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Learning Science through Design. ERIC Digest.

Mention of "hands-on" or experiential learning and skill development in science education generally brings to mind the emphasis on inquiry in current reform efforts. Inquiry has been a major focus in science education for three decades (Haury, 1993), but it is only one component of the active learning in science endorsed by national science curriculum standards (National Research Council, NRC, 1996). Actively engaging students in technological design is the complementary strand that has received much less attention. The lack of attention to learning science through design is unfortunate since this neglected counterpoint to inquiry has the potential to profoundly enrich science teaching. The neglect is also ironic, since the underlying concept is as ancient as humanity itself. Teaching anything through design taps into the most basic of human tendencies: designing procedures and artifacts--using "tools"--to meet environmental challenges, accomplish difficult tasks, reach goals, increase personal and collective well-being, and generally enrich life. Using technology to meet the challenges of life is a characteristically human endeavor that predates science by thousands of years. Sadly, technology as a subject has been largely ignored in U. S. schools (Project 2061, 1993) and "has no fixed place in elementary education, is absent...in the college preparatory curriculum, and does not constitute part of the content in science courses at any level" (p. 41).

Teaching science through design formally engages students in this basic human approach to meeting life's challenges, and in the process addresses several longstanding issues in science education, including the following:

* Integrating the sciences with other subject areas in the arts, humanities, and social studies.

* Forging connections to daily life.

* Facilitating active learning.

* Accommodating a variety of student learning styles.

* Attending to science in the context of technology and society.

* Nurturing imagination and creative thinking.

* Developing skills in critical thinking, problem solving, and decision making.

* Increasing awareness of science-related dimensions in occupations and avocations.

Further, Alexander (Foreword to Davis, Hawley, McMullan, & Spilka, 1997) has pointed out that, "Whether the objective is a product, a building, a city plan, or a graphic communication, when children are engaged in the process of designing, they are learning to identify needs, frame problems, work collaboratively, explore and appreciate the context within which a solution must work, weigh alternatives, and communicate their ideas verbally, graphically, and in three dimensions." In short, learning through design engages students in activities fundamental to a satisfying and productive life in the desig7ned environment of our culture.

WHAT DOES LEARNING THROUGH DESIGN ENTAIL?

The design process varies to some extent according to situational circumstances and the individuals involved, but it generally includes the following steps:

* Identifying and defining problems.

* Gathering and analyzing information.

* Determining performance criteria for successful solutions.

* Generating alternative solutions and building prototypes.

* Evaluating and selecting appropriate solutions.

* Implementing choices.

* Evaluating outcomes (Davis et. al., 1997, p. 3).

In describing the abilities to develop among students the NRC (1996) delineated a 5-step framework for design:

* Stating the problem.

* Designing an approach.

* Implementing a solution.

* Evaluating the solution.

* Communicating the problem, process, and solution (p. 137).

Though this framework is elaborated somewhat differently for standards in grades K-4 (p. 137), 5-8 (p. 165), and 9-12 (p. 192), the same 5-step structure is maintained. In the NRC model there are modest, but significant, deviations from the general design process: First, four discrete elements in the generalized model are combined into the single step of "designing an approach" and second, the important step of communicating the problem, process, and solution is explicitly stated. Some have questioned the validity and value of depicting the design process in such a simplistic, linear model (Roth, Tobin, & Ritchie; 2001), but there is widespread agreement that engaging students in design is an important dimension of science education (American Association for the Advancement of Science, 1989; Project 2061, 1993).

The concept of learning through design is not new (Royal College of Art, 1976), and there have been a number of programs in U. S. schools during the past 30 years promoting the design process. Until recently, however, it could be said that "the use of design activities in U. S. schools remains an isolated practice that has its strongest support at the level of the individual teacher" (Davis, et. al., 1997, p. 8). The current science education reform movement and publication of national standards (National Research Council, 1996), however, have reemphasized the need to pay greater attention to design, particularly in the context of technology and engineering. Though the standards present design as "the technological parallel to inquiry in science" (p. 135), others go further in making a distinction between the roles of analysis and synthesis, pointing out that analysis is more central to inquiry, but synthesis is more central to the problem solving strategies associated with design (Davis et. al, 1997, p. 4). The differences between inquiry and design also relate to differences in the purposes of science and technology: "scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems" (NRC, 1996, p. 192).

BENEFITS OF LEARNING THROUGH DESIGN

As noted by Roth, Tobin, and Ritchie (2001), the act of designing focuses student attention on doing something rather than knowing something, which changes the school learning context to a more natural condition that resembles learning situations outside schools, learning on a "need-to-know" basis. Design involves learning along the way in the process of pursuing goals, goals that can be set by students themselves and pursued at their own pace (p. 27).
Another benefit of design activities is the opportunity to naturally weave together skills, processes, and knowledge that are typically taught separately in the discrete subjects of traditional curricula. Design activities engage students in "enterprise" rather than "school subjects"(Davis et al, 1997, p. 4), an approach that introduces students to the integrated, synthetic problem solving required of adults in their work and daily lives.

Design activities also provide an experiential context for students in the early grades to gain familiarity with the materials and forces of nature before they are able to engage in direct scientific inquiry (Davis et. al, 1997, p. 74). Young students can examine familiar objects from zippers to can openers and cars to study design problems and evaluate effectiveness.

Roth (1996b) has also pointed out that design activities give rise to questions for which teachers do not have predetermined answers. Questioning patterns can be directly based on student experiences and their thinking relative to the challenges and concerns emerging from the design process. Student understanding and reasoning, then, can be evaluated on context-specific criteria associated with the design activity rather than semblance to predetermined "answers."

Finally, learning to frame and solve the problems associated with design activities prepares students for the lifelong challenge to frame questions, gather information, learn, and develop competences as they solve problems in the context of daily life (Roth, 1996a, p. 45).

SOURCES OF INFORMATION AND SUPPORT

Formal attention to learning through design is an emerging field in education, and there are few sustained programs with resources and proven practices to lead the way. There are, however, widely scattered programs, case studies, and information sources where science educators can gain direction and assistance. For reports on the implementation of engineering design projects in 24 secondary-science classrooms following an inservice professional-development course conducted at a university engineering college, see Carlsen (1998). Several detailed case studies of learning through design are presented by Roth, Tobin and Richie (2001). Following is a brief compilation of resources that can point the way to learning science through design.

- "Learning by Design from Theory to Practice"
- J. L. Kolodner, D. Crismond, J. Gray, J. Holbrook, & S. Puntambekar
- http://www.cc.gatech.edu/edutech/projects/lbd_icls98/icls_LBD.html
- "LEGO/logo: Learning Through and About Design"
- M. Resnick & S. Ocko
- http://llk.media.mit.edu/papers/1991/ll.html
- "NASA Earth-to-orbit Engineering Design Challenges"
-

http://www.terc.edu/TEMPLATE/Products/item.cfm?ProductID=10

- "Science by Design" Series

- High school challenges published by the National Science Teachers Association. Individual titles include: "Construct-a-glove", "Construct-a-boat", "Construct-a-greenhouse", and "Construct-a-catapult".

- http://ra.terc.edu/publications/Alliance_Access/Vol5-No1/design.ht ml

- "Science, Design, and Education"

- http://www.sit.wisc.edu/~crusbult/methods/

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