SCIENCE + ART = ENHANCED LEARNING EXPERIENCES FOR STUDENTS

by Richard Frazier and Adele Caemmerer

"What really captured our imagination was how the single tap of one thing led to so many others and how motion was carried through the whole time."

"I like it when classes intertwine; I think it expands your knowledge."

"From this project especially I think that I gained a deeper understanding of what you can achieve when you combine art and science."

Seventh-grade students made these comments after a study of motion that integrated science and art. The investigation resulted from the collaboration between a middle school art teacher and artist whose recent works are inspired by motion (Brummer 2012) and a middle school science teacher long interested in children's experiences with phenomena and concomitant growth in scientific understanding. As colleagues, we often shared examples of projects that blurred the boundaries between art and science. When we explicitly blended art into the seventh-grade study of motion, the results outpaced our expectations, powerfully involving students in thinking, interaction with the phenomena, and diverse modes of expression. In this article, we share the origins, development, and benefits of the project.

The art of motion

The science-art collaboration began after seventh graders had been introduced to motion. Before the project, students had staged various motion events, such as races, pulling carts, and rolling balls. These events provided data that students used to create and analyze graphs. Ideas such as constant speed, acceleration, and force were introduced and examined experientially and graphically (Frazier 2006). When the time came to initiate the project, the science class visited the art room to view and discuss the art teacher's original, motion-inspired work. We hoped to stimulate the design and implementation of students' own science-art investigations. In the art teacher's first category of paintings, called *Traffic Patterns*, patterns were produced by the artist's hand as she directly experienced motion in vehicles such as cars, airplanes, and trains. The technique came about serendipitously as the art teacher drew during a daily commute. Rough roads made it difficult to control lines, and the art teacher saw an opportunity to artistically explore daily motion experiences (see Figure 1). When the art teacher began using a morning routine to observe the arrival of various entities (people, pets, vehicles, birds, etc.) in her neighborhood, she developed a second category, called *Morning Watch*. She invented a code for each arrival and translated the data into a visual record that often consisted of an ordered array of shapes and colors (see Figures 2 and 3).

FIGURE 1 *Traffic Pattern 1, September, 18, 2010*

FIGURE 2 *Morning Watch, April 28, 2012*

FIGURE 3 *First 10 Things, 7 Days, April 28–May 4, 2012*

The art teacher introduced students to the investigation by challenging them to develop their own methods of observing, coding, and translating something of immediate interest in their purview. They entered into this process easily and found innovative ways for gathering and displaying data. Simple phenomena such as the order of pencils in a jar or students' hair color according to seating order became stimuli for data gathering and representation.

Students' captivation with the visual art forms, interest in the various arrays and patterns of color representing data, and devoted focus to their own observations, coding, and visual translations led us to decide they were ready for the science-art project. We told students there were two main purposes for the project: to gain deeper appreciation of motion and to link concepts and practices of science and art through creative investigation. Students could choose from three approaches: (1) creating an object that involved motion or balance, such as a kinetic sculpture; (2) producing a tracing that captured elements of particular motions; or (3) rendering an artistic visualization of data acquired through observation of a motion event. The assignment included a narrative that described both creative, artistic processes and links to scientific concepts and practices. A list of prompts assisted students in writing their reflections. The opportunities and constraints afforded through the guidelines offered various ways for students to explore phenomena and to express understanding.

Students met for science class on alternating days, as is typical for a block schedule. At the first meeting, they developed and discussed plans for their investigations, with the art teacher available for consultation as needed. The second and third meetings were devoted to continued investigation and composition; many students spent this time tinkering and troubleshooting. For example, students who wanted to use paint to leave motion traces tried out their ideas with water first and then adjusted the viscosity of the paint. The art teacher met with every student during the third meeting to discuss progress, offer advice, and provide feedback. Students finished during the fourth meeting and made presentations during the fifth. The art teacher served as commentator for the presentations, asking students what the most artistic and scientific aspects of their works were and summarizing her impressions.

Students created a variety of projects: Calder-like balance sculptures; Rube Gold-

FIGURE 4 Painting made from a tire swing on the elementary school playground

FIGURE 5 Water balloons coated in paint and dropped

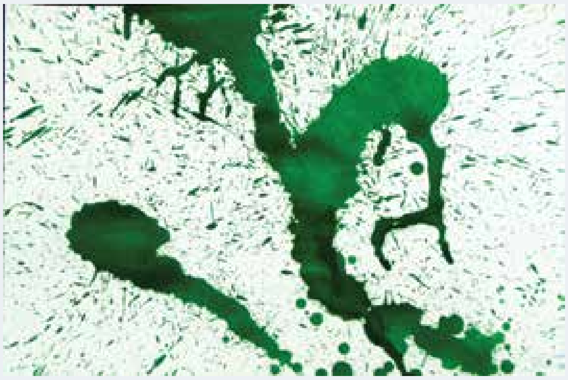


FIGURE 6 Animal movements coded

berg systems that students called "kinetic sculptures"; pendulum paintings; and various two-dimensional images produced by the coded motion of a chair rolled down a hallway, dueling remote control cars carrying markers, water balloons covered with paint and dropped on paper, animal movements coded and included as part of the design of an iconic ecosystem, and toy cars rolling down an inclined plane through puddles of paint (see Figures 4, 5, and 6).

Interviews with students during investigations and presentations revealed several important points. Student enthusiasm and engagement were particularly high. Their reflective stance was conspicuous, and many commented on new perspectives and connections. The art teacher noticed upon questioning presenters that when asked what was most artistic and most scientific, students seemed to feel that the features and qualities that made their works scientific also made them artistic; students felt creative and scientific processes enhanced and even propelled one another.

Visual explanation

While one class participated with the science-art project, other sections of seventh-grade science explored motion in ways that might be considered more conventional. Students in the classes that did not explicitly combine art and science practices were quite interested in the work done in the class that had. Furthermore, we were curious about the fact that students in the class that integrated science and art had not developed visual representation of data to the extent we predicted. We felt an emphasis on the visual in the next project for students in all classes would help us investigate students' thinking more deeply while taking advantage of their excitement at combining art and science. We speculated we could push the visual aspect by blocking off their usual verbal and numeric ways of representing data.

The subsequent activity involved building, launching, describing, and explaining air-pressure water rockets. Students built and launched rockets, identified variables, and decided how to manipulate those variables. The assignment involved recording the performance of each rocket and then explaining the results visually; no words, letters, or numerals could be used in the description and explanation. What was fascinating was that phases of building the rockets and then building the explanations had remarkable similarities. There was a sense of active construction as students developed explanations. They tinkered with ideas in the same way they would tinker with materials while constructing a physical device. Additionally, the visual mode of expression pushed students to dig deeper into their own thinking. One student reflected, "I never would have figured out the reason of why the rocket flies if I had just written it." The use of symbols such as "=" and "→" spread wildly through the classes. Students also invented symbols, such as a flexed bicep to represent force. Students found visual analogies to be powerful modes of explanation (see Figures 7 and 8).

Implications of integrating science and art

The benefits to students' learning in combining the practices of art and science are immense. Students are provoked into deeper thinking as they integrate various modes of investigation and representation. They find the approach engaging, personally fulfilling, and naturally aligned with their own ways of seeing. The sense of ownership powers the sustained engagement we observed in both instances of the study of motion. Our discovery of how incredibly taken students were with selecting their own observations, designing their own codes, and then rendering the observations into a visual portrayal of data led us to consider optimal sequences for teaching practices such as observation and graphing. The art teacher believes that expressive, student-propelled engagement in gathering and representing information "humanizes" data for students and their audience. Anxiety and fear experienced by students during school science can be mitigated by bringing them into relevant practice at their own levels of interest. Students' reflections, as represented in the quotations introducing this article, indicate the power of weaving science and art together.

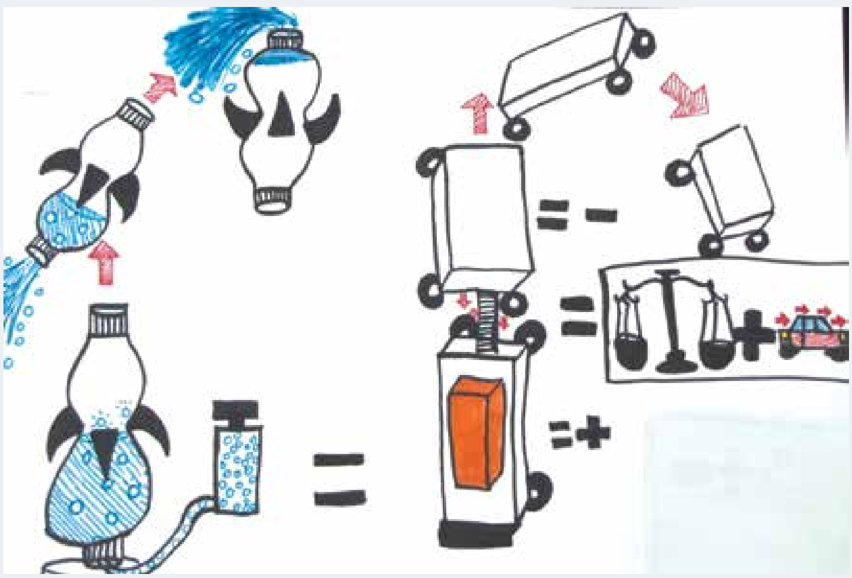
For us, the collaboration proved profound. We were both impelled to consider new ways of looking at students and learning, actively seeking multiple modes of expression when designing learning experiences for our students. For the science teacher, the techniques we employed both renewed and generated ideas about students' thinking and learning in science. The art teacher was intrigued by the ease with which students incorporated visual elements into their data gathering and representation, even when the combination initially seemed unfamiliar. For both of us, the attention to process that the science-art merger initiated created a certain sense of discovery for the entire classroom community, engaging students in the whole stream of events leading to what we would usually identify as their "real" outcome. This perspective, of examining the progression of learning, has not always been fully incorporated into the assessment of achievement in science. In our case the product *was* the process.

The explicit use of visual explanation exposed elements of students' thinking that would not have been revealed by written tests or even probing interviews. For example, students' visual explanations demonstrated the widespread idea that expanding air from the rocket needed to push off the ground for a successful launch. Visual explanation helped clarify students' thinking and thus improved our ability to assess that thinking. As we observed how students' thinking was provoked by the various creative constraints of the science-art approaches, we felt validated on several fundamental beliefs:

- There are multiple portals into creative practice.
- Creative practice and scientific inquiry are compatible.
- Direct experience and familiarity with phenomena are essential.
- Deep engagement in exploration and explanation is possible for all students.
- Engagement may look different for different students.
- School practices should build upon nascent inclinations, practices, and ideas students bring to school.

Our reflection has led to new practices that build on students' ideas and also provide opportunities to fashion bridges to standard scientific conceptions. Plans include expanding the approach throughout the science program so that students have regular occasions

FIGURE 7 Visual explanations of an air-pressure water rocket by Student A



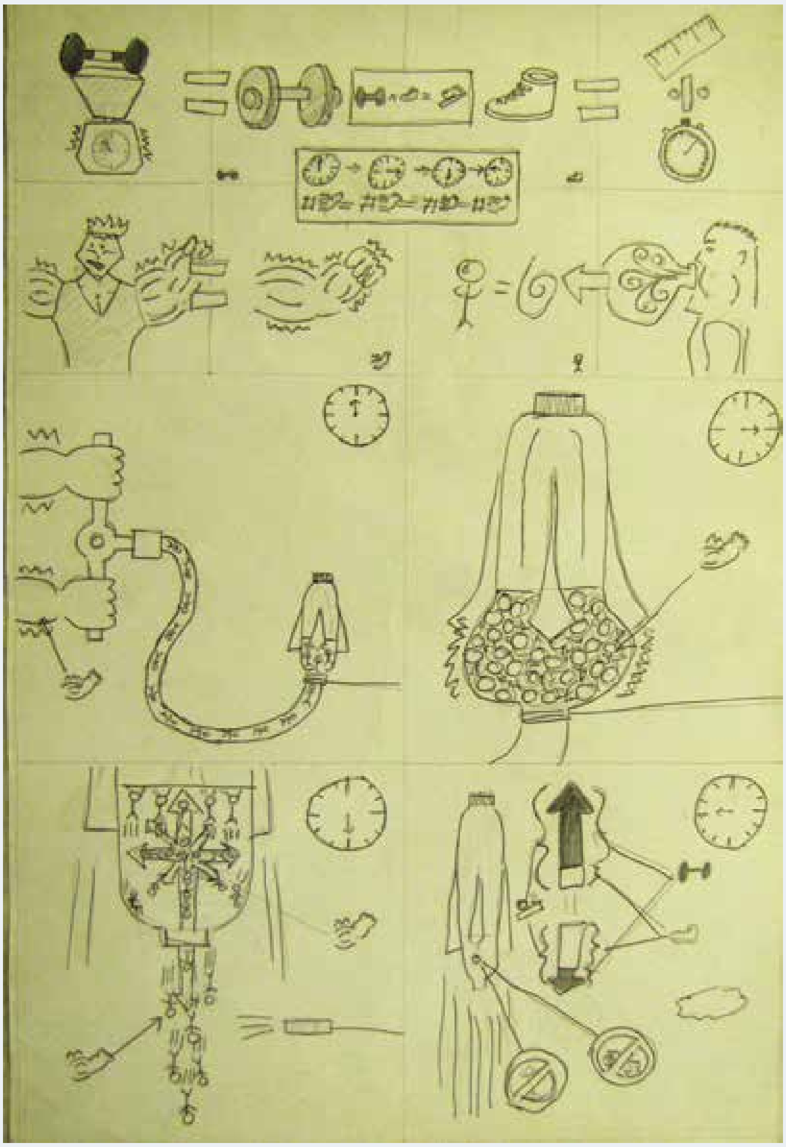
to investigate curricular topics firsthand and to express themselves creatively, visually, physically, and verbally.

Science-art: Collaboration for our times

Throughout the development of the *Next Generation Science Standards (NGSS)*, integration of science with literacy, engineering, technology, and mathematics has been rationalized and emphasized. The importance of students' understanding big and crosscutting ideas and practices is a major theme of the *NGSS* (NGSS Lead States 2013). Because design, problem solving, experience and familiarity with phenomena, and creative expression are indispensible aspects of art, it makes sense to consider the integration of art into this broader view of science. Examples abound in publications, websites, online videos, and projects and labs funded by prestigious institutions of scientists who do art and artists who do science.

Our students have reassured us of their need for multiple modes of expression in a demanding subject such as science. Shifts in our own thinking have led us to articulate how the visual arts can affect the acquisition and display of data, visualization and visual explanations, and clear communication. The active inclusion of art has fostered ownership, engagement, and creativity in school science. We believe that that the science-art link is not only beneficial for learning but also highly relevant in contemporary scientific practice and our modern culture. ■

FIGURE 8 Visual explanations of an air-pressure water rocket by Student B



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