# A Model for Unified Science and Technology

By Roy Q. Beven and Robert A. Raudebaugh

## The Problem

Scientific concepts and processes are best developed in the context of technological problem solving. However, even some of the best secondary science curricula are weak in technology education and visa versa. A goal of technology and science education is to integrate student learning of science and technology. This is evident in the theme and papers of the 1996 Jerusalem International Science and Technology Conference and the efforts of the National Science Foundation, the American Association for the Advancement of Science (Project 2061, 1990), the National Research Council (National Science Education Standards, 1995), and The International Technology Education Association (Standards for Technological Literacy, 2000).

## Science and Technology

Humans first used technology in a very intuitive way. Prehistoric evidence indicates that people learned to use the materials at hand, mostly stones and tree branches, to fashion simple tools to aid in gathering food and providing security. Discoveries of copper, bronze, and iron were mostly accidental, and their use in tools and weapons mostly intuitive. During the Renaissance, craft guilds were formed and the skills and knowledge of technology became more formalized, but it was still developed primarily through trial and error by highly creative and intuitive individuals. As societal needs grew and the demands on technology grew more sophisticated, links to the scientific community were forged, giving rise to formal engineering. According to Shamos (1995), "the more complex forms of technology, which could prosper only through painstaking design, eventually gave rise to the formal disciplines of engineering, whose main objective is to reduce the purely empirical content of technology, to make it, in effect, more 'scientific' " (p. 70).

This link has also been recognized in Project 2061: Science for All Americans (American Association for the Advancement of Science [AAAS], 1990) as evidenced by the following statement: "But just as important as accumulated practical knowledge is, the contribution to technology that comes from understanding the principles that underlie how things behave-that is from scientific understanding" (p. 26).

Shamos (1995) also recognized the mix of science and technology as an interdependent relationship in which technology uses the tools of science, which by extending human capability allows us to harness or modify nature to our needs. Project 2061 (AAAS, 1990) described this relationship as one in which

> scientists see patterns in phenomena as making the world understandable; engineers also see them as making the world manipulable. Scientists seek to show that theories fit the data; mathematicians seek to show logical proof of abstract connections; engineers seek to demonstrate that designs work. (p. 27)

This relationship is again described in the *Technology for All Americans* (International

Technology Education Association [ITEA], 1996) document.

> Science is a study of the natural world, and technology extends people's abilities to modify that world. Science and technology are different, yet symbiotic. Technology is much more than applied science and science is quite different from applied technology. When people use technology to alter the natural world, they make an impact on science. Science is dependent upon technology to develop, test, experiment, verify, and apply many of its natural laws, theories, and principles. Likewise, technology is dependent upon science for its understanding of how the natural world is structured and how it functions. (p. 28)

## Teaching Science and Technology

Today, probably as a result of the concerted drive during the past few decades to introduce technology education into the schools, science and technology are often considered one and the same. The problem with this is that most of what society experiences are the end products of scientific inquiry, namely those produced by technology, and almost all so-called science-based societal issues are actually based in technology rather than in science.

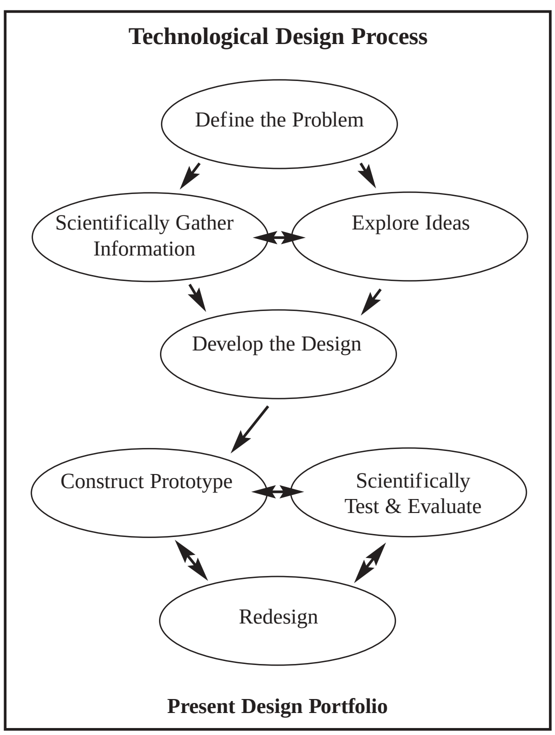
> Hence painting both with the same broad brush is a disservice not only to the science and technology communities, but also to society, which must understand that technology is fundamentally a social activity and that the social and economic forces which prompt technologists to modify nature are very different from those that motivate scientists to seek ways of understanding. (Shamos, 1996, pp. 68)

Obviously one cannot deal effectively with the nature of science solely in the abstract; it must be placed in the context of science itself, both for example and emphasis. According to Shamos (1995), educators now know that given a choice between stressing science or technology for the general student, the better choice is technology. But this poses a problem in respect to certain topics because technology is not the best exemplar of many of these, while science is. It is easy to focus a curriculum on technology alone, but such a program would not convey an awareness of how science works, which should be science education's main objective. Hence, both science and technology must have their own roles in the proposed curriculum, with the former used mainly to depict science process but with the actual content leaning heavily on technology.

This is more easily said than done because it brings us full circle to the question of how to present science to the general student in a meaningful fashion, something we have not managed to do well in the past. "The obvious answer, we believe, is to begin with technology, with problems that evoke familiar images of one's common experiences, and use these to work back to the underlying science needed to deal with such questions as scientific truth, laws and theories" (Shamos, 1995, p. 224-225).

To help guide students toward the kind of scientific awareness that Shamos (1995) believed to be the appropriate objective of general education in science, science education must sharply change the emphasis of conventional curricula from science content to the process of science, continually stressing technology.

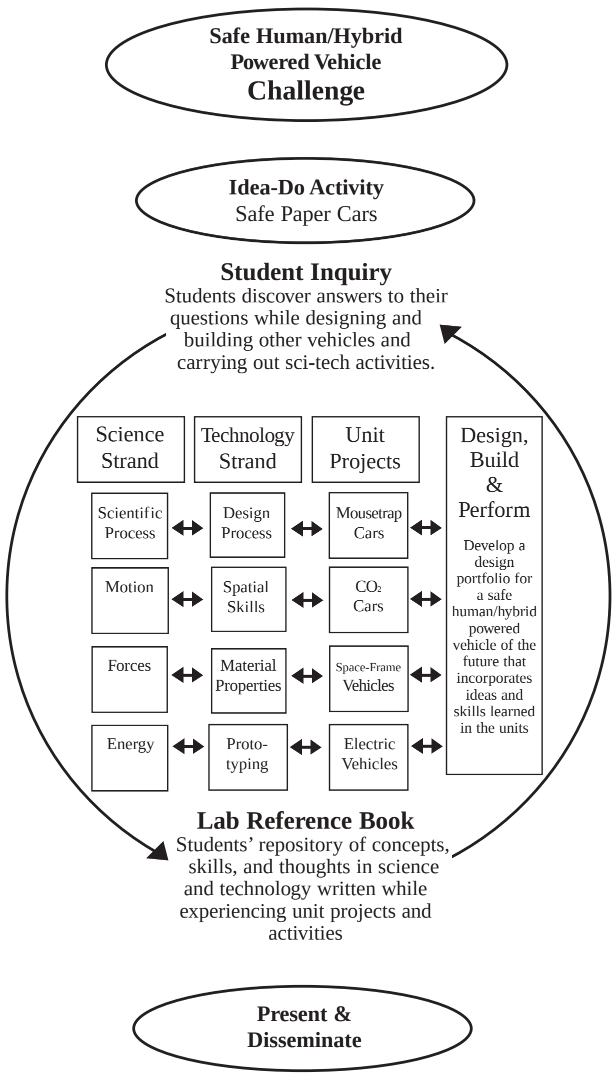
**Figure 1. Format for Learning and Curriculum Design**



## One Proposed Solution

The relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science (National Academy of Sciences [NAS], 1996. The key to a unified approach for science and technology lies in the use of the Technological Design Process as the format for learning and curriculum (see Figure 1). The model presented here represents a unified science and technology curriculum with a transportation theme for the middle grades. Students are engaged in the design-build process involving familiar concept vehicles and research of pertinent information in a scientific manner. Thus, students build the middle school science ideas associated with these vehicles while developing an understanding of the design process and building technical skills.

**Figure 2. Move with science and technology curricular design**




## Curriculum Design

The curriculum model in Figure 2, which the authors have titled "Move with Science and Technology," is composed of a unifying project and four related units of study. Students are hooked into the notion of vehicle design with a quick, fun paper-car activity. They are then given the overall design challenge: design and build a human/hybrid-powered vehicle that addresses safety and environmental and transportation problems for the future. To help them in this unifying project, they will be guided through four instructional units of study.

Each unit challenges teams of students to design and build concept vehicles. The result of each design process is written up in individual design portfolios and presented by the team to the class. These vehicles are somewhat familiar middle school technology projects: a mousetrap car, CO2 car, space-frame vehicle, and an electrically powered vehicle. These units build hierarchical science and technology process skills and make a complete science and technology curriculum, especially when tied together with the unifying project. The four units can be used as stand-alone units, but the unifying project adds greatly to the real-world authenticity of the curriculum.

Throughout the curriculum, students return to the unifying project—safe human/hybrid-powered vehicles. As they move through this design process, they employ the ideas and skills developed in the units. The prototype of their human/hybrid-powered vehicle should be, but does not necessarily have to be, a working prototype. The overall assessment of this and the smaller projects is based upon their documentation of the design process, not how well their project actually works.

## Conceptual Development

This unified science and technology model is guided by the National Science Education Standards mandate to supplement middle-level science coursework with "activities that are meant to meet a human need, solve a human problem, or develop a product" (NAS, 1996, p. 161). Current trends in technology education include providing middle-level students with activities that allow them to develop "real technological products, systems, and environments" (ITEA, 1996, p. 38) and the recognition that "some technological problem are best solved through [scientific] experimentation" (ITEA, 2000, p. 110).

The human/hybrid-powered vehicle is the central challenge that ties together the four smaller design-build units of this curriculum. These four units build the necessary ideas, knowledge, and skills required to design and build a human/hybrid-powered vehicle.

An additional goal of this curriculum is the understanding of the risks associated with vehicles and how to reduce those risks. Students learn that "science cannot answer all questions and technology cannot solve all human problems or meet all human needs" (AAAS, 1990, p. 169). This curriculum recognizes that middle-level students can "begin to develop the ability to assess the impacts of [technological products and systems] on individuals, society, and the environment" (ITEA, 1996, p. 38). Thus, the activities are designed to allow students to learn the what, how, and why of human safety associated with vehicles.

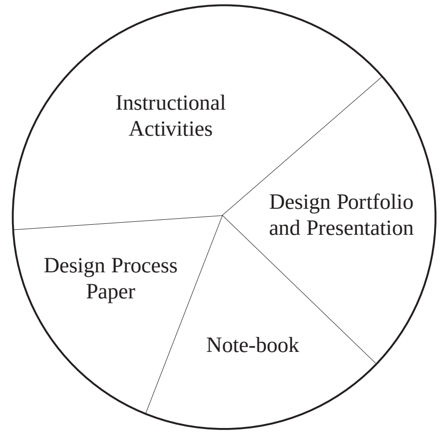
From the first activity, paper cars, students recognize the need to have an energy source that results in a force forward on their vehicle in order to cause the vehicle to move in the desired direction. The relationship between energy, force, and motion is a common theme in each of the design-build activities. The goal is to "provide concrete experiences on which a more comprehensive understanding of force can be based" (NAS, 1996, p. 149). Specifically, students are asked to describe the motion, identify the forces causing it and the energy source in each of the design-build activities, and develop the ability to do this through well-connected science and technology instructional activities. These activities help students develop the concept of energy because they may "have some of the same views of energy as they do of force—that it is associated with animate objects and is linked to motion" (NAS, 1996, p. 154). In addition, students are repeatedly asked to describe energy transfers because middle level students "improve their understanding of energy by experiencing many kinds of energy transfer" (NAS, 1996, p. 154).

Another theme of Move with Science and Technology is establishing the meaning and use of scientific inquiry. All the instructional activities "engage students in identifying and shaping an understanding of the question under inquiry" (NAS, 1996, p. 144). The use of a centering design-build activity provides relevant and meaningful context so that students "know what the question is asking, what background knowledge is being used to frame the question, and what they will have to do to answer the question" (NAS, 1996, p. 144).

## Unit Design

Each unit challenges teams of students to design and build a vehicle, create a design portfolio, and present their design to the class. As described above, these vehicles are somewhat familiar middle school technology projects: a mousetrap car, CO2 car, space—frame (crash test) vehicle, and an electrically powered vehicle. These units build hierarchical science and technology process skills. Each unit has eight instructional activities, including four in science and four in technology, all centered upon scientific research and the design process for these concept vehicles. The instructional activities associated with the *scientifically gathering information* and *scientifically testing and evaluation* phases are exemplary science investigations in which a controlled experiment is

**Figure 4. Suggested unit assessment**

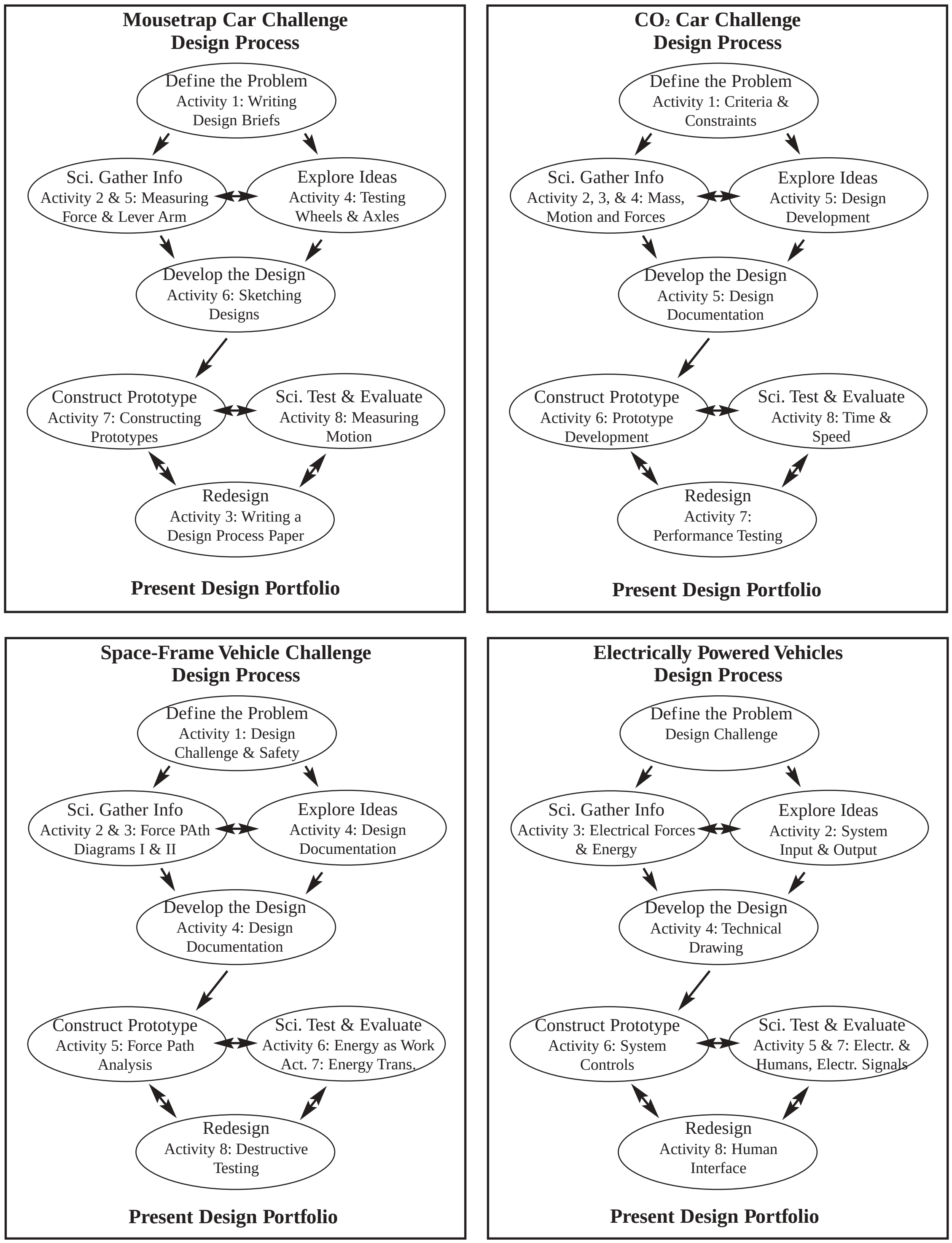


self-evident. Instructional activities associated with *define the problem* phase help students write design briefs while learning about criteria and constraints. Activities associated with *exploring ideas* and *developing the design* lead students through an exemplary sketching and technical drawing process described in an extensive supplemental piece.

In the units, the unification of science and technology is so seamless that students are focused upon a design process involving scientific inquiry and not, unless queried, aware of which activity is science and which is technology. At the completion of each unit, students are asked to write an expository paper documenting their design process. Students are then asked to

**Figure 3. Unit summaries with activities and their association to the design process.**

**Move with Science and Technology Units**



create a personal showcase portfolio composed of this technical paper and all the activities and notes of this unit as artifacts. To bring closure to each unit, student teams are invited to present their composite design portfolio to the class, including their vehicle and other artifacts of their design process. Figure 3 shows each unit, the eight activities, and how these activities are associated with phases of the design process.

### Assessment

Student achievement in this model can be assessed, as prescribed in the curriculum, as a balance between students' performance in instructional activities, writing in their design process papers and notebooks, and their compiled portfolios and presentation. This balance, shown in Figure 4, indicates suggested weights of each of the artifacts. As students move through the four units and on to the unifying project, more and more weight can be put on the portfolio and its presentation.

The authors have developed, tested, and published the curriculum "Move with Science and Technology" as described in this article. Currently, the National Science Teachers Association (NSTA) Press, through a cooperative agreement with the National Highway Traffic Safety Administration, is publishing three of the units shown in Figure 3 in a curriculum guide called Fender Bender Physics. This curriculum guide includes student pages designed for reproduction as in-class materials and an associated teacher's guide that helps with the delivery of each unit and activity. Fender Bender Physics also contains a supplemental materials section that is written in grade-level, relevant terms intended for the instructor and/or students. Fender Bender Physics is currently available for on-line purchase at the NSTA Website, http://www.nsta.org.

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