Science and Technology: A New Alliance

MARK SANDERS

Where does science end and math begin? The lines of demarcation among science, math, and technology are a lot easier to spot in school than they are in the real world. Is it science, math, or technology when a student works on an Ohm's law problem? The Technology/Science/Math (T/S/M) Integration Project is an attempt to bring these areas together by better coordinating instruction. In doing so, content is more relevant and therefore better internalized by students.

The T/S/M Integration Project is an attempt to use hands-on, technological, problem solving activities to interest more middle school children in science and math. These activities draw upon the inherent excitement most kids have for working with tools, materials, and technological processes while challenging them to apply science and math principles in new and interesting ways. Through this process, perhaps more middle school students will become more interested in science.

An alliance between science and technology

Educators in general and science educators in particular are increasingly aware of the growing importance of technology in our society and its increasing relevance to the science curriculum. At the same time, teacher teams in contemporary middle schools are better able to address the interdisciplinary nature of content than was possible with the traditional junior high school structure of the past.

These two trends call out for a new collaboration in the middle school: a collaboration between science and technology teachers. Just as science isn't "business as usual" in the middle school, neither is technology education. Today, technology teachers are moving toward integration with science—and mathematics as well—particularly in the middle school where interdisciplinary teaching is already taking place.

Despite the fact that this union between technology and science is entirely logical, with the exception of a few scattered innovative science and technology teachers, the true integration of science and technology has not yet occurred. The Science, Technology, and Society movement (STS) has begun to address this need, but the STS curriculum emphasis is much stronger in the social sciences than it is in technology, and technology teachers have seldom been involved in STS curriculum development or implementation.

Mark Sanders is an associate professor in the Technology Education Program Area at Virginia Polytechnic Institute and State University, Blacksburg.

What is technology education?

Technology education is the area that studies many different technologies . . . not just computers. Technology educators organize their content to fit within three major technological systems: communication, production, and transportation. In the middle school, technology teachers teach content in all three of these areas. Units on communication include desktop publishing and electronic communication systems; units on production deal with manufacturing and construction; and transportation units study aerospace and mass transit systems, to name a few.

You know technology education's predecessor very well . . . "industrial arts." Woodshop and metalshop. Birdhouses and waterpump lamps. But that is not what technology education is! For more than 40 years, the field has been working to change it's focus to technology. This shift began in 1947, when William E. Warner presented a paper titled "A Curriculum to Reflect Technology" at the annual conference of the American Industrial Arts Association.(1) Since that time, the field has made massive strides toward transforming to technology education. In 1985, the American Industrial Arts Association changed its name to the International Technology Education Association, and the "technological problem solving method" has quickly taken hold as the preferred method of instruction. It is now common to see technology teachers using a series of technology problem solving activities such as the "mousetrap car," "bridge and structure design," or "glider construction" to form the core of their curriculum.

The shift from the "project method" to the "problem solving method" of instruction represents one of the biggest changes in technology education. For many industrial arts teachers, the project (for example, bookshelf) became an end in itself. In the most extreme but not uncommon cases, students were provided with plans, thereby limiting the higher-level thinking that takes place during design and development. Contemporary technology teachers, on the other hand, focus on presenting design and construction problems. Students in these classes use a wide variety of tools, materials, and technological processes to design and construct solutions to the problems posed.

But what they are not generally doing is coordinating these efforts with science teachers. Thus students are not necessarily relating and applying science as they design and build solutions to these problems. Moreover, there is rarely an evaluation component to these activities, which is critical.

The T/S/M Project

With funding from the National Science Foundation, The Technology/Science/Math (T/S/M) Integration Project is developing activities that require the application of science and math principles to solve technological problems. Consider, for example, "Capture the Wind," one of the activities developed by the project. "Capture the Wind" challenges middle school students to design, construct, and evaluate a device that transforms wind energy into electrical energy. This is a problem that engineers and inventors have wrestled with for centuries, and it's a problem with a solution that involves science, math, and technology at every step of the way. It's a challenge middle school students can have a lot of fun with and a chance to apply the concepts they're learning in science and math classes in a way they can understand.

This approach is not new. Many science fair projects involve a great deal of technological problem solving. Similarly, "Odyssey of the Mind" competitions (developed by Sam Micklus, an industrial arts/technology education professor) take advantage of the inherent motivating power of technology problem solving activities. It is also worth noting that the first-prize award in the 1992 Duracell/NSTA competition went to a student who developed a battery-powered adjustable wrench, devised under the guidance of his technology teacher.

But these examples of technological problem solving are all implemented as extracurricular programs. The T/S/M Integration Project is an attempt to develop activities that fit within the existing middle school structure and curriculum. They are activities that should be delivered by science, math, and technology teachers working together. Although a shared block of time among these three teachers would be optimal, even the most progressive middle schools usually are not set up this way, and sharing blocks of time is not essential. But successful implementation requires communication and coordination among the three teachers so their instructional units are complementary rather than unconnected.

Capture the Wind

To get an idea of how this sort of activity brings science, math, and technology together, let's see how "Capture the Wind" might work in a middle school. As with the other 15 T/S/M Integration Project activities, "Capture the Wind" is introduced to the student with a one-page "T/S/M Integration Brief." (See Figure 1.) This activity challenges students to design, construct, and evaluate a device that transforms wind energy into electrical energy. "Capture the Wind" would be introduced in all three classes—technology, science, and math—at about the same time. Unfortunately, in most cases, only

Figure 1

A typical T/S/M Integration Activity Brief. Students see only this one-page brief, but science, mathematics, and technology teachers receive detailed instructional support materials as well.

Capture the Wind

Situation

Wind has long been a valuable source of energy. Sailboats and windmills, for example, have taken advantage of wind energy for many centuries. As you may know, it is possible to convert wind energy into electrical energy. Because wind is "free" and nonpolluting, engineers are working to figure out efficient ways of converting wind energy into electrical energy.

Problem

Design and build a device that efficiently transforms wind energy into electrical energy.

Design Constraints

Your solution must

1. Use wind to produce electricity;
2. Fit into a volume of 3540 cubic centimeters (216 cubic inches);
3. Mount easily on the electric generator supplied by your instructor; and
4. Capture wind coming from any direction.

The Challenge

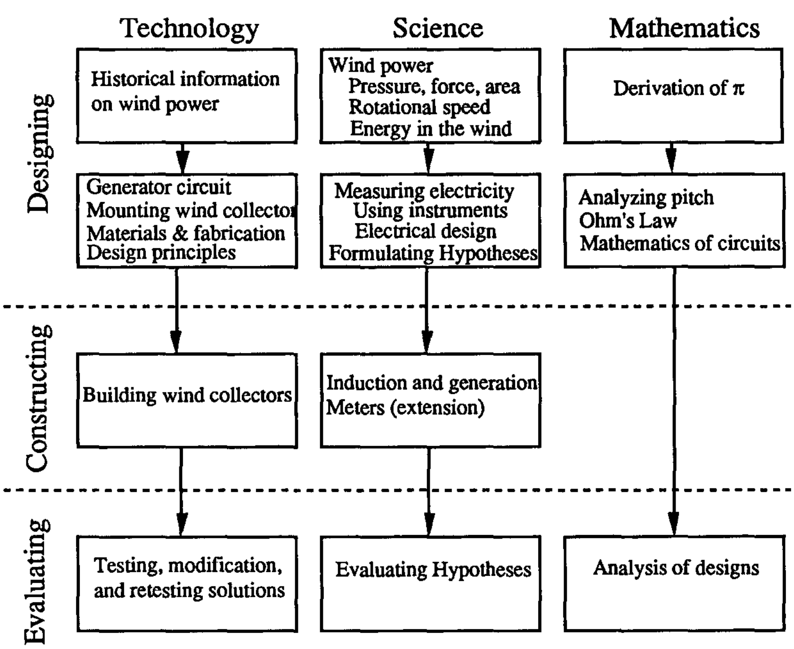
Your solution will be placed 15cm (6in) away from a fan supplied by your instructor. With the fan running, the electrical power (in watts) generated by your solution will be measured. The fan will be moved to one or more other locations (determined by your instructor). Once again, the power generated will be measured. The solution that generates the highest average wattage from these tests will be deemed the winner of this challenge.

Documentation

Document your work in a portfolio that includes

1. Sketches of all the possible solutions you considered;
2. A chart/graph showing how your solution performed;
3. A description of the science and math principles used in your solution;
4. Information gathered from resources; and
5. Notes made along the way.

Figure 2



some of the science and math students will be also taking a technology class. That poses a problem, but one that can be overcome through cooperation among the teachers involved.

With adequate planning, science concepts may be introduced by the science teacher within the context of the T/S/M Integration Activity. For example, in preparation for the design phase, the science teacher might introduce concepts such as force, pressure, electricity, and induction, relating each to the "Capture the Wind" problem. (See Figure 2.) Following this introduction, the teacher might divide the class into groups, trying to put at least one student from the technology class in each group. Each group would then design a solution, employing the science principles that were introduced. The design of a propeller/turbine that most solutions incorporate, for example, would draw directly from the principles of force and pressure studied in science. Since these are topics already being taught in the science classroom, it is a matter of coordinating current science instruction with the technology activity.

After the group agrees upon a design, the technology student on the team would take primary responsibility for building the solution in the technology laboratory according to the team's specifications. Since many technology teachers utilize computer-aided design (CAD) systems in their labs, the design might be developed with a CAD system. When completed, each solution is tested in the "Challenge" phase of the activity. During this challenge, students test their solutions to see which one works best. To do this, they attach their contraption to a simple electric motor (purchased at low cost from any Radio Shack) and wire a small light-emitting diode (LED) into the circuit. A fan is placed a prescribed distance away from the solution causing it to turn the motor/generator shaft. Two multimeters (also common in technology education and science labs) are connected to this circuit so that amperage and voltage can be measured simultaneously. This part of the activity would be timed to correlate with the study of electricity in science class. Before conducting the challenge, the groups in science class might formulate hypotheses as to which design will work best and why. During the challenge, they would make scientific observations that relate directly to their hypotheses and record the data.

To further connect science and math to the activity, the challenge could be run in science or math class or both, as well as in the technology laboratory. Two or more repetitions of the challenge are very important, as they encourage students to make careful scientific observations and rework their solutions accordingly before retesting in subsequent challenges. The data collected during each challenge is critical to the problem solving that takes place. Too often, competitive tests such as this are done only once. When this happens, students usually have no idea why one solution was successful and another was not. Several repetitions of the challenge allow students to "troubleshoot" problems and re-engineer their solutions. The "Challenge" thus takes on a much different meaning when it is run several times.

With amperage and voltage data in hand, the students are primed for math class. Students use the data they gathered with multimeters to calculate the power each solution generated. These data are used to develop charts and graphs. Students might hypothesize the effects of doubling the speed of the fan used in the challenge and create a mathematical prediction model. With the apparatus available, they can actually test this prediction model to see if it works.

To extend the activity, the math teacher might relate the concept of power generation to power consumption and ask students to calculate the power consumption of appliances in their homes. As in the case of the science applications, the mathematics used in this activity are those now taught in middle school math classes. The difference with the T/S/M Integration Activity is that it requires the application of math to a real-world problem. For that reason, the math activities suggested in "Capture the Wind" address all 13 of the NCTM Standards identified for grades 5–8.

Making it work

In practice, there are many different strategies for implementing the T/S/M activities. Some schools now field-testing the T/S/M Integration Activities ask technology students to bring the solutions they build into their science and math classes. Others take their science and math classes to the technology education laboratory to see how the solutions work. Either way, the students who build solutions typically explain their contraptions to the science and math students who are not in the technology class, and let the science and math teachers use their solutions as teaching aids.

A common denominator to the success of any implementation model is communication among the teachers involved. There must be formal planning time for the team; thus there must be administrative support for the overall concept.

Obviously, it takes tools, materials, and resources to make T/S/M Integration Activities work. Fortunately, most middle schools already have the tools and expertise they need to begin implementing activities of this sort in the technology education laboratory.

But building solutions to technological problems takes ample quantities of class time. The technology teacher is comfortable with that, but most science teachers will not want to give up that much time from science class. Thus, collaboration with a technology teacher on T/S/M Integration Activities provides an extension and reinforcement of the science class.

Logistic concerns

Activities like "Capture the Wind" are by no means exclusive to technology education teachers—a relatively small number of science teachers use this same type of hands-on technology activity to motivate their students. But most science teachers do not have the background, the facilities, or the time in their curriculum to support technological problem solving.

The many reasons why science and technology curricula have not come together are mostly logistic. Science teachers, for the most part, are not trained to teach about technology. (A typical technology teacher education program includes about 40 semester hours of coursework in materials and processes [wood, metal, plastics, ceramics], communication technologies [computer graphics, technical design/CAD, photographic processes, graphic production methods, audio and video production, and electronics], manufacturing, construction, power and energy, and transportation technologies.) Likewise, the science background of many technology teachers is inadequate to prepare them to meaningfully integrate science into their technology curriculum.

But perhaps the biggest hurdle to the integration of science, math, and technology is the structure of the schools. As long as these courses are thought of as mutually exclusive, it will be difficult to integrate the content. We are beginning to realize that the content is not mutually exclusive, and the T/S/M Integration Project is an attempt to do something about the artificial separation between science, math, and technology. ■

Reference

1. Warner, W. (1947, Reprinted 1965). A *Curriculum to Reflect Technology*. Columbus, OH: Epsilon Pi Tau.

Hands-on Technology versus Hands-on Science

Simply stated, science is the study of natural phenomena while technology is the study of the human-made world. But technology is different from science, and the T/S/M Integration Project seeks to capitalize on those differences.

Whereas science tends to corroborate theories through observation of natural phenomena, technology is the application of tools, materials, and processes to develop "human adaptive systems." Science curriculum focuses on scientific principles. As a result, "hands-on" science teachers often employ experiments that are designed to substantiate the principle being studied. That is, students are expected to get similar results on any given experiment. Conversely, there are always many solutions to any given technological problem.

This basic difference lets children be very creative in designing and constructing solutions to technological problems. Technology problem solving, hands on technology, is therefore a great way to apply the concepts and principles studied in a hands-on science curriculum.