation to designing and constructing physical models; the inclusion of arts, crafts, and constructions within NGSS-aligned science lessons enriches the learner’s experience, thereby accomplishing the learning objectives more effectively. The research articles in this issue conclude that integration of arts into a science lesson can have a positive effect on children’s engagement and attitude toward science, as well as retention of the science content.

Integration of arts, crafts, and constructions is particularly well-aligned with engaging students in certain Science and Engineering Practices and the Crosscutting Concepts. All eight of the Practices can be addressed through integration of arts, crafts, and constructions in a science or engineering lesson, but Developing and Using Models, Designing Solutions, and Communicating Information are three practices that lend themselves particularly well to arts integration. Likewise, the Crosscutting-concepts supported by arts integration in this issue’s articles are Patterns; Structure and Function; and Systems and System Models. Examples included in this issue are described in the following paragraphs.

How Practical Articles in this Issue Address the NGSS

This article presents three articles that focus on classroom practice. In the descriptions below, the application of Next Generation Science Standards are examined.

Flipping about the Sun

In the first practical article in this issue, Flipping about the sun and its pattern of apparent motion, written by Crystal Betts and Allison Pattee (2017), first graders used the **engineering design process** to create an aesthetically attractive shadow clock. The standard this work supported was *1-ESS1-1: Use observations of the sun, moon, and stars to describe patterns that can be predicted.* Students communicated their understanding of the sun’s **pattern** of apparent daily motion through creation of a sequence of **beautifully drawn pictures** that were subsequently **arranged**

into "flip books" to animate the sun's motion across the sky. This lesson incorporated the arts by having students draw pictures of the sun's position in the sky at different times of day. The lesson also included the construction of shadow clocks. Finally, students compiled their drawings into a flipbook, a craft activity that required the application of spatial skills, sequencing, and stapling. Each activity directly supported the lesson's learning objectives and the NGSS standards. Figure 1 shows several pages of a flipbook made by a student.

Figure 1. Several flipbook images from a first grade student's work.

Ecosystem Food Web Lift-the-Flap Pages

In the second practical article, Ecosystem food web lift-the-flap pages, authored by Dana Atwood-Blaine, Audrey Rule, and Hannah Morgan (2017), third grade students attended closely to the structures of artistically but accurately drawn animals in a lift-the-flap craft activity. Students exercised their spatial thinking skills when putting the pages together properly, cutting the flap doors, and gluing the pages together without gluing the flaps shut, too.

The Next Generation Science Standard addressed by this project was 5-LS2-1: *Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.* Students had to consider food web relationships and determine which animal should go behind each window flap using the inferred functions of each animal's visible structures to determine each animal's diet. The lift-the-flap page was an artistic construction that supported students learning of the **Cross-Cutting concepts of Structure and Function**, serving as a **System Model** of the food-web system. Figure 2 shows a preview example of a lift-the-flap page being made by a student in the project described in this article.

Figure 2. Lift-the-flap page under construction

Students Explore Fossil Creatures of the Cambrian Period Burgess Shale

This issue includes a third practical article about a lesson in which elementary and middle school students made physical models of Precambrian fossils. This article, titled, Students explore fossil creatures of the Cambrian Period Burgess Shale through model-making, was written by Andrea Anderson, Ksenia Zhbanova, Phyllis Gray, Jolene Teske, and Audrey Rule (2017). This lesson focused on the **Cross-cutting concept of structure and function**, and also on the **Science and Engineering practice** of developing and using models to understand something that cannot be observed directly. As learners make choices about which materials to use in designing and constructing their models, they think about the specific structures and functions of the object, organism, or system they are trying to represent. Students must pay close attention to these details to create an accurate model that is also aesthetically appealing. Furthermore, they come to understand a bit more about the nature of science as they realize that scientists often don't know important details such as the actual color of a fossilized organism. Within these gaps of scientific evidence, learners are able to make artistically creative and aesthetic choices. This opportunity for artistic activity during science engages some students with the content who would not otherwise be motivated to learn about fossils. Figure 3 gives a preview of some of the fossil models that students created during this project.

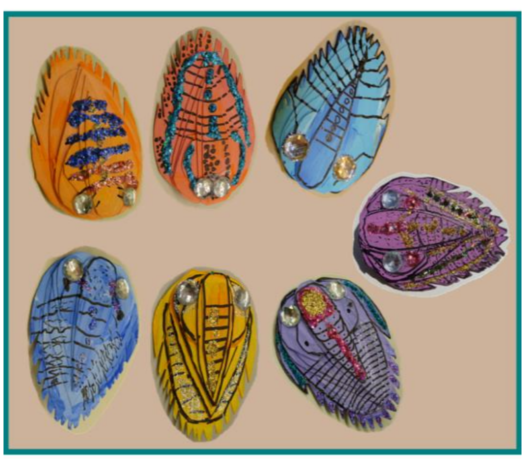

Figure 3. Example Olenoides trilobite models

How Research Articles in this Issue Address the NGSS

Teaching Kindergarten Students about the Water Cycle

The first research-focused article in this issue is titled, Teaching kindergarten students about the water cycle through arts and invention, and authored by Latisha Smith and Deepanee Samarakoon (2017). In this lesson, students simultaneously engaged with art and the science and engineering practice of **"communicating information"** as they painted watercolor depictions of their understanding of the water cycle. Also, their paintings served as conceptual models of the water cycle; developing and using models is also a science & engineering practice. Finally, kindergarten students designed solutions for wet feet by constructing waterproof boots using the engineering process to design, create, and test their boots. Next Generation Science Standard ETS1-1, which states that *students will analyze the data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs* was supported by the boot invention. Figure 4 shows children testing the boots they invented to determine if they are waterproof.

Figure 4. Children testing their boots in water.

Form and Function of Modern and Fossil Organisms

The science and engineering practices include asking questions/defining problems, developing and using models (replicas). All of the art, craft, and construction elements included in the articles in this issue provides students with particularly effective opportunities to engage in NGSS Science and Engineering Practices. For instance, in the second research article, Form and function of modern and fossil organisms, written by Jolene Teske and Phoebe Pittman (2017), 8th grade students drew and labeled detailed models of modern insects and fossilized marine organisms. The NGSS standard MS-LS4-2: *Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms*, was supported by this project.

The focused attention on the details of **form and structure** required to draw an accurate model gave students the time to consider multiple perspectives on the organism to make more thoughtful and fully considered inferences about the functions of those structures. In addition, students communicated what they had learned through a craft activity that involved creating pop-up elements inside a manila folder that included their fossil form drawing on the top of the pop-up and the written description of its form and function underneath. Students who participated in this craft activity scored significantly higher on a distal posttest of science content than those who did not participate in the craft activity. Figure 5 provides a preview of a pop-up construction from this study.

Figure 5. Student detailed drawings on a pop-up construction.

Sixth Graders Investigate Models and Designs

Finally, in the last research article, Sixth graders investigate models and designs through teacher-directed and student-centered inquiry lessons: Effects on performance and attitudes, written by Benjamin Olsen and Audrey Rule (2017), students worked with the Models and Designs Module of the Full Option Science System (FOSS). NGSS standards addressed included, among several others, MS-ETS 1-1 Define the criteria and constraints of a design problem with sufficient precisions to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. This entire unit explored the value of constructing models of phenomena as a way of understanding how and why something occurs. This research study concluded that, up to a point, students' conceptual learning, attitudes, and motivation to learn all improved with increasingly open inquiry approach and the autonomy to design and construct their own models. Figure 6 shows scientific principle-based toys created by students during their last challenging lesson set.

Figure 6. Example student-made toys: a. kaleidoscope covered with wrapping paper; b. rain stick covered in duct tape; c. blue tie-dyed design jumping acrobat; d. jumping acrobat of natural wood decorated with marker; e. pecking hens toy with weight attached to strings below that pulls on hens as rotated; f. musical instrument tone cups of different sizes and pitch; and g. two decorated spin tops.

Conclusion

This issue of the *Journal of STEM Arts, Crafts, and Constructions* provides solid examples of the kinds of art, craft, and construction activities that support science learning in each of the three dimensions of NGSS. In addition, the research articles in this issue provide evidence that including arts, crafts, and constructions in science lessons results in overall better learning, attitude, and motivational outcomes for students. The *Journal* staff and I hope you enjoy this issue of the Journal of STEM Arts, Crafts, and Constructions and that you decide to integrate similar activities into your own science teaching.

Acknowledgements

Several articles in this issue are based upon work supported by NASA under Grant No. NNX15AJ16H. A grant from the Iowa Biotechnology Association also supported several of these projects as noted in the individual articles.

References

American Association for the Advancement of Science. (1993). Benchmarks for science literacy. Oxford, England: Oxford University Press.

Anderson, A. E., Zhbanova, K., Gray, P., Teske, J. K., & Rule, A. C. (2017). Students explore fossil creatures of the Cambrian Period Burgess Shale through model making. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 32-57.

Atwood-Blaine, D., Rule, A. C., & Morgan, H. (2017). Ecosystem food web lift-the-flap pages. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 16-31.

Betts, C. M., & Pattee, A. (2017). Flipping about the sun and its pattern of apparent motion. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 8-15.

Fogarty, R. J., & Stoehr, J. (2008). *Integrating curricula with multiple intelligences: Teams, themes, and threads*. Thousand Oaks, CA: Corwin Press.

Griffith, G., & Scharmann, L. (2008). Initial impacts of No Child Left Behind on elementary science education. *Journal of Elementary Science Education*, *20*(3), 35-48.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academies Press.

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

Olsen, B. D., & Rule, A. C. (2017). Sixth graders investigate models and designs through teacher-directed and students-centered inquiry lessons: Effects on performance and attitudes. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 95-114.

Smith, L. L., & Samarakoon, D. (2017). Teaching kindergarten students about the water cycle through arts and invention. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 60-78.

Teske, J. K., & Pittman, P. J. Z. (2017) Eighth graders explore form and function of modern and fossil organisms. *Journal of STEM Arts, Crafts, and Constructions, 2*(1), 79-94.

Workosky, C., & Willard, T. (2015). Answers to Teachers' Questions about the Next Generation Science Standards. *The Science Teacher, 82(6), 29-31.*