the da Vinci Potential in All of Us

Integrated learning in the arts and the sciences

Sarah Petto and Andrew Petto

Work in both the arts and sciences is rooted in tenacious curiosity and intellectual creativity. Whether in the art studio or the science laboratory, practitioners use materials to envision and shape aspects of the world around them. In both science and art, this practice is meant not just to illustrate but also to transform our understanding (Crease 1995).

In this article, we describe an instructional approach that integrates learning science and the visual arts (Dambekalns 2005; Hall 2005) and meets curriculum objectives in both disciplines (Petto and Petto 1998). To describe this approach, consider the example of studying the form and function of the human skeleton. Students build a model of the human skeleton to apply skills in both domains and complete inquiry-based lessons on body structure, shape, and proportion.

Shared skill development

However frequently science teachers use models and other visual representations of scientific ideas and processes, we rarely engage the one expert in the school who could help students render these visualizations more effectively—the art educator. In addition, most of the work students produce in science class typically uses art only as a decorative or illustrative element. The artwork is added on to the scientific material; students learn the science first and then try to engage the artistic skills necessary to produce a visual representation of one or two key concepts.

The approach presented in this article is founded on the concept that the essential skills for successful learning in both the arts and sciences require higher-order thinking, creative problem solving, and an adaptive dialogue between the student and the materials and resources used to facilitate learning (Petto 1994; Burton, Horowitz, and Abeles 2000). In the process, students' understanding in both disciplines is deepened, enriched, and transformed (Yore, Hand, and Prain 2002).

Although the primary example in this article is used in a biology or life science unit on the human skeleton, we have successfully applied this approach to units on light and shadow, the curvature of Earth, animal camouflage, the immune system, eggs and nests, architecture, and several other areas in which the arts and sciences converge. In this article, we briefly describe the animal camouflage and architecture examples in addition to the human skeleton example.

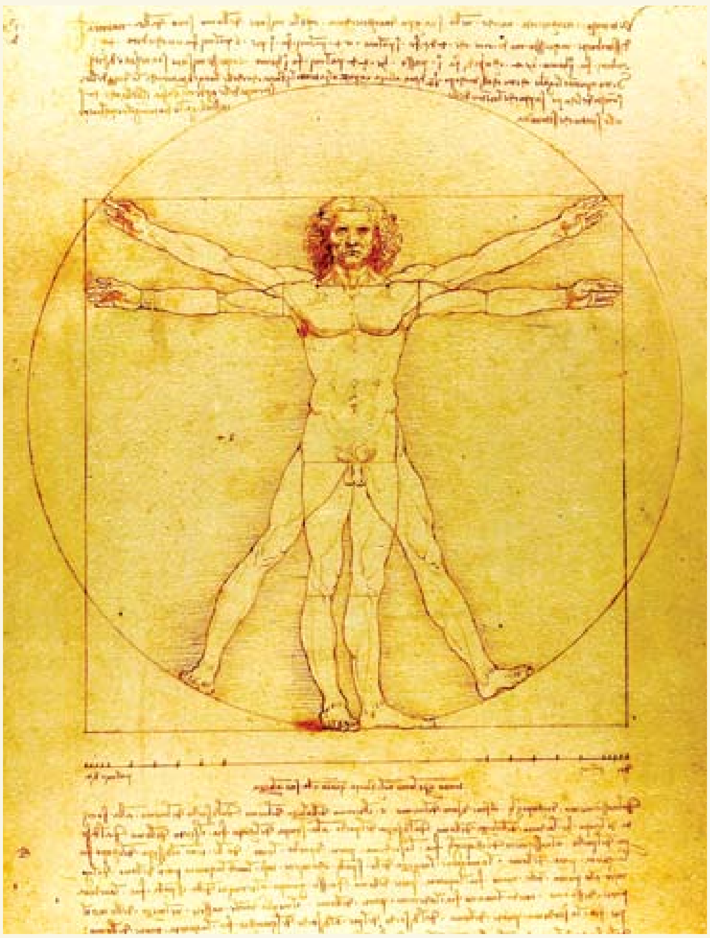
Building skeletons

The study of the human form is fundamental to both science and art curricula. For vertebrates, perhaps no feature is more important than the skeleton to determine observable form and function. As Leonardo da Vinci's famous *Proportions of the Human Figure (Virtruvian Man)* illustrates, the size, shape, and proportions of the human body are defined by bones and their articulations (Figure 1). In a unit that focuses on the human skeleton, we introduce these concepts by asking students both to study da Vinci's drawing and to relate its features to their own bodies. Students compare the relative proportions of limbs and torso to the "ideal" ratios described by da Vinci.

FIGURE 1

***Vitruvian Man* (Leonardo da Vinci).**

Virtruvian Man (ca. 1490) is based on a geometric ideal of human proportions suggested by the Roman architect Vitruvius as the basis for architectural design.



Activity overview

Once students have been introduced to form and function through da Vinci's drawing and a related discussion, each student (or small team of students) begins to build a model from newspaper and other recycled materials, such as magazines, shredded paper, or construction paper from old bulletin boards. Figure 2 shows one example that uses a recycled plastic milk jug for the skull. Others have used tennis balls, craft sticks, or bubble wrap to create skeletons—the essence of this lesson is for students to explore different materials to find those suitable for their own models.

In this activity, students first learn that newspaper becomes stronger when layers of paper are rolled into tubes. These tubes are made more resilient when fastened with strips of masking tape. Tubes are then joined together with additional tape to create newspaper bones. This experience helps students understand the structural characteristics of the materials they are using as well as how those characteristics compare with real bone. To create accurate life-size models—the culminating activity of the unit—students need to consider both the structural characteristics and articulations of the skeletal elements.

We point out to students the microscopic anatomy of compact bone and show them the circular arrangement of bone mineral around a central canal, which forms the functional unit of compact bone: the osteon. Just as the newspaper rolls are bundled together with tape, osteons are bundled together to make up each bone (Figure 3, p. 52); the layers of newspaper pages model the layers of compact bone tissue that surround the central canal in each osteon. The imitation bones should reflect the size, scale, and proportions of the human body: They are the building blocks that will be connected by tape to create a life-size model of the human skeleton. At the end of the unit, each student (or team of students) will have his or her own skeleton to represent learning.

The unit on skeletal structure most directly addresses the curriculum standards in the arts and sciences—compared to the examples of architecture and animal camouflage—since familiarity with the human form is fundamental to both disciplines.

Assessment

In the culminating activity in the human skeleton unit, students complete a skeleton that is reasonably accurate in terms of size (i.e., life-size), scale, and proportion. For other vertebrates, life-size may not be reasonable. For example, it may be more reasonable to construct a baby *Tyrannosaurus rex* rather than an adult—this is also an opportunity for the teacher to introduce the idea that body proportions differ between immature and adult vertebrates.

The assessment of student success in this unit takes two forms. The first is the objective assessment of the disciplinary content. Students' skeletons or human figures should demonstrate the appropriate size, scale, and proportion—key articulations should be placed in the correct location and orientation to the rest of the skeleton. Also, students should exhibit understanding of both the skeleton's contribution to bodily form and the stresses placed on different parts of the skeleton relative to position and role in the body.

The second assessment is a student-centered reflection on the project that includes a self-assessment of both the process and the outcome. The assessment is derived from a model of art criticism (Feldman 1992) and examined in integrated curriculum settings (Petto 1994; Petto and Petto 1995). The summative assessment is also based on students' meeting grade-level standards for both life science and visuals arts. Teachers who collaborate to design and teach these units should be able to build their units around applicable middle or high school national and state standards. (**Editor's note:** For the connections to standards, visit *www.nsta.org/highschool/connections.aspx*.)

Extensions

Teachers may limit student choices to construction of the human skeleton, or they may direct students to choose from among a number of other organisms appropriate to the curriculum. In our classes, students have modeled skeletons of nonhuman primates, domestic animals (e.g., dogs and cats), and farm animals.

We have also used newspaper bones as the basis for student studies in comparative anatomy. A further extension of this activity is to "flesh out" the models and use various colors of craft paper on the surface to represent skin, fur, feathers, or scales. We use students' work and models—as well as other images and specimens—to demonstrate how the underlying skeletal structure influences the outward form of the body.

Additional examples

The following brief examples describe units on animal camouflage and architecture, which further support the art and science integrated approach to teaching and learning.

FIGURE 2

Student model of skeleton.

A newspaper model of the human skeleton (center). Note the attention to moveable joints in the knees, ankles, elbows, and shoulders. Note also the unique solutions to the problems of complex skeletal structures, such as the use of a recycled milk jug for the skull. This model is shown in comparison to a gorilla skeleton (left) and orangutan skeleton (right).

Animal camouflage

In a unit on animal camouflage, we introduce nine camouflage strategies that students must identify and understand (Figure 4, p. 52). Examples of animal camouflage are found in most biology texts, and students are often familiar with many of these (Powzyk 1990). However, this unit also introduces examples from art history in which some of the same strategies are used—for example, René Magritte's use of mimicry and concealing coloration in *La condition humaine* [1933; Figure 5, p. 53]

Learning about animal camouflage strategies is enhanced by practicing skills typically emphasized in art curricula. Looking at examples, students first learn to recognize camouflage strategies, elements, and shapes. Later in the unit, they should be able to compare the use of visual elements in different strategies and understand their

FIGURE 3

Microstructure of bone.

The layers of newspaper wound into tight rolls model the microscopic structure of compact bone. Osteons consist of thin layers of mineralized bone tissue wound around a central canal containing nerves and blood vessels. The newspaper skeletons are made up of several rolls bundled together, just as bone consists of several osteons bundled together.

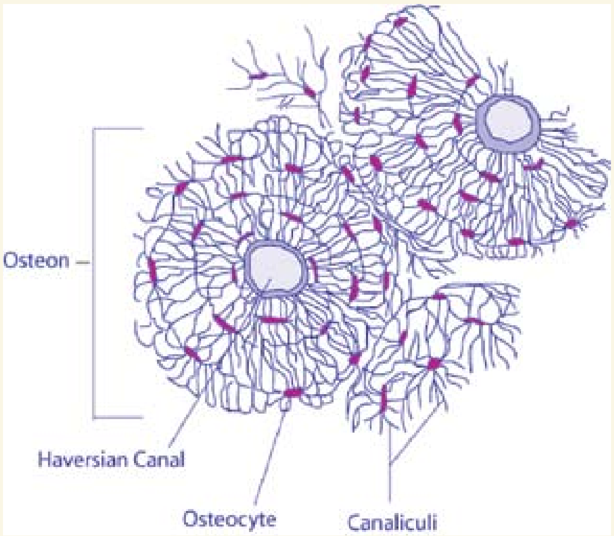


FIGURE 4

Common camouflage strategies.

Strategy name	Description
Concealing coloration	Body colors match or blend into an organism's immediate environment.
Disguise	The organism looks like a specific object in the environment (e.g., a stone or a stick).
Disruptive coloration	Irregular patches, stripes, spots, or other patterns catch the eye and make it difficult to see the overall shape or outline of the organism.
Aposematic coloration	Instead of hiding, some organisms make themselves more visible through "flashy advertising" because they taste bad, can sting their predators, or are poisonous (see "mimicry").
Mimicry	The organism looks like (or even behaves like) another organism, especially one that tastes bad or is dangerous.
Deflection	Markings and shapes on the body keep the predator's attention (and first attack) away from vital parts. One example is "eye spots" that appear on the tail or wings.
Countershading	The organism has different colors above and below; sometimes a gradient exists along the sides to counteract the effects of overhead light and to make picking out the silhouette more difficult.
Masking	The organism gathers materials from the environment to construct a "mask" or "blind" to conceal itself.

effects in an ecological context. Through both science and art lessons, students learn to develop and apply strategies that enhance critical observation and thinking.

In the unit's culminating activity, students apply concepts from camouflage lessons to the problem of concealment. In the final project, students may use images of animals and environments or a combination of natural and artificial materials to demonstrate their understanding of both visual arts and scientific principles.

Architecture

An integrated unit on architecture can serve as the foundation for the study of the human skeleton. This unit specifically engages students in visual thinking and provides a way to imagine and represent aspects of structure and design that may not be obvious from inspection of the outside alone. For example, students might not consider the arches, vaults, arcades, and columns that make up a building, just as students might not realize the skeletal forms that make us appear as we do. The ability to recognize the relationship between structure and function is essential in several aspects of art and design (e.g., painting, drawing, sculpture, and industrial design) and in scientific and technological fields (e.g., anatomy, engineering, and biochemistry).

Learning how to envision the internal structure of an object and to relate it to the external form goes beyond just acquiring skills in drawing different aspects of the object. The activities in this unit challenge students to understand how structure produces form and how form affects function—essential elements in both the visual arts and science.

Discussion

What students learn from these units has several characteristics. Taken together, these characteristics make a strong case for the value of integrating art and science learning. First, the learning is personal. Each student (or group of students) finds, defines, and addresses a problem presented by their model that needs to be solved (e.g., adults/children, a figure in action, humans/nonhumans). Even if that problem is similar to those of other students, the process produces a sense of ownership and a personal commitment to overcoming hurdles to solve the problem.

Second, the learning is multimodal. The exploration of materials used in the process engages students in visual, tactile, kinesthetic, spatial, and metaphorical thinking as they combine these rich sensory and intellectual experiences into a deeper understanding of the concepts and content that contribute to the problem they are solving (Gardner 2006; Hall 2005).

Third, the learning is robust. Students' descriptions of their work and the learning they derive from it typically are less bland and more expressive than the short answers they produce in response to quiz and exam questions. Instead, these answers are usually elaborate and detailed narratives of the process of finding the problem, applying the materials to its solution, and the many ideas and insights generated along the way.

These examples show that successful integrated teaching supports student-centered learning in more than one discipline, while providing a rich resource for both assessment of student understanding of important concepts and achievement of the learning goals embodied in state and national education standards.

Children are often told: "Look with your eyes, not with your hands." It is clear from our students' performance in these integrated projects that they "see" more when they engage more than just their eyes. This understanding of learning is the foundation for contemporary curriculum standards in the sciences (NRC 1996) and in the visual arts (Rollins 1994).

Our students do not just learn more effectively because they receive information through multiple channels—that would be a simple additive model not unlike adding additional highways to allow more traffic to enter a city in a shorter time. Instead, groups of students use different materials to construct their own understanding of the curriculum content. In this approach, drivers choose their own path into the city and sometimes build a road where one did not previously exist. Although this would make for a bad rush-hour commute, it can be a powerful process for real learning. ■

Sarah Petto (sarahpetto@hotmail.com) *is an artist-in-residence at the University of Wisconsin Hospital and Clinics in Madison, Wisconsin; Andrew Petto* (editor@ncseweb.org) *is a senior lecturer in anatomy and physiology at the University of Wisconsin–Milwaukee and editor of* Reports of the National Center for Science Education.

FIGURE 5

***La condition humaine*, 1933.**

This is one example of mimcry and concealing coloration from artist René Magritte. The image can be accessed from the U.S. National Gallery of Art at *www.nga.gov/fcgi-bin/tinfo_f?object=70170&detail=none.*

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