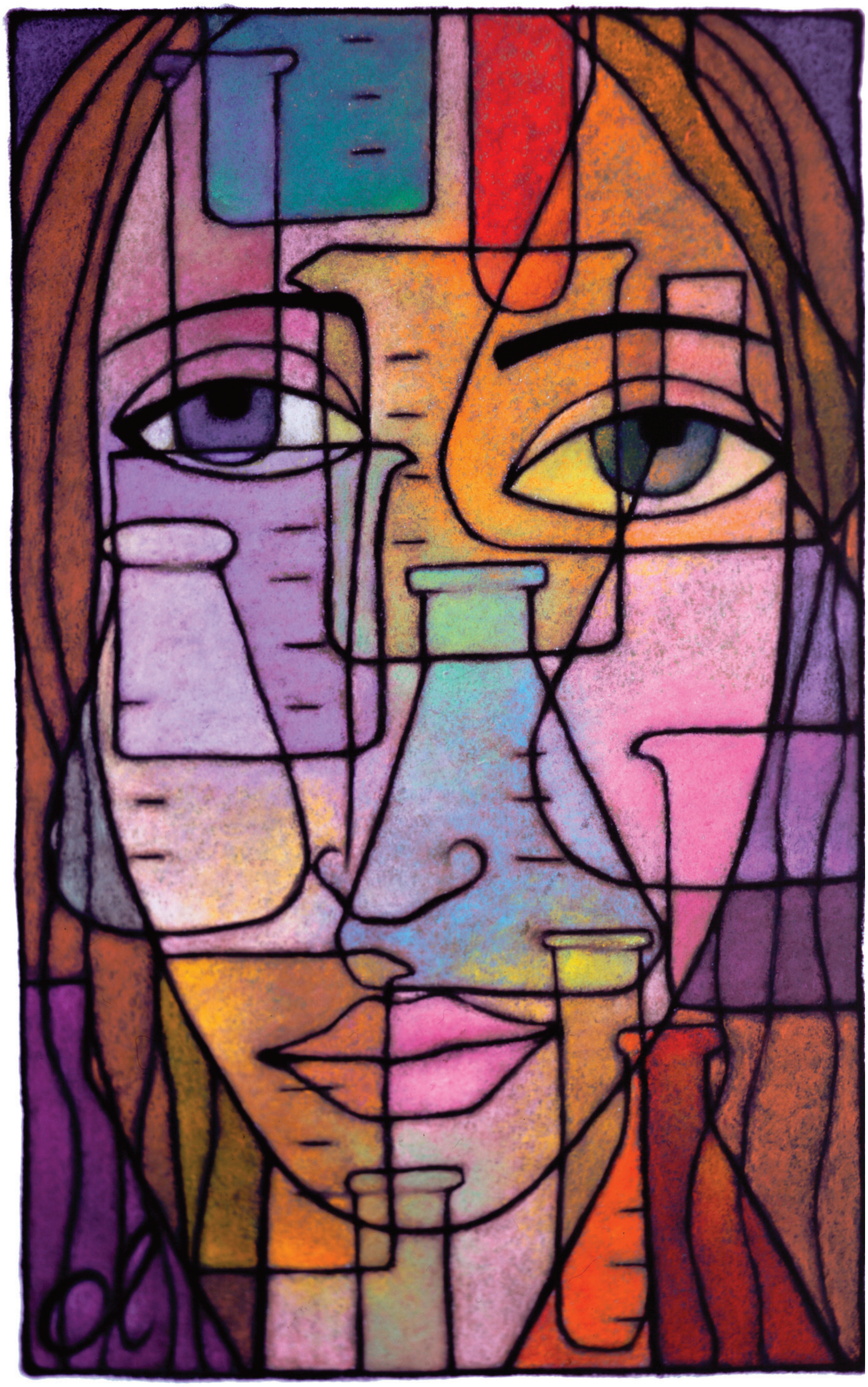
Artist as Chemist



Students link art and chemistry through problem-based learning activities

Arthur Eisenkraft, Carl Heltzel, Diane Johnson, and Brian Radcliffe

All artists are chemists. Artists understand and study the properties of specific materials and find ways to explore these properties to express views of themselves and the world around them. In this curriculum unit, chemistry students create an original artwork and describe the chemistry principles involved in their work. Before beginning the challenge, students learn the chemistry concepts and related art techniques through a series of eight activities.

The five-week chemistry unit centers on the Artist as Chemist and uses a problem-based learning model. We have found that students in class and teachers in professional development workshops become equally engaged in this chemistry unit. As part of an NSF-supported curriculum project (Eisenkraft 2006), the project leans on the National Science Education Standards

(NRC 1996), the research findings of cognitive science (Bransford, Brown, and Cocking 2000) and assessment (Pellegrino, Chudowsky, and Glaser 2001), and is cohesively structured using novel curriculum design strategies (Wiggins and McTighe 1998).

The curriculum

On day one of the class, students are exposed to the unit challenge: "Art is the result of the human need to express ourselves. It tells stories of societies, eras, and individuals. Your challenge is to create a work of art that represents you and/or your times using appropriate artistic techniques. You will also need to create a museum display that includes: a demonstration of the techniques involved, your original artwork, and a museum placard that explains the chemistry involved."

After hearing the challenge, students discuss the criteria of an excellent unit challenge. Facilitated by their teacher, students discuss the qualities that must be present in the work of art as well as the number of chemical principles that will be required for the museum placard. This discussion leads to the development of a scoring rubric that will be used to evaluate the projects at the close of the unit. The rubric delineates the expectations for each level of success. Examples of "exemplary" criteria are shown in Figure 1.

As our introduction to the high school chemistry course, students will have to learn some chemistry over the next month in order to succeed. In the problem-based learning model, students learn the chemistry because they are confronted with a challenge that requires knowledge of chemistry to complete (Delisle 1997). Students learn chemistry on a need-to-know basis. Students never ask, "Why are we learning this?" because the premise of the challenge and their engagement in the challenge presupposes the response. Students are learning chemistry because they want to create an original piece of artwork for a museum display.

Students learn chemistry through a series of eight activities. The philosophy of Artist as Chemist demands that all activities follow a structure to strengthen inquiry (Olson and Loucks-Horsley 2000). The 7E instructional model (an enhancement of the 5E model) (Eisenkraft 2003) includes eliciting prior understandings, engaging the students, exploration of the concepts through an activity, explanation by the students and teacher, elaboration of the content, extending the concept (transfer of knowledge to the unit) with evaluation throughout all aspects of the lesson.

Throughout the unit, the overarching theme is that chemistry is about change. Threaded through each activity are discussions of these changes at the macro and nano level. Students are encouraged to view all chemical interactions from the observable properties of the material substances before and after the reaction (macro) and the atomic level explanation of what is occurring (nano). Students are also introduced explicitly to the symbolic structures that are used throughout chemistry including formulas and equations, math, molecular models, dot diagrams, graphs, and computer images.

FIGURE 1

Rubric: Exemplary criteria.

	Excellent
Demonstration of techniques	• Display contains a thorough and accurate description of the artistic techniques used, which includes the chemistry involved. • Display contains accurate and key information concerning how techniques were applied to your work.
Original work	• Original work employs techniques described accurately and with craftsmanship. • Original work is creative. • Original work is an excellent representation of yourself or your times.
Placard	• All information on the placard is accurate. • All information on the placard is clearly written and easy to understand. • Seven or more chemical principles are addressed. • Placard is neat and correct. • All sources of information are correctly documented. • Placard is very creative.
Effectiveness of display	• The layout of the display has visual appeal. • The layout is engaging and interesting to a wide range of audiences. It is very creative. • Display is realistic; it could appear in a museum. • Display shows insight and understanding of art and chemistry.

The content

One of the early activities in The Artist as Chemist challenge focuses on the choice of artistic media for durability. Students are shown images of statues that have suffered the effects of acid rain ("engage" in the 7E model). The *What Do You Think* question ("elicit" in the 7E model) asks students what is in the air that can cause this damage.

In the *Investigate* section ("explore" in the 7E model), students generate sulfur dioxide and determine the effects of both sulfur dioxide and carbon dioxide on the pH of water; this is related to the effects of weathering on outdoor artworks. Students are also asked to design a procedure to determine which media will best hold up under acidic conditions.

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The *Chem Talk* section ("explain" in the 7E model) then leads students through a discussion of Arrhenius acids, their dissociation, and the chemical equations representing the reactions that they carried out. The *What Do You Think Now* question ("explain" in the 7E model) asks them to revisit their original response to the statue deterioration question and how their understanding has changed.

In the *Reflecting on the Activity and the Challenge* ("elaborate" in the 7E model) section, students review what they have experienced in light of the Unit Challenge. Students are prompted to develop an understanding of the chemistry concepts learned in terms of the macroscopic observations, nano level explanations, and symbolic structures used. At the macroscopic level students saw gases form, visible color changes of water as pH changed, and the effects of acids on marble, limestone, and other materials. On the nanoscopic level students learned about the formation of hydrogen ions and chemical reactions between acids and various materials. Symbolically, students used chemical equations to represent these changes.

The *Chemistry to Go* ("elaborate" in the 7E model) section provides students with homework problems that focus on the topics learned. A final section, titled *Preparing for the Unit Challenge* ("extend" in the 7E model), asks students to sketch a sculpture that would be placed outdoors. Students need to describe the material they would use and explain how it would resist deterioration caused by exposure to the elements. Once again, students are reminded that they are learning chemistry concepts because they will be required to create an original piece of art.

This approach and 7E instructional model is then used in subsequent activities to illustrate the connections between chemistry and art. Two activities, centered on the use of metals for artwork and tools, help develop the concepts of the metal activity series and valence electrons. Students practice electroplating and form alloys as well as annealed, tempered, and hardened steel.

Artists use a variety of materials and chemicals and there is a kinesthetic activity to allow students to understand bonding and how compounds are named. A further activity covers ceramics in terms of anhydrates and hydrates where mass percent and the mole concept are examined. Paints are investigated by carrying out precipitation reactions in an activity that incorporates the solubility rules. Intermolecular forces and polarity are investigated in an activity on typical solvents that artists encounter. In another activity students extract dyes from natural sources and gauge the effect of pH on colorfastness. The final activity is on the use of metals for coloring glass.

Figure 2 (p. 36) includes details of each of the activities and their related chemistry principles. Some of the labs are those traditionally done in chemistry classes. In this unit, these labs are not an end in themselves but rather necessary content to complete the unit challenge—creating a work of art that represents you and your times using appropriate artistic techniques.

The unit's impact

A successful problem-based learning unit should be able to challenge all who attempt it. Teachers experienced the Artist as Chemist unit during workshops and the unit was then field tested with students in their classes. Both groups experienced similar positive reactions to the unit.

The field test of the Artist as Chemist unit began with teacher professional development at Ohio State University during July 2004. Twenty-four high school teachers from across the United States participated in the training. Working in teams, all of the teachers proceeded through each of the eight activities to get a feel for what their students would be doing in the fall.

FIGURE 2

Summary of activities.

[**Editor's Note:** These procedures are not intended to be full descriptions; be sure to follow normal safety guidelines. For two complete Artist as Chemist activities, visit the online version of this article at *www.nsta.org/highschool#journal*.]

Title and summary of activity	Chemistry principles
What is Art? Present images of art—important and questionable work. Broad term discussion of the chemistry behind art.	• create a definition of art • materials that are used in art • How is chemistry related to art?
Choice of media for durability. Generation of sulfur dioxide in plastic bag, examining the effect of this gas and CO_2 (from breath) on the pH of water. Students design experiment to test how acids react with various metals, carbonates, silicates and sulfates (environmental impact on sculpture).	• acid/base chemistry • pH scale • chemical reactions • single displacement reactions • synthesis reactions
Chemical behavior of metals. Students determine relative activity of various metals (testing combination of metals in a solution with voltmeter to see which way current flows). Discussion of properties of metals based on electron arrangement. Electroplating; copper coating a nickel.	• chemical reactivity of metals • atomic structure–valence electrons
Physical behavior of metals. Make brass from a post-1982 penny.	• physical properties of metals • metallic bonding • alloys
Clay. (a) make observations of changes in crystalline structure, color (b) determine molar ratio of water in an unknown hydrate (c) conservation of mass—mass before and after dehydration. Why is clay "fired"? What happens when clay is fired?	• chemical reactions • hydrated and anhydrous compounds • mole concept • molar mass • percent by mass
Paints. Production of pigments from double displacement reactions. Testing of precipitates (and other compounds provided, e.g., metal oxides) in water, guar gum and oil to determine usefulness as pigments for paints. Produce a painting.	• chemical reactions • double displacement reactions • solubility
Dyes. Extracting and testing (effect of pH) natural dyes from plant sources on various fabrics (with and without a mordant).	• solubility • organic molecules • chromophores • auxochromes • mordants • dyes
Glazes and glass. Students make borax beads and show how the beads take up metal compounds and become colored. Discussion of glazes.	• naming compounds

Each group then produced an original work of art and a presentation explaining the various chemical concepts that were involved in the production of the artwork. The artwork included wire sculptures; multimedia mobiles; clay sculptures decorated with homemade paints, colored borax beads, and heat-treated bobby pins; dyed yarn and painted paper sculptures; and jewelry made from copper-plated nickels and brass pennies. All teachers were excited about the works of art, the process of discovery and inquiry in the activities, and the prospect of getting their students involved in chemistry though art.

One group of teachers presented a sculpture using one piece of clay molded into three female figures. The teachers explained that the physical features and uniqueness of each of them was represented in the art with the common base denoting that they are all strong and independent. Another group of teachers created a wire mobile with ceramics. The meaning of the art was described as the need that people have to be kept in balance and the changes that occur during life.

Student projects during the year were just as creative. One student group created a bracelet and described it in this way, "The bracelets represents us in a material form. The strings represent us and the beads represent important moments of our lives. These events range from deaths in our family to moving to a new town. The color of the beads also symbolically represents that no matter how bad an experience may seem, there is always a good lesson to be learned from it."

What is outstanding about the displays of artwork, but not surprising from a problem-based learning model, is that the chemistry concepts are correctly explained while the artistic aspects are original and creative. As the student teams display their work, the pride comes not only in their correct explanations of dehydration or suspensions but also in the novel ways in which they applied the chemistry to express themselves. The creativity of the teams emerges in ways that we usually don't see in a science class. We find out more about each other as individuals while we continue to learn the science content.

The nature of the challenge also provides an opportunity to respect and celebrate the different cultures in our classroom. In schools throughout the country, a wide diversity of students work side by side, often ignorant of their neighbors' ethnic backgrounds and cultures. The art project encourages students to create a meaningful art project that may indeed reflect their backgrounds. Research on equity issues recommends that we bring the cultural backgrounds of our students into the lessons. Here is an approach that fosters such inclusion in our chemistry classes.

Artwork created for the unit challenge by the teachers and students was creative and much broader than the writers of the unit had originally envisioned while working. For example, the writing team had anticipated that the bobby pins would be used for a metal sculpture but never imagined that pieces could be used for hair as part of a pottery figurative sculpture. The glass beads, originally intended for ceramics, became jewelry. Student engagement increases when the results of student work are not predetermined or fully predictable (Perrone 1994). During the presentation of the artwork, teachers realize that they did not anticipate their students' level of creativity and this adds to student pride and satisfaction.

Artist as Chemist rewards both knowledge of chemistry and student creativity. It fosters collaborations among students and provides an opportunity for all students to succeed. Through their creation of an original artwork and the accompanying museum placard, students communicate their knowledge of chemistry. They become artists because of their chemistry knowledge in much the same way that they realize that all artists have become chemists as a necessary component of their need to understand materials and their interactions. ■

Arthur Eisenkraft (arthur.eisenkraft@umb.edu) *is a distinguished professor of science education at the University of Massachusetts, Boston and is a past-president of NSTA; Carl Heltzel* (c_heltzel@acs.org) *is editor of the American Chemical Society's* ChemMatters *Magazine in Washington, DC; Diane Johnson (*diane.johnson@lewis.kyschools.us) *is an instructional supervisor for Lewis County Schools in Vanceburg, KY; and Brian Radcliffe* (Bjrdclff@alltel.net) *is an educational consultant for the Tracy Farmer Center for the Environment at the University of Kentucky in Lexington, KY.*

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