Pre-College Materials Science Education: The Materials World Modules Program

Materials World Modules (MWM) is an educational program designed to supplement traditional science, math, and technology courses for middle and high school students. MWM is based on the principles of inquiry and design, and emphasizes active, hands-on learning. The program, which originated in 1993 with support from Northwestern University and a grant from the National Science Foundation, provides middle and high school students of various ability levels with opportunities to apply what they learn in the classroom to real-world problems.

From its inception, MWM has been a collaborative project involving university professors, secondary school teachers and students, editors, and graphic designers. When developing the program, R.P.H. Chang, director of Northwestern's Materials Research Center and founder of the Materials World Modules program, and his staff approached the project as if they were a company. Their first priority was to learn the needs of their customers, beginning with teachers, in order to satisfy those needs. Among other things, teachers wanted to provide their students with stimulating activities that related science to everyday life, to find practical ways of promoting collaborative learning, and to bring cutting-edge scientific research into their classrooms. With these goals in mind, the MWM staff began to collaborate with teachers in the greater Chicago area to develop a series of modules. Teachers who field-tested the modules provided valuable "tips from the trenches," which are included in the teacher's edition of each module.

The nine modules in the series deal with specific topics in materials science: Composites, Biodegradable Materials, Biosensors, Concrete, Food Packaging, Polymers, Sports Materials, Smart Sensors, and Ceramics. While each module is designed to cover approximately two weeks of class time, the modules are flexible enough to accommodate students' and teachers' specific needs and circumstances. MWM is designed not to supplant but rather to supplement and enhance traditional science, mathematics, and technology courses. Because materials science is an interdisciplinary field, the modules easily fit into a broad range of classes, including biology, chemistry, physics, life science, and health. The *Biosensors* module, for example, highlights concepts from chemistry (oxidation-reduction reactions, making sequential dilutions), biology and life science (bioluminescence, enzymes), mathematics (slope-intercept formula, calculating ratios), physics (electromagnetic spectrum, atomic structure, and energy states), and health (cardiovascular disease).

The Structure of the Modules

MWM was designed in order to excite students' curiosity about science, math, and technology. Toward this end, each module begins with a "hook" that demonstrates a unique property of the material being studied (see Figure 1). In *Composites*, for example, students receive two frozen pucks—one composed of pure water, the other of water blended with shredded tissue paper. Students are asked to make predictions about the relative strength of the ice pucks. Immediately thereafter, students test their hypotheses by dropping, pounding, and hurling the pucks to the floor. The fact that the water reinforced with tissue paper is significantly stronger than its pure counterpart surprises many students, whose intuition leads them to equate purity with strength. This discovery prompts questions that the rest of the module will address.

"When are we going to use this?" is a familiar refrain in many classrooms; it reminds teachers that students feel more motivated to learn when they see how the knowledge will help them. MWM seeks to make the connection between the "what" and the "why" of education explicit by casting students in the roles of real-world scientists and engineers. After the initial demonstration, students proceed purposefully through a series of hands-on activities, learning valuable information and scientific principles that they will apply to the design challenge. First, students develop researchable questions to guide their investigations, just as scientists do. In the *Composites* module, students predict and test the strength and stiffness of different materials—such as metal, string, and wood—that they might be able to use in the construction of a fishing pole that is both flexible and strong.

Following the activities, students tackle the design project. Working in teams, students create a prototype product designed to meet specifications. From a fishing pole (*Composites*) to a humidity sensor (*Polymers*) to a voltage protector (*Ceramics*), each module challenges students to design items that they use in their everyday lives. Like engineers, students develop testing procedures, identify their design's constraints, and redesign their prototypes in the quest for optimal performance. Teachers report that the design challenges really motivate their students, some of whom even stay after school or use their free periods to continue perfecting their products.

Benefits to Students and Teachers

Bill Weber, who taught the Sports Materials module to his integrated first-year science classes at Rufus King High School in Milwaukee for the first time in 1998, saw how the module transformed students into "explorers and investigators." Some of his students decided to use principles from materials science to test a hypothesis that they had read about in *Sports Illustrated*. They tried to answer the question of whether aluminum baseball bats had more "pop" than wooden ones. To do so, they used a restitution coefficient to measure rebound height against the regular height. Weber's students were motivated to experiment and apply their knowledge because they genuinely wanted to know the answer to a practical

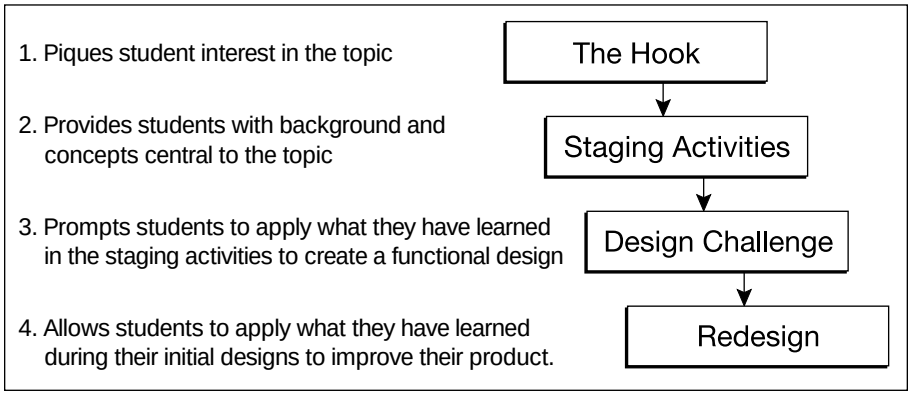

Figure 1. *Main components of Materials World Modules.*

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question that was relevant to their lives.

MWM also provides opportunities for teachers to continue their professional development. Many teachers report that their introduction to materials science through the MWM program has led them to revamp their teaching styles, to rethink their goals and classroom practice, and to collaborate with teachers working in other subject areas. Ken Turner, a chemistry teacher in Schaumburg, Illinois, has worked with Northwestern scientists to develop several modules in the series. Turner identifies MWM as "the single most important reason for the teacher I have become." He believes that his work with MWM has benefited his students; it has also garnered him numerous teaching awards including the Toyota Tapestry Award and the GTE Growth Initiative for Teachers Award. Turner, like many high school teachers, was unaware of the field of materials science prior to his involvement with MWM. Since participating in the program, Turner has conducted research in the area of materials science (through summer programs at Northwestern University), and continues to follow new developments in the field.

Meeting National Education Standards

MWM is an attractive resource for teachers because it can help them meet national education standards. MWM helps students to integrate science and technology and to understand contemporary problems and their relationship to science and technology. It uses the team approach, thus providing students with collaborative opportunities to engineer designs. The modules emphasize the historical development of products and technologies through human efforts and provide students with a broader perspective on scientific topics as they hone their researching skills.

State and national standards for science and mathematics education indicate that students must be able to apply what they learn to real-world situations. A major focus for Renee DeWald, a chemistry teacher in Evanston, IL, is to find inquiry-based materials for her classes. She finds that textbook publishers have failed to respond adequately to the growing need for inquiry-based materials recommended by the standards. She sees how the MWM modules help schools implement the National Science Inquiry and Technology Standards, for which teachers are least prepared.

Synergism between Industry and Education: MWM in the Community

Materials World Modules was designed to foster relationships among academic faculties, industries, and middle and high school students and teachers. The program is ideally suited for use in faculty members' outreach programs for pre-college students and teachers. Several universities, including Princeton and Cornell, have incorporated MWM into their educational outreach efforts. Similarly, MWM offers opportunities for industries to become involved in the communities they serve by supporting and sponsoring the use of Materials World Modules within their local schools. Because it emphasizes real-world connections, corporate partners like Boeing, USG, Intel, and AlliedSignal regard their support of MWM as an investment in future human resources. After all, the student who designs a new kind of sensor while doing the *Smart Sensors* module in her high school chemistry class may well become the engineer whose groundbreaking invention propels a company to the top.

A Total Educational Program

MWM is not just another science textbook. The MWM program provides teachers with the resources they need to successfully implement the modules into their classrooms. In addition to the student and teacher editions of the modules themselves, the program sells activity kits that contain the most essential supplies needed to run the activities and designs. Most importantly, MWM provides workshops and training for teachers new to the program. Working with module developers and master teachers, workshop participants become familiar with the history and philosophy of MWM, experiment with module activities and design challenges, and discuss practical and theoretical issues regarding the implementation of MWM into their classrooms. Teachers also receive instructional support from the MWM website and the nationwide network of module users.

Matthew Hsu, module development coordinator, helps to train new teachers during these workshops. Novice users of the modules generally feel anxious about the prospect of teaching concepts outside of their disciplines. With the help of the MWM staff, teachers are able to use the module effectively with their students. Many experienced teachers now serve as contacts for teachers new to the program, advising them by e-mail and answering their questions. A network of educators has evolved from the program.

National and International Dissemination

MWM has established a total of 16 hub sites in 14 states across the United States. Like all other aspects of the program, the establishment of these hub sites has been a collaborative effort between teachers and the MWM staff. First, teachers and administrators respond to MWM's outreach efforts by expressing an interest in bringing the program to their schools. The MWM staff then works with teachers to build up a group of at least 15 or 20 teachers in that area who would be interested in using the modules. At that point, the MWM team can travel to the site to provide training. These hub site visits were initially funded by the NSF grant. MWM is currently developing partnerships with corporations to continue such outreach and training efforts in schools around the country.

To date, the program has been used by over 9,000 students and 500 teachers. MWM has recently expanded internationally: U.S. students stationed at military bases overseas will be using the modules as the basis for an integrated science course, "Science, Technology, and Society," in the coming academic year. Plans are being made to continue this international expansion by translating the modules into other languages.

Materials World Modules welcomes collaborative partnerships with academic institutions and industry. To learn more about the program or to become involved in MWM outreach efforts, see the MWM website (http://www.mwm.edu/) or contact Christine Belden, the program coordinator, at mwm@nwu.edu or 847-467-2489.

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Education Exchange highlights experiences of scientists and engineers with local schools (K–12), community programs, and university programs, along with helpful hints and resources. If you would like to share your own involvement in science education, contact *MRS Bulletin*, Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573 USA; fax 724-779-8313; e-mail Bulletin@mrs.org.

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