COMMUNICATING SCIENCE CONCEPTS THROUGH ART

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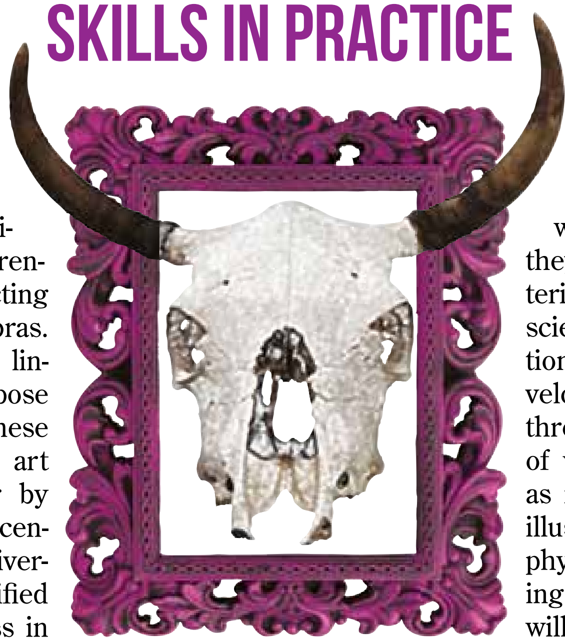
21ST-CENTURY SKILLS IN PRACTICE



There is a dynamic synergy between the visual arts and the natural sciences. For example, science relies heavily on individuals with visual-art skills to render detailed illustrations, depicting everything from atoms to zebras. Likewise, artists apply analytic, linear, and logical thinking to compose and scale their work of art. These parallel spaces of science and art are pulled toward each other by the education needs of the 21st century (Chandler 1999). Five universal constructs have been identified as essential features for success in the 21st century: adaptability, complex communication skills, nonroutine problem solving, self-management, and systems thinking. By blurring the boundaries between art and science, specific strategies emerge that allow middle school students practice with these 21st-century skills as they manipulate images and materials in the process of capturing science content. The next generation of scientists will need to develop their communication skills through both traditional means of writing and speaking, as well as more artistic means including illustrating, animating, videography, cartooning, and model building. These 21st-century scientists will be called upon to design visual displays to communicate information at conferences, in classrooms, and in boardrooms, using digital tools such as YouTube and podcasting, as well as more traditional visual displays.

Marshall (2010) described five conceptual art strategies that can be implemented to foster science learning: depiction, projection, reformatting, mimicry, and metaphor/analogy (Figure 1). In order to demonstrate the strength of integrating these conceptual art strategies into a variety of science curricula, science teachers at Seabury Hall, a 6–12 college prep academy in Maui, Hawaii, recruited the school's art teacher to provide basic art lessons during science classes. This arrangement allowed students to have expert initial direction in applying the fundamentals of art from a qualified art teacher. During these initial sessions, student were taught basic "how to draw" skills, such as how to observe size and angle relationships, negative and positive spaces, patterns, and textures. To learn to draw well, students were also tutored on shading techniques and how to apply highlights. It was also important that students had the appropriate artistic tools, such as watercolor paper; colored pencils, chalks, and markers; kneadable erasers; charcoal; pen and ink; graphite pencils; to have the sense of being artists (we did not use any paints).

FIGURE 1 Strategies for integrating art and science (Marshall 2010, p. 18)

Strategy	Learning through
Depiction	Observing/interpreting
Projection	Imagining/envisioning
Reformatting	Using contexts of pop culture
Mimicry	Authentic copying/performing
Metaphor/analogy	Comparing/is like a . . .

Then, as science teachers, we began to employ various art strategies in our science lessons. We also asked students to process and interpret verbal and nonverbal information and to select key pieces of complex ideas to communicate. Through these art projects, students learned to recognize patterns, link various pieces of information, and reflect on the adequacy of various solutions to problems. Using physical models refined their understanding of specific science content.

Depiction

Depiction simply means drawing a realistic likeness of an object. For this strategy, human body structure was taught in seventh-grade life science, and then the art technique was introduced. The objects of study were plastic replicas of human body parts from an anatomical model and a skeleton model. This strategy tasked students with observing an object very closely and, from this careful scrutiny, making a recognizable drawing of the object.

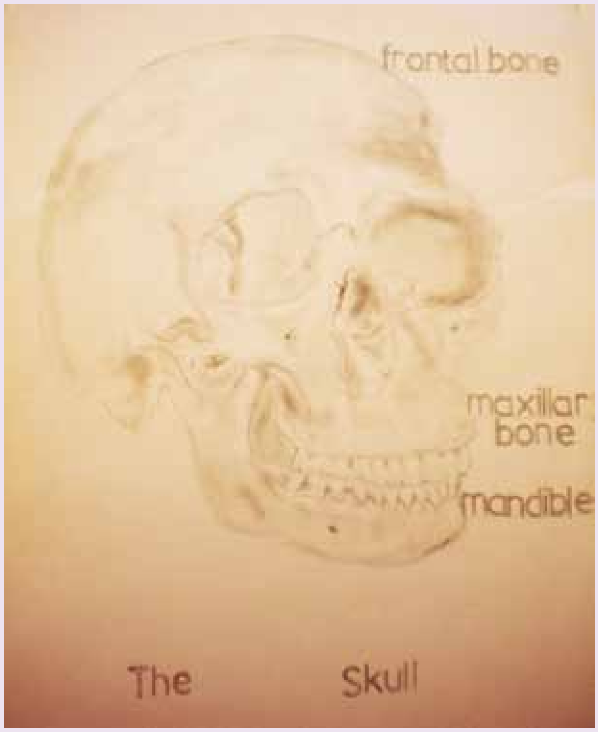
The use of this strategy mandated that students consider the notions of scale, shadow, and proportion. This fits with the crosscutting concept of scale, proportion, and quantity in the next-generation science standards (NRC 2012). Appropriate understanding of scale relationships is critical to art as well as to science. Typically, when middle school students are asked to draw what they see under the microscope or to illustrate a scientific object, they produce a crude sketch that is rather cartoonish in nature, and completely out of proportion. This "symbol" of the object seen under the microscope is usually a stick figure or ball-and-stick image (Buczynski and Fontichiaro 2009). For example, a muscle joint might be illustrated as two conjoined, striped ovals with no regard for a meaningful scale of magnification.

However, to depict what a muscle really looks like in nature, students were told, "First create a grid on your paper, then draw what you see, not what you think it should look like. You need to pretend that you are an ant. Follow the lines as an ant would and draw this on your paper, keeping the scale of the drawing to fit the grid." Struggling artists practiced on a dry erase board to plan out their drawing, a great way for them to get some practice before starting. If they were using pencils, various grades (B and 2B) were available so that students could sketch lightly and not dig into the paper. Students avoided fuzzy lines by making sure their pencils were sharp. It was also suggested that students place a clean sheet of paper between their hand and the drawing to prevent smudging.

Next, students were introduced to lighting by being asked to "pretend that the Sun is in the upper-left corner. Where would the shadows be? Make those areas darker and lighten up the areas exposed directly to the Sun." If students were working with colored pencils, they were encouraged to make their drawing "pop" with opposing colors shaded around the drawing. With the assistance of art instruction, science students learned techniques of scale, one of the thematic threads that runs through nearly all of the sciences, and how to produce a three-dimensional effect so that the object looks more realistic.

The more realistic and detailed the drawing, the more students were able to identify and discuss various elements present within that drawing and elaborate further on their understanding of form and function (Figure 2). The final illustrations were not necessarily graded on artistic ability. However, a student's ability to use lines not only to create shapes but also light and dark areas was evaluated. Understanding scale required some insight into measurement. A narrative critique was added to the evaluation to communicate the impression and value of the student's art and also to evaluate neatness and effort, and if all of the components of the particular body part were present and accurately depicted/labeled.

FIGURE 2 Depiction: Pencil drawing of skull to scale



Projection

With the projection strategy, students were asked to predict the outcomes of a scientific event, and then to present that outcome as a two-dimensional drawing rather than a paragraph of text. This strategy gave students some creative license in making an artistic hypothesis. Their prediction, based on known evidence and observations, took into account all of the ramifications of that conjecture. For example, students were asked to take a science topic (e.g., acid rain, water pollution, smog) and to explain the chemistry behind it while making predictions of the effect of these elements in our environment. Students used inventive and envisioning techniques such as storyboarding, cartooning and Claymation productions to consider future consequences related to these issues. The impact of this art strategy was that students learned that scientific facts might be remarkable; however, imaginative interpretations make scientific facts all the more meaningful and compelling. Learning to articulate thoughts and ideas effectively using nonverbal communication skills is necessary to ensure 21st-century readiness for every student.

To stimulate their imaginations, the teacher asked one group of students to formulate their topic in the form of a children's book that would make the subject matter comprehensible for a younger audience. As teachers, we know that in order to make complex subject matter understandable to learners, we must have a firm command of the subject matter ourselves, as well as the ability to state it in a variety of ways. When students were asked to teach a science concept to younger learners, they had to have this same grasp of content. While authoring a science "primer" book, students learned to prioritize essential content or big-picture ideas while providing science details and facts in the form of illustrations. In doing so, students came to understand the critical role that art and fiction play in deepening our thinking and moving us forward. For example, one student explored and illustrated alternative energy technologies that could solve critical environmental issues in the future (Figure 3). These books were graded on scientific accuracy, illustrations, and readability using a rubric (Figure 4).

FIGURE 3 Projection: Storybook envisioning end to air pollution

Reformatting

In technology, reformatting usually means to change the arrangement of data in a storage device. Similarly, as an art strategy for a science class, reformatting means using content from science in an arrangement more associated with art from popular culture. Pop cul-

FIGURE 4 Rubric

Criteria	Science writer seeks editor 1	Science writer with potential 2	Published science author 3
Images	A picture is worth a thousand words. Please illustrate your story more fully.	The use of illustration supports the plot, but the images need more detail and attention to visual appeal.	Story includes at least 10 images that complement the content very well.
Prediction	Consider plot development to provide rising action, a climax, and resolution to your story, including scientific facts.	Your story has a beginning, middle, and end; however, the science of your story must be grounded in actual scientific fact.	Your speculation on the outcome of the scientific event is possible.
Writing conventions	Spell-check to make sure your book is error-free before publishing.	One or two grammar or spelling errors occur in the work, so it is not quite ready for publishing.	Send to the publisher, as spelling, grammar, and punctuation are accurate.

ture might include art projects in the form of a comic book, magazine, advertisement, or film. For this assignment, instead of having students write the usual science lab report on egg osmosis, students created a cartoon lab report. One of the expectations of this strategy was that students, prior to beginning the lab, would have illustrated the steps of a procedure that they could follow to conduct the experiment. Effective communication in the 21st century requires more than the ability to read and write text. Students must be able to make choices in the type and amount of information needed in order to express themselves logically and persuasively to the intended audience. As students shared the lab steps with their partners, all students knew exactly what they would be doing during the lab. Requiring students to draw their procedure made the teaching of the lab much smoother. Students knew what to do because they spent time not only reading the procedure, but also interpreting the steps of the lab and anticipating partner involvement as they illustrated the lab in their notebook. Class time was now spent on analysis of data rather than organization of the lab. Due in no small part to the success of requiring illustrated lab protocol, another drawing assignment was added.

As the class conducted its shell-less egg experiment that involved massing the egg before and after a 48-hour submersion in Karo syrup, followed by submersion for 12 hours in distilled water, students were asked to give their egg a personality and devise a cartoon that included the scientific terms

FIGURE 5 Reformatting: Egg-osmosis cartoon lab

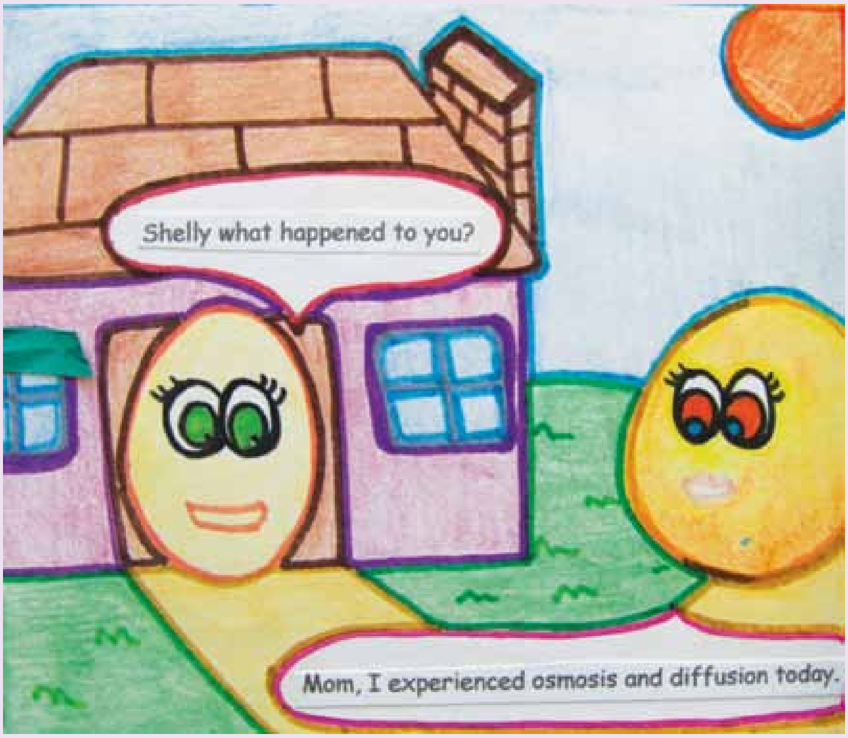


FIGURE 6 Mimicry: Herbarium of crown flower

specific to osmotic events. Overall, students can easily experience the obvious changes occurring as the egg shrivels and swells in these two environments, but they often stumble when explaining the mechanism of osmosis at a molecular level. Allowing them to move from a strictly scientific explanation to a cartoon permitted them some artistic freedom in illustrating their cartoon clearly and engagingly, so that the reader is taught the meaning of terms such as *hypotonic*, *hypertonic*, and *concentration gradient*. Students once again employed the crosscutting concept of scale by illustrating what was happening at the molecular level and drawing the resulting consequence on the whole "organism" (egg). Unlike the attitude that resulted from a lab-report requirement, students looked forward to the egg cartoon assignment. They competed for the best story line to go along with their mass-shifting egg (Figure 5). What we found was that when learners rework the steps of their scientific investigation, they often understand their procedures and results better.

FIGURE 7 Metaphor: "Gut reaction" mobile

Mimicry

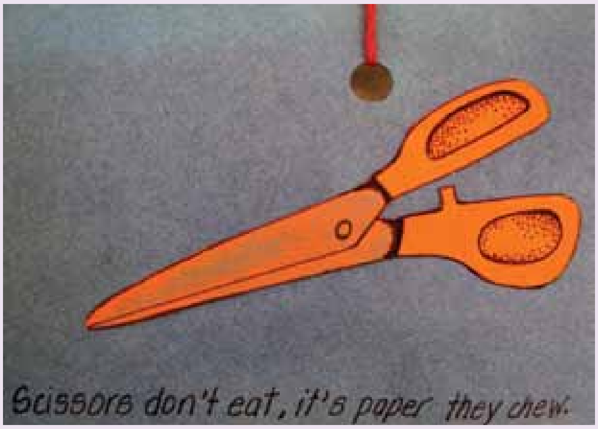
Another of Marshall's strategies that we found particularly effective for science teaching was mimicry. In this context, mimicking is having students use the same methods as science practitioners to help them learn through the experience of being in a scientist's shoes. For example, the early explorers of Hawaii were scientists, engineers, and innovators, and they were also artists who documented the history of Hawaii through the drawing of events and landscapes. By mimicking the methods of these scientists, we cast light on the ways they constructed knowledge and how art revealed the thinking of the times. For example, students were asked to use the methods and tools associated with botanists to choose a local plant to present to the class using a scripted outline. The outline asked students to provide the taxonomy of the plant, details of the life cycle, and cultural, medicinal, or agricultural uses of the plant. Constructing an actual herbarium mount added tactile learning involving texture. Along with the presentation, students brought an artifact made from the plant. Most of these artifacts were baked goods, but they also included bowls, ceremonial leis, and musical instruments. Making the herbarium involved collecting, drying, arranging, labeling, and photographing the botanical sample (Figure 6) just as a scientist would do. The biological specimen collections were evaluated on the basis of presentation, use of plant identification resources, and elements of the outline.

Metaphor/analogy

The concept of metaphor crosses disciplinary boundaries, as it is essentially the description of one idea in terms of another. Making a visual metaphor helps learners to hone their perceptual and analytic skills and fosters symbolic thinking. Practicing these skills can start with making an analogy. In an analogy, entities have similarities and differences, and there is a remote connection. We applied this technique by asking students to create a three-dimensional model of the digestive system, which we creatively called a "gut reaction" to the digestive system. Students constructed a mobile with small

FIGURE 8 Analogy: Teeth are like scissors

FIGURE 9 Analogy: Teeth are like scissors



cards hanging at differing lengths from a coat hanger. On one side of the card, the student illustrated an organ in the digestive system, and on the other side of the card the student illustrated an everyday household item that could be likened to the organ. Therefore, by the completion of this project, the student had imagined and illustrated a separate analogy for each of the organs of the digestive system. For example, the large intestine is like a sponge because it absorbs water from the digested material, and teeth are like scissors because they physically break apart food (Figure 7–9).

Conclusion

Chandler (1999) likens the disciplines of art and science to twins who have been separated at birth. In his metaphor, these disciplines share chromosomal identities and values, sensing one another's affect and communicating nonverbally across dimensions. The case is made for this conceptual twinning between the arts and science by invoking Marshall's (2010) five conceptual art strategies in a science classroom. We can testify that learning science through the arts is compatible with quality academic instruction. The 21st-century learning paradigm offers students an opportunity to synergize the margins of science and art, bringing them into a framework that encourages learners to take intellectual risks. This approach also provides opportunities to make the classroom "learner driven" with self-directed, art-based projects that capitalize on innovation and creativity. As we strive to teach science in ways that incorporate skills necessary in the 21st-century workplace, projects that permit creative and critical thinking, along with imaginative communication methodologies, are of great worth. The value of arts-based approaches to the promotion of scientific literacy is well worth the classroom time invested. ■

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