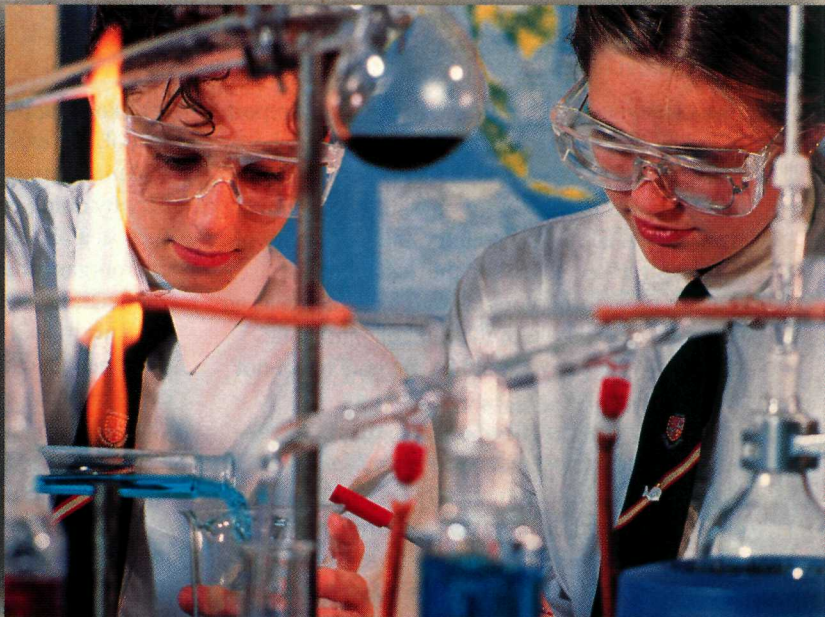




© Gail Zucker



© Peter Cadley/Tony Stone Worldwide

EXEMPLARY CURRICULUMS

Reconnecting the Sciences

**John Eggebrecht, Raymond Dagenais,
Don Dosch, Norman J. Merczak, Margaret N. Park,
Susan C. Styer, and David Workman**

The solution which I am urging is to eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum. There is only one subject-matter for education, and that is Life in all its manifestations.

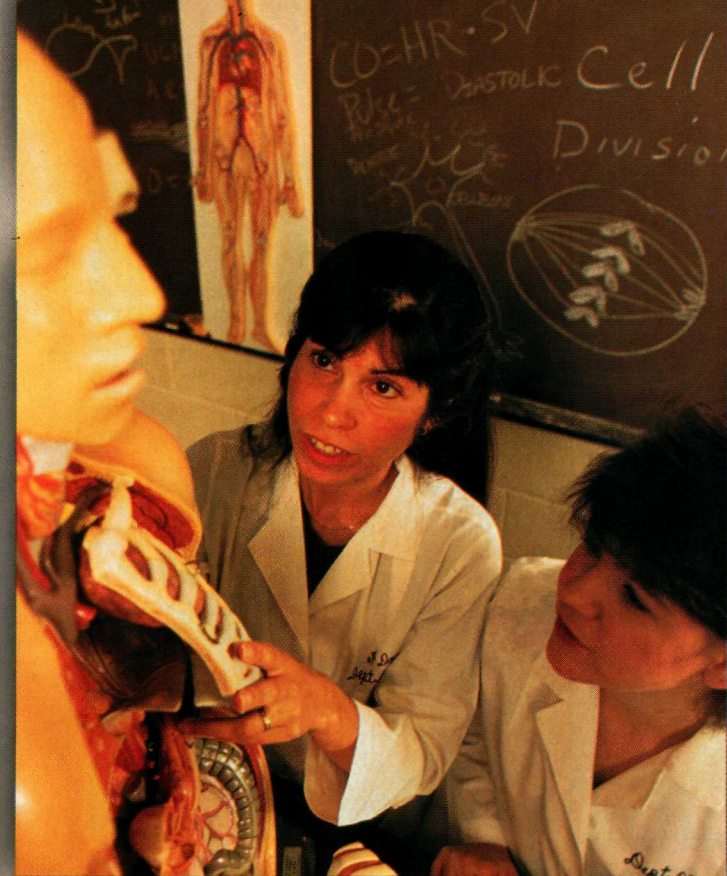
— Alfred North Whitehead (1929)

During the last three years at the Illinois Mathematics and Science Academy, we have been working on a partial reconstruction of Whitehead's "one subject matter," a course reconnecting biology, chemistry, earth and space sciences, and physics into an Integrated Science program.

The Academy's Integrated Science program is a three-semester, double-period course offered as an alternative to

our core sequence of science instruction—consecutive, two-semester, single-period courses in chemistry, physics, and biology. Integrated Science began in fall 1993 with a single section of students meeting with three teachers who were developing the program. As a result of interest among students and teachers, we offered three sections in 1994 and 1995. After the first year, a single instructor was assigned to each class; six teachers now participate.

The Integrated Science program is not, and never will be, finished. By design, as new adults and students participate, it evolves. In keeping with our Academy's mission—to transform mathematics and science education—the program will not result in a static textbook of integrated science but will yield a collection of interconnected experiences that other learning communities can use. The Academy faculty knows that, with the development of national standards (American Association for the Advancement of Science 1993, National Research Council 1994), schools will be examining their science curriculums. Perhaps what we learn about integrating science instruction will help others.



© Peter Cade/Tony Stone Worldwide



Tricia Louise Baham



Leonard Crosby

When science teachers at the Illinois Mathematics and Science Academy reconnected the sciences into one course, they discovered that dialogue and standards became glue for any rifts in their integration process.

What Is Integration?

Integration has many meanings. Our integration provides engaging experiences in which students encounter essential content in multiple and meaningful contexts in response to their own inquiry. We have embraced integration to get rid of two serious deficiencies of traditional secondary school science instruction—deficiencies in transfer of knowledge and in transfer of authority.

If learning has value, students should be able to transfer the knowledge they acquire in school to the world beyond the classroom. Today's schools, in spite of intentions, may not enable this transfer (Ceci and Ruiz 1994). While learners can demonstrate success in a familiar context, in new situations their former misconceptions reemerge. For example, many graduates of our science programs, when asked to explain a scientific phenomenon in their experience, regress to the "mind of the 5-year-old child" (Gardner 1991). In the Integrated Science team's search to identify what would help students transfer knowledge from familiar to novel situations, we learned, as have others before us, that engagement and learning in multiple contexts enhances

the transfer of knowledge.

According to the American Psychological Association (McCombs 1992), learning is

an individual process of constructing meaning from information and experience, filtered through each individual's unique perceptions, thoughts, and feelings.

This reminds us how it is that we learn: the expert does not create or convey meaning to the novice. The student must take ownership of his or her own learning, and remove any barriers to inquiry. When the student directs his or her own learning, the learning is often not neatly compartmentalized within the scientific disciplines.

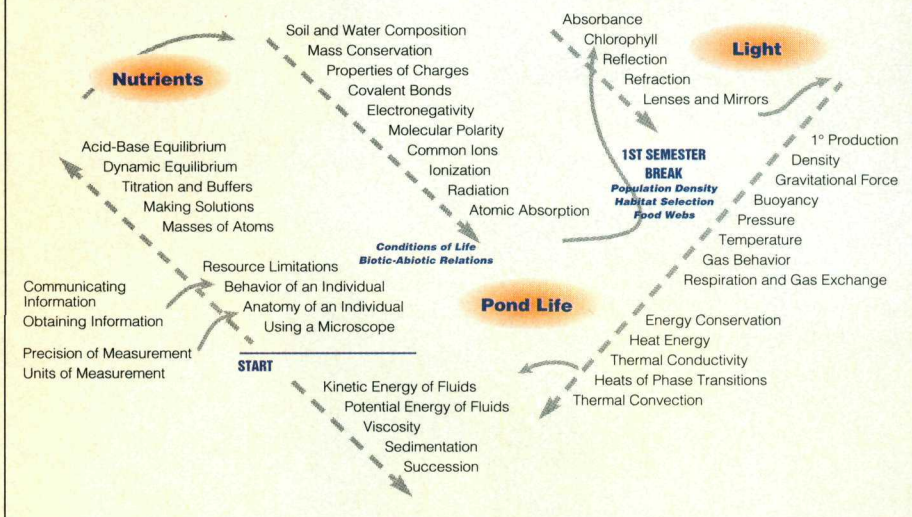
Tackling Dilemmas: Lessons We Learned

Our program confronted the problems in transferring knowledge and authority, but we faced other, unexpected problems on the way.

The rift of thematic organization. In our first year, we began by reading futurist literature. We encouraged our students to use these works to help define the problems they

FIGURE 1

The Pond Platform



© Dave Harp

considered of greatest urgency for their futures. This did not work as well as we had hoped; students perceived the organizing theme of Human Population Growth as one chosen by the instructor. We then proceeded through a content sequence on population distributions. While the connections between these pieces to the organizing theme were clear to the instructors, they were not clear to most students.

Through this frustration, we recognized that to integrate content through conceptual themes was a serious flaw in our design. Of a list of such themes as population, energy, information, gradient, and cycle, Whitehead (1929) said,

The best that can be said of it is that it is a rapid table of contents which a deity might run over in his mind while he was thinking of creating a world, and has not yet determined how to put it together.

This echoes our experience. These are organizing principles for instructors, not for students.

The glue of physical context. We reexamined the structure of the course before the second group of students entered the program. We replaced the thematic organization with a focus on the concrete by introducing the idea of a problem platform, a physical,

project-based context to support the curriculum. Because a small drainage pond lies nearby, our first problem platform rested on the question, “Why is life as it is in the pond?” Students used library resources to identify questions, not answers, that might be fertile paths of investigation. The three most commonly identified issues were

- What is the effect of light on the pond?
- What nutrients control life on the pond?
- What are the relationships among different kinds of life in the pond?

Figure 1 shows a specific sequence of content pieces that followed from student questions. Students observed and described microscopic pond life; brought samples into the lab and maintained them in tanks; and initiated, designed, and carried out experiments that manipulated the tanks’ chemistry, light, or temperature. In so doing, they encountered essential content in support of their experiments.

The glue of analogy. A second problem platform supports the remainder of the content, which we presented during the second semester. Students were asked to design a Mars-like base for human habitation. As before, we began with the students’ set of “need-to-know” questions:

- What conditions exist on Mars?
- Is colonization a right of our species?
- How can a sustainable habitat be created?

The first question provided us with a useful context for the primary component of an introductory physics course—mechanics.

Analogy is a powerful tool for the creation of new science and also for learning. By examining the atmospheric and geologic conditions on Earth, we develop concepts that can be applied to Mars. A sustainable design for Mars requires an understanding of energy transformations and conservation on Earth. Adaptation, selection, and evolution emerge as natural consequences of terraforming Mars. Obviously, our second problem platform also provided us with many integrated activities.

The rift of passive minds. Another misconception we had at the start was that all secondary school science students have, and are willing to express, interests they wish to pursue. Our students, when given the opportunity, did not rush to take ownership of their learning or discard their passive learning habits.

We also had to confront our own

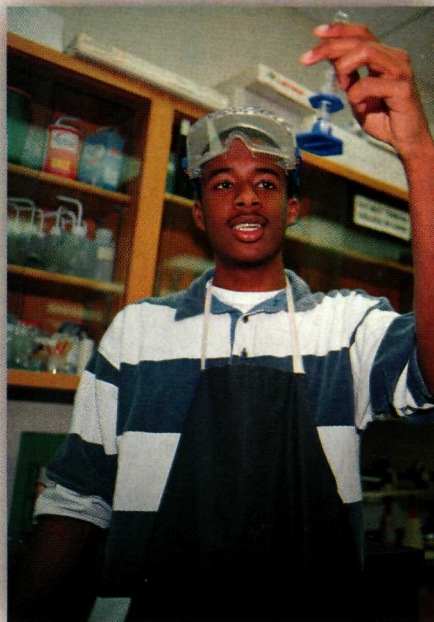
habits of mind. As disciplinary experts, we examine a complex problem, such as “understand the pond,” from a narrow perspective. We see connections to familiar activities and jump to a typical sequence of topics. Without seeking open dialogue across disciplines among our colleagues, we resort to these sequences, and students encounter a program no less fragmented than traditional approaches.

We instructors face another difficulty in delivering rather than writing curriculum. We must confront questions and challenges outside of our disciplines, and be willing and—as a model for the student—eager to confess ignorance.

The glue of dialogue. When we confronted the problem of our own habits of mind, we decided to change the schedules so that Integrated Science teachers would have a common preparation period in which to collaborate. These opportunities for dialogue have produced challenges and self-reflections necessary to break down the dogma of our disciplines. We have been surprised and excited by the consequences. Examining standard activities with fresh eyes has produced more powerful experiences for students and more connected learning.

The rift of assessment. Our Integrated Science program is an experiment in progressive education. Gardner’s critique (1991) of progressive education could have been written from observations in our classroom during the first year. He praised this approach over all others, warned of its difficulty, and identified two weaknesses: (1) some students will be insufficiently motivated to accept the responsibility of active learning, and (2) an individualized and project-based curriculum creates great difficulty for assessment.

The glue of significant standards. In the program’s second year, we developed a subjective assessment method that focuses the teacher and the student on the characteristics of self-directed learners, our Standards of Significant Learning, shown in



When the student directs his or her own learning, the learning is often not neatly compartmentalized within the scientific disciplines.

Figure 2 (Illinois Mathematics and Science Academy Outcomes Council 1993). We communicate the importance of these standards explicitly and frequently to students. Where a sequence of activities connects very strongly to a particular standard, we ask the students to assess their performance in writing. Each student has an individual conversation with the instructor to discuss this self-assessment. These conversations are perhaps the program’s most exciting element.

The instructor adds a narrative evaluation to the student’s. This performance description is much more valuable to the student than a grade. The student’s family receives these narratives twice during the semester, and residential and college counselors have access to them. More important,

these assessments help students learn to evaluate themselves. In evaluating the course, students often indicate the value of these narratives:

The Standards of Significant Learning are a very good idea because they give me a chance to tell you and whoever else reads them about how I am doing. While I write them, I get a chance to reflect and decide what I need to work on. They make me set little goals.

Assessing the Program

Does Integrated Science work? Five other questions helped us answer this question:

■ *Is the program consistent with emerging national and state standards?* The emerging national standards for science education (American Association for the Advancement of Science 1993, National Research Council 1994) are expressed in discipline-free terms. The Integrated Science program’s content and its interdisciplinary nature align with these standards.

■ *Does student performance match the conceptual and skill outcomes defined by these standards?* From examinations that all sophomores take, we compared the performance of students in Integrated Science and in the traditional disciplinary sequence. Performance the first year was indistinguishable from the disciplinary control group. The performance of the second class of Integrated Science students was significantly better than the control group on three of six questions, which is encouraging.

■ *Does the program positively affect the student’s attitude toward science?* We use the Mayer attitudinal survey (Csikszentmihalyi et al. 1993) to evaluate students’ levels of engagement with science. These surveys suggest that students in the Integrated Science program are more engaged, but also more frustrated, than their peers in the traditional sequence. We believe that the greater frustration arises from a more challenging curriculum, greater responsibility for learning placed upon the student, less guidance in the discovery process, and an immature curriculum.

FIGURE 2

Standards of Significant Learning

Standards of Significant Learning (SSLs) represent the habits of mind that contribute to integrative ways of knowing. We expect these ways of knowing to broaden and deepen over time.

I. Developing the Tools of Thought

- A. Develop automaticity in skills, concepts, and processes that support and enable complex thought.
- B. Construct questions that further understanding, forge connections, and deepen meaning.
- C. Precisely observe phenomena and accurately record findings.
- D. Evaluate the soundness and relevance of information and reasoning.

II. Thinking about Thinking

- A. Identify unexamined cultural, historical, and personal assumptions and misconceptions that impede and skew inquiry.
- B. Find and analyze ambiguities inherent within any set of textual, social, physical, or theoretical circumstances.

III. Extending and Integrating Thought

- A. Use appropriate technologies as extensions of the mind.
- B. Recognize, pursue, and explain substantive connections within and among areas of knowledge.
- C. Recreate the "beautiful conceptions" that give coherence to structures of thought.

IV. Expressing and Evaluating Constructs

- A. Construct and support judgments based on evidence.
- B. Write and speak with power, economy, and elegance.
- C. Identify and characterize the composing elements of dynamic and organic wholes, structures, and systems.
- D. Develop an aesthetic awareness and capability.

V. Thinking and Acting with Others

- A. Identify, understand, and accept the rights and responsibilities of belonging to a diverse community.
- B. Make reasoned decisions that reflect ethical standards, and act in accordance with those decisions.
- C. Establish and commit to a personal wellness lifestyle in the development of the whole self.

■ *Does the program prepare the student for success in more advanced science courses?* After completing the core sequence, our students may choose from many science electives. So far, Integrated Science students perform in these more advanced science courses as well as do students who have completed the disciplinary sequence.

■ *Does the program enhance growth toward the habits of mind represented by the Academy's Standards of Significant Learning?* This question is the

most difficult to answer. As of now we have only the subjective measures provided by the student and instructor narratives on the Standards of Significant Learning. But we also have the immeasurable value of our conversations about this question.

The Path of Integration

We are practitioners seeking a stronger relationship between the children for whom we care and a way, which we love and trust, of revealing and inventing the world. We have chosen a

path of integration as a means of creating a learner-centered institution, where both adults and children pursue useful knowledge. We have encountered many problems associated with the development of an integrated science program for secondary students. We also have found, however, that the problems are outweighed by the intellectual growth for both students and instructors and by the engaging nature of situations framed, not by discipline boundaries, but by their place in the real world. ■

References

- American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.
- Ceci, S. J., and A. Ruiz. (1994). "Transfer, Abstractness, and Intelligence." In *Transfer on Trial: Intelligence, Cognition, and Instruction*, edited by D. Detterman and R. J. Sternberg. Norwood, N.J.: Ablex.
- Csikszentmihalyi, M., K. Rathunde, and S. Whalen. (1993). *Talented Teenagers: Roots of Failure and Success*. Cambridge, England: Cambridge University Press.
- Gardner, H. (1991). *The Unschooled Mind*. New York: Basic Books.
- Illinois Mathematics and Science Academy Outcomes Council. (1993). "Standards of Significant Learning." Unpublished manuscript.
- McCombs, B. L. (1992). *Learner-Centered Psychological Principles: Guidelines for School Redesign and Reform*. Washington, D.C.: American Psychological Association.
- National Research Council. (1994). *Draft of National Science Education Standards*. Washington, D.C.: National Academy Press.
- Whitehead, A. N. (1929). *The Aims of Education*. New York: The Free Press.

Authors' note: This work was supported by the Smithsonian. Cathy Veal and Jay Thomas assisted.

John Eggebrecht, Don Dosch, Norman J. Merczak, Margaret N. Park, Susan C. Styer, and David Workman are Science Instructors. **Raymond Dagenais** is a Research Specialist. The authors may be reached at the Illinois Mathematics and Science Academy, 1500 W. Sullivan Rd., Aurora, IL 60506 (e-mail: egge@imsa.edu).