Accepted 12/04 for Publication in MRS Proceedings
Submitted for publication in JME

Materials Science and Technology: A curriculum that works

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Materials Science and Technology is a curriculum developed at Battelle Pacific Northwest National Laboratories, which emphasizes hands-on, minds-on studies of materials science and technology. This curriculum has been taught to over 1000 middle and high school teachers nationwide in a series of week-long institute programs, and is used in classrooms in 16 states. Evaluations have shown that the curriculum is highly effective in getting students interested in science and technology, and in encouraging them to study more science.

This paper presents the basics of the curriculum and its approach, along with venues used for promoting the curriculum and the teaching methods used. Full evaluation results are discussed, including the assessment of increased student interest and increased student involvement their own learning. Means of adapting the program to a local situation are also presented.

Introduction

Materials Science and Engineering encompasses topics as widely varying as ceramic tiles to medical implants. Within this scope is the wide range of everyday materials that every student encounters in their lifetime. Using this knowledge of everyday materials and their properties and performance, the Materials Science and Technology (MST) curriculum[1] provides high school teachers and students with practical means of enhancing their chemistry and physics courses, along with others.

While millions of dollars have been focused on enhancing science education at the K-12 level over the past 40 years, the interest among students in science and technology has been decreasing. Today, a much smaller number of students aim at careers in science and technology than 40 years ago. One potential reason for this is that science has been taught as a subject based on *abstract* reasoning and *abstract* concepts. More recently it has been understood that an enormous increase in understanding can be gained through the manipulation of real objects and by focusing science instruction on real subjects that the students can intuitively understand.[2,3] Clearly, materials is one of those areas.

Curriculum

The Materials Science and Technology curriculum is a hands-on, minds-on program designed at Battelle Pacific Northwest Laboratories.[1] This is a practical materials curriculum focused 75% on laboratory exercises for the students. Topics covered are basic metals, ceramics, polymers and composites, and concepts related to these topics are focused on the practical. A course outline, along with related class/lab activities is given in Table A. The excitement of melting glass, rolling pennies or extruding plastic focuses the students on the materials in their bicycles, kitchens and automobiles. This then leads to interest in the science of more complex materials, and the course then expands to include individual projects for the students in these areas.

Table A –Materials Science and Technology Curriculum Outline and Typical Activities

	Module				
	Solids	**Metals**	**Ceramics & Glass**	**Polymers**	**Composites**
Topics Covered	• Importance of materials science and technology. • Solids are typically separated into four categories. • Simple chemistry including chemical bonding, the periodic table, and oxidation-reduction. • Crystal structures, physical properties. • How metals are claimed from their ores. • Importance of maintaining a student journal and keeping good records is stressed.	• Introduce the properties and historical developments of metals. • Investigate mechanical properties of metals along with the effects of heat-treating. • Study alloys and alloying techniques along with phase diagrams. • Study testing of metals and manufacturing processes. • A major project is the making of sterling silver jewelry using the process of lost wax casting.	• Learn that most ceramics are crystalline solids. • Study properties related to the ionic or covalent bonds that hold them together. • Learn that glass has different properties than most ceramics due to the amorphous structure of glass. • Study processes used to manufacture ceramics including a stained glass and a Raku pottery project.	• Study synthetic polymers and their chemistry. • Include the classification of polymers along with how they are altered chemically or with additives. • Emphasize concerns with recycling. • Review the chemical changes brought about by cross-linking. • Include historical developments and manufacturing processes.	• Describe and categorize types of composites. • Emphasize strength-to-weight ratios including strength measuring, testing, and altering. • Use wood and concrete as two traditional composites to introduce many concepts. • Discuss fiber reinforced composites including those containing graphite and Kevlar fibers.
Activities	• Material safety data sheets • Identification of materials • Formation of crystals • Destructive testing • Reactivity series of metals • Oxidation/reduction of copper	• Rolling a coin • Drawing a wire • Alloying copper and zinc • Cost of a penny • Making a light bulb • Making lead-tin solder • Annealing copper • Powder metallurgy • Lost wax casting	• Forming, firing, and glazing clay • Thermal shock • Glass bending and blowing • Glass batching and melting • Dragon dribble & dragon tears • Coloring glass • Stained glass project • Making Raku • Ceramic slip casting	• Cross-linking a polymer (slime) • Polymer identification • Making nylon 6-10 • Latex rubber ball • Memory in polymers • Epoxy resin cast • Polymer foam creations	• Stressed-skin composites • Plaster of Paris matrix composite • Compression and tension in a bending beam • Laminated wood beams • Using Portland cement to make & test concrete • Hand lay-up of a glass fiber reinforced polymer

The course as originally developed does not include activities in electronic materials, biomaterials or nanotechnology. These could and probably should be added as more advanced topics; some curriculum in these areas is available in the Materials World Modules project.[4] A variety of other curricula are available from several sources.[5-7] No comprehensive source of curricula is currently available, although one is planned at Edmonds Community College.

The MST curriculum is essentially the science of "stuff," presented in an interdisciplinary manner based on chemistry, physics and engineering. It is designed for a team approach, and can be taught by any science teacher and sometimes by technology teachers. Students use a journal throughout and apply scientific concepts in all units. The students learn why and how "stuff" behaves as it does and what it does by developing an understanding of properties and its relationship to structure, and processing.

The MST curriculum is sufficient for a stand-alone course at the high school, usually at the sophomore level, perhaps in place of a general physical science course or of Principles of Technology. The modules and activities within the curriculum are also well adapted for inclusion into chemistry or physics courses.

Teacher training

Because of the lack of knowledge of materials science and engineering among teachers, a training program is essential. We have trained over 1000 teachers in a variety of venues over the past 8 years, using funding from National Science Foundations sources and from the ASM Materials Education Foundation.[8] Short workshops at National Science Teachers Association meetings are used to recruit teachers; usually a presentation on MST attracts standing room only. Other short workshops are held in school districts and for other groups on request.

The training itself consists of a one-week intensive summer course. Since most of the teachers are conversant in science concepts and are generally experienced teachers, the training course consists of as many hands-on activities as is possible from the curriculum. Five 8 to 10 hour days allows the teachers to experience the hands on activities that they can then use in their classrooms. This is essential because the teacher needs to have experienced the activity before she or he will be willing to actually use it in the classroom.

Reference materials for the teacher include the Materials Science and Technology Teachers Handbook, available in print[1] or CD form,[9] along with complete classroom sets of the curriculum that are available from Energy Concepts, Inc[10] and the other curricula noted above. Based on a variety of teacher training programs, personnel from at least 16 states have been trained in the MST curriculum.

The ASM Teachers Camp program is the most active of these at present, having offered 6 training sessions in 2004 with more projected for 2005. This program is sponsored by the ASM Materials Education Foundation, which also sponsors the ASM Materials Camp program for high school students.[8]

Evaluation program

Several official evaluations have been undertaken for this program, along with a number of informal polls of teachers who have used the curriculum and students who have taken courses in MST from teachers who have been trained in the programs noted above. One evaluation, published elsewhere,[11] provided positive input on all survey items. This study also provided the following anecdotal input:

- I increased my knowledge in science, technology and mathematics.

- I increased my knowledge of applications of science/technology/mathematics
- I gained new perspectives on how science/technology/mathematics should be taught
- I learned activities I can use in my classroom
- I learned laboratory skills I can teach to my student.

The excitement generated by the training program can be summed up from one quote from a teacher in the Albuquerque ASM Teachers Camp: "I think I learned more in a week…than I have in all of my science experience at school….I know that this is the most educating and fun experience I have ever had." Clearly this training excites teachers because they can then excite their students in science.

Perhaps more interesting is the response from the 221 students from 7 high schools taking the course. The results of the survey are reproduced in figure 1. Students indicate a significant enhancement in their self-concept, problem solving and hands-on skills. Their perception of science was changed and the career opportunities in science and technology were made clear to the students. Enthusiasm for science and technology was evident in the students and in their teachers. This type of program, which is aligned with National Science Standards, provides a means for motivating teachers to engage students more in real science and to motivate students toward more understanding of science and engineering. One of the more interesting responses to come from the student survey was the fact that 96% of the students would recommend, or would probably recommend, this class to their peers. Student's comments fell into several distinct categories: activity related comments, overall expressions, and negative comments. Comments, which stood out, include:

1. "I love working with materials. I learn so much easier by working with my hands."
2. "It was a nonstop action class. Almost every day we are doing something new. I got to make a lot of cool stuff that I can keep forever."
3. "My friends used this class as a stepping stone to get into the Boeing Manufacturing Internship in Auburn, WA."

The most prevalent negative comment was a dislike of journal writing, followed by a dislike of any written work at all.

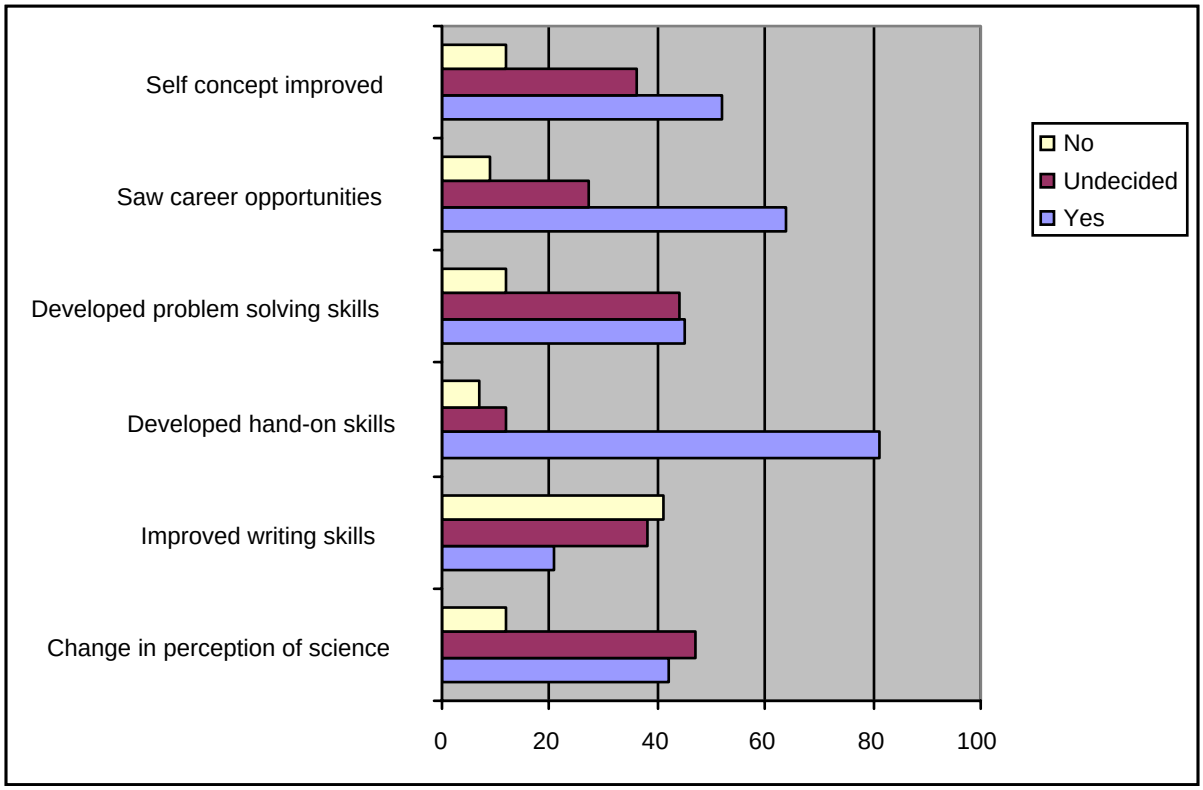
An additional survey was sent in 2002 to 200 teachers who had previously taken MST training, either in the UW or the Edmonds programs. Seventy eight questionnaires were returned. Of these, 26% are currently teaching the Materials Science and Technology (MST) course in their schools, representing 20 schools. Including others teaching the MST curriculum in their schools, a total of 37 teachers were identified from this group, with 2050 students. In several high schools, MST had become the most popular science course. In addition to the teachers teaching the MST course, another 40% of the respondents indicated that they are using these concepts in other science and/or technology courses. The remaining 34% of respondents are divided between teachers who are new and are trying or planning to use the material, and more experienced personnel who have moved up to administrative positions.

Educators in related science and technology areas including chemistry, physics, engineering and manufacturing have realized the positive effect of including materials activities in their programs. This is emphasized by an additional finding in the latter survey was that chemistry and physics became more interesting to the students after taking the MST course. In manufacturing education, comments related to a new modular curriculum <pscme.org> indicate a need for more materials content. Indeed, one suggestion for the field of manufacturing, which makes considerable use of materials but often has a negative image, could be to rename it materials technology instead to make use of the more positive image of materials.

Future of MST

One challenge to teachers in utilizing the MST curriculum is the question of how they fit into state science standards. This is an important question in all states today. To assist teachers

Figure 1: Results for selected responses to high school student survey after taking Materials Science and Technology course, from Journal of Materials Education, 24, 23-30 (2002)



In this regard, the MST curriculum has been "crosswalked" with the national science standards[12] which are usually well aligned with state standards.[13] Teachers in some states have specifically aligned the MST curriculum exercises with state standards as well.

However, teachers also indicate that the excitement developed in their classes in science as a result of the inclusion of materials activities, is sufficient for the students to continue to excel in science and thus to achieve whatever standard is required.

The MST program requires teacher training, as noted. The ASM Materials Education Foundation has "stepped up to the plate" in this regard and is expanding its program of teacher training at various locations across the U.S. The Foundation is willing to develop partnerships with other organizations and with universities interested in promoting materials education at the high school level across the globe, with the goal of extending this program to as wide an audience as possible. Since the goal is to enhance the understanding and interest in science and engineering in general using the concepts of materials, all of us in technical fields will benefit from enhanced cooperation in this and related programs.

Acknowledgments
The authors thank Ms. Karen Wieda and Dr. Jeff Estes at Pacific Northwest National Laboratory for their dedication to the development and deployment of this curriculum. This program has been supported in part by the Advanced Technology Education program at the National Science Foundation, grants DUE 0101582, and DUE 0402211, along with an NSF Engineering Education grant EEC 0211666. Teacher educational programs would not have been successful without the support of a cadre of master teachers, whom to whom we express our thanks for their interest and dedication. Teacher education programs were originally supported by the U.S. Department of Energy, and later by NSF and by the ASM Educational Foundation. A commercial version of the curriculum is available from Energy Concepts, Inc.

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