Creating an MST Environment
MST Curriculum Philosophy/Rationale

The philosophy that underlies this introductory materials science and technology (MST) curriculum has as much to do with how things are taught as with what is taught. The instructional approach is based on the idea that students cannot learn through talk or textbooks alone. To understand materials, they must experiment with them, work with their hands to discover their nature and properties, and apply the scientific concepts they learn by “doing” to designing and creating products of their own choosing.

Learning comes, as it has for humankind for generations, from the active pursuit of solving problems. In this case, students learn from solving problems using the scientific process, which is speeded by scientific knowledge. Students get a chance to use and build their mechanical skills as well as mind skills. We call this approach hands-on/minds-on learning.*

Learning by doing is not a new or complicated idea, but it is not common in today’s classrooms. Unlike many mathematics and science classes, students enrolled in MST classes are excited instead of bored. They ask “What happens if ...?” instead of “What’s the right answer...?” Instead of sitting at a desk reading about science and technology, they work on science and technology activities. They’re not memorizing facts about mathematics and science, but using the thinking processes of scientists and mathematicians to become better reasoners, and learning facts and concepts while solving problems relevant to them as they create their projects.

The MST course can only be fostered by good teachers, those who are a regular part of the school system and community members who have mastered their skills and are willing to pass on what they have learned. Teachers must create a learning environment where students are willing to risk and are willing to learn from mistakes they make.

Beyond MST’s basic project approach, other fundamental elements of the program include fostering student creativity, developing journal writing skills, and teaching in teams (science and technology teachers). Peer teaching also plays an important role. Students who have just mastered a skill or gained an idea can be the most convincing teachers.

*A combined emphasis on “know-how” and “ability to do” in carrying out technological work transforms mathematical and scientific principles into reality.*

— International Technology Education Association

* “Hands on/minds-on”: this phrase originated with Herb Thier, Lawrence Hall of Science, and refers to experiential learning that physically and intellectually engages the student.
When scientific concepts, thinking skills, and mechanical skills are combined, then science and technology are truly combined, and an atmosphere exists that appeals to a broad range of students. Not just “science smart” students, but also the so-called average students not usually reached by traditional science, mathematics, and technology curricula and also young women and traditionally underrepresented students.

Working with materials appeals to all students because materials are the medium for art, handicrafts, and the myriad of things that surround them. Students enrolled in honors science courses find that MST focuses the science knowledge they have learned in other courses and gives them a chance to use mathematics skills in concrete ways. Other students, more oriented toward applied technology than traditional science, who are not usually adept at memorizing or doing mathematics, often shine in the MST course as they discover how to connect subjects usually taught in isolation. They can apply their abilities and strengths in areas of problem solving in which they do well.

Through the process of working with materials, students begin to understand science as a highly socialized activity. They discover that science is not just facts and figures, but a process that relies on people’s visions and imaginations, as well as their abilities to follow through a step-by-step process. The degree of “handiness”* MST students develop goes a long way toward instilling in them a sense of self-confidence. Although few students take advanced materials classes in college, most say MST has changed the way they look at the world.

* “Handiness”: a term contributed by Eugene Eschbach, Manager of Innovation and Technology at Battelle, refers to the ability to solve materials-related problems with available or limited resources (see page 2.15)
Multi-Instructional Approach

Because this MST course is designed to be taught to a wide range of students, we use a multi-instructional approach that includes elements to appeal to many learning styles. In general, we describe the instructional process shown in Figure 2.1 as “observe, correct, and create.” It works something like this: Students ponder, plan, experiment, GOOF UP, correct, discover, and learn in a laboratory setting. These concepts are the principles of the scientific process. As part of the process, students experiment individually or in groups, record their observations in a journal, and discuss the experiments and their observations in class or small groups. In addition, students read and research, using periodicals and other library resources in relation to the unit of study or their selected project. Students are encouraged to gather information by interviewing or working with those who are familiar with the materials or are experts in the field of study.

The multi-instructional approach focuses on solving problems, creating student projects, working in small groups on open-ended experiments, writing as a means of learning, participating in high-interest demonstrations and activities, using community experts in materials, showing videos, and using a host of written resources. These approaches reach many minds and learning styles, and can interest many students in the learning process.

* The process may be recursive, allowing students to cycle back to gain additional information, even as they move forward.
Course of Study

Four major units of study form the basis of the MST curriculum. Each unit typically includes the following activities as shown in Figure 2.2. Note the approximate percentage of time required for each activity.

**Student Experiments**—Students conduct experiments individually and in groups (35%). The experiments feed student projects.

**Student Projects**—Students design, research, create, and build individual or group projects (35%).

**Instructor Demonstrations and Presentations**—One day per week (20%).

**Films, Videos, Guest Speakers, and Visits to Industries and Laboratories**—Fostering creativity, developing handiness, and using community resources are also major elements of the MST multi-instructional approach. These elements are integrated into the curriculum through student projects and the instructor’s ability to promote these concepts (10%).

**Reading, Writing, and Discussion**—These activities are integrated throughout. Students 1) write and sketch in a journal to record observations, procedures, experiments, and progress on projects (information from presentations, guest speakers, tours, readings, and films also is recorded); 2) read and research (through interviews, periodicals, and library resources) in relation to the unit of study or the students’ selected projects; 3) participate in journal writing activities to practice and enhance student writing skills; 4) explore through discussion, writing, and applying the process of creativity, innovation, and scientific inquiry; and 5) study specific occupations that require a special understanding of material characteristics and how these occupations can change as a result of technological change in materials.

“As children we were fascinated with ‘tearing’ things apart. As we matured and went through the educational system, the desire or fascination somehow died or was stuffed until only those who could memorize written data and regurgitate it were recognized as being smart or gifted. The so called ‘handy’ student was lost or ran out of places where their skills could be evaluated and appreciated.”

— Andy Nydam, MST Teacher

River Ridge High Schol
Solving Problems

Engineers and scientists approach materials and materials processing by attempting to solve problems important to society or industry. One good example of a current materials research problem is how cars are designed and built. Right now in the United States materials scientists and engineers are working on how to build a lighter car that will be more fuel efficient and constructed of recyclable materials. This “new” car must have a frame and body as strong as current automobiles. The materials used in its design and manufacture will be revolutionary. That’s a problem. A big problem!

How do they go about solving it? First, the auto industry has called in materials experts. In the past, the auto industry’s research laboratories have based most of their research around metals, because they always built cars from metal; but now, to design future cars, the laboratories have had to recruit scientists and engineers who are experts in working with ceramics, polymers, and composites. These experts gather together and brainstorm over what kinds of new materials they might be able to fabricate, what new processes they need to manufacture the new materials, and what kind of new procedures they need to test new materials.

From this "pool of ideas" created by brainstorming the auto industry decides which materials to research, fabricate, and test. These are not all new and revolutionary ideas, however, because some scientists and engineers have been working on similar problems with aerospace crafts for many years. Their expertise proves invaluable in hastening some new materials that will be integrated into future cars.

A Technique Scientists Use to Solve Problems

As materials scientists approach a problem involving new materials, they use statistically designed methods to acquire as much information as they can from a minimal number of experiments. Of course, before doing any experiments, which tend to be expensive and time consuming, they conduct a literature search to look at the reports of the extensive research already done on many materials.

Scientists acquire valuable information from reading what already has been published in scientific and technical journals and reports, which aids them in their research. In some cases, by reading the literature, scientists find that the research they planned to do already has been conducted. The experiment is then designed to aid scientists in narrowing their area of focus to the desired properties and materials they will examine and to learn more detailed information as they study the materials.

The MST course uses problem solving as the foundation of its approach to studying science and technology. One way the course accomplishes this is by having students experiment with materials as scientists do.

“By taking [the MST] class I have really learned a lot. Last year I took a chemistry class and stumbled my way through it. I read the book and did the problems and never really understood any of it. After taking MST, I understood ionic bonding and van der walls forces because this class allowed me to take what I learned last year and apply it. Now when I think about chemistry and math I know there is more to it than just numbers, because I can apply this knowledge to real world every day problems.”

— Tom Gannon, MST Student
Richland High School
The instructional approach allows students to experience specifically how scientists approach a materials problem. Students combine, process, and examine materials as scientists do, then draw scientific conclusions based on what they find. Students learn problem-solving skills by experimenting with materials. They also further this problem-solving process by creating, designing, and building a project of their choice.

Creating Student Projects

Research on teaching and learning shows that people learn best in meaningful contexts and when involved in things they care about. Designing and creating a project is often what draws students to enroll in the MST course, partly because they are attracted to the idea of building something and studying what is current and relevant to them. The project also helps make science, technology, and school relevant to what scientists, engineers, and technologists encounter in their work. The project builds on concepts and skills students learn while experimenting with materials in the classroom. With the project, students get a chance to further use and develop problem-solving skills, demonstrate knowledge of subject material, and follow the scientific process on their own.

The basis of the project is designing, researching, creating, and building an object with materials—a ring, superconductor, belt buckle. Students spend some class time each week working on these objects.

What Constitutes a Project?

Students can choose a project that involves creating some traditional object, requiring traditional tools and equipment (pliers, saw, hammer), or they can focus on an object related to a recent scientific and/or technological advancement, such as a superconductor or foam beam, necessitating laboratory equipment such as a digital scale or balance, beakers, chemicals, and/or a furnace.

For example, a student may decide to make a stained glass window or create a ring from precious metals. Students learn about stained glass in the ceramics unit (amorphous structures), metal alloys in the metals unit (crystalline structures), and the nature and properties of both of these groups of materials. But as students apply this knowledge in a project, they have to connect all the concepts of academic study to real life. These concepts are reinforced by the hands-on/heads-on process involved in the projects. Other student project examples include a honeycomb core stressed-skin composite material, shuttle tiles, a bridge, a polymer/wood cabinet, a radio-controlled airplane, materials testing devices, a chess set, and a belt buckle.

“As an MST teacher, you have to develop an attitude that you’re learning too. When you don’t carry an air of knowing it all, students begin to have some ownership and become more willing to share their successes and failures.”

— Len Booth, former MST teacher
The Project as a Problem-Solving Tool

Many students choose to design and create metal belt buckles as a project. It would be easy for the teacher to give students a recipe for how to make the metal and directions for what kind of buckle to make, but that would defeat the purpose of MST. Instead, you must guide students in creating a design, selecting the type of alloy they think most appropriate to make their projects, right or wrong, and let them experiment with it. Naturally, in the process of making the buckle, they will encounter problems with the material, such as bubbles forming between the mold and the metal, or the metal deforming too easily because it is too soft or heavy. But these problems are the tools that give students opportunities to develop critical thinking skills, handiness, creativity, and problem-solving techniques.

In using the hands-on problem-solving approach with the metal belt buckle project, for example, students become familiar with the individual elements in the alloy. As students experiment with it, changing proportions of the elements to obtain a metal that is either softer and easier to work, or tougher and more resistant to deformation, they experience alloying first-hand, but they also learn an invaluable lesson about problem solving, how to change materials to meet desired requirements, and they get the personal satisfaction of having worked through a problem.

Teacher as Problem-Solving Facilitator

We see the teacher’s role in the project as that of facilitator, a valued resource, someone who encourages students who may need a boost in this open-ended learning process. You have the experience and knowledge to know how to direct students’ thought process to help solve problems. You should give students the kind of “help” that will let them solve the problem themselves. Guide students through problems by offering suggestions, not solutions, directing them to ask the right questions, and focusing their direction. In many cases, you may be learning right along with the students.

Projects and the Laboratory Journal

Using a laboratory journal is an integral part of all student projects and other laboratory and class activities. The journal becomes a means for students to explain steps they have taken that may be critical in solving problems they have encountered (see sample student journal entry). When students keep detailed notes, the teacher, or a materials expert or specialist can step in, look at the notes, and perhaps, help assess the process the student is following, and look for areas that may be causing problems in building a project. The journal also gives the teacher a tool for evaluating the unit of study. A more-detailed description of the laboratory journal and tips for how to use the journal follow.
Using The Laboratory Journal

Writing is important in the world of science and technology. Many jobs in scientific fields depend on clear written communication. Some say that scientists spend as much as one-half of their working hours writing.

The major tool scientists, engineers, and many others such as doctors, surveyors, architects, or factory production workers use for written communications is the laboratory notebook or journal. This book becomes the permanent record of collected data, experimental results, and conclusions. It is also a tool scientists use to help them in the process of “thinking-out” a problem, for asking questions, making speculations on paper, and clarifying hazy issues or concepts.

Students need to write, too, as part of their exploration of science and technology. They need to practice writing in the journal (see Figure 2.3), not only to record information and observations, but also as an
essential means of learning. Learning to write is learning to think. It prepares the mind for discovery. Students’ use of the laboratory notebook can be a novel experience for them. It can also become a symbol of scientific discovery and learning, a way they can relate to and identify with scientists, by having their own scientific “tool,” just like a real scientist or technologist. After using the laboratory journal, some students may be motivated to take the scientific concepts they have learned with them and continue the data collection, information gathering, and application process on their own.

Rules for writing in a laboratory journal are not important in this course. The main task is to motivate students to write what they are thinking, observing, or need to remember—information that will be useful for the future. Students can use the journal, as scientists do, to think out a problem, ask questions, or clarify concepts. The important task is to get them to write, draw, think, and collect data in a notebook (see Figure 2.4).

Simply put, students who write about subjects understand them better.
Journals used in industry are bound so the numbered pages do not come out. Written items cannot be erased, and generally, any corrections are done with a single line drawn through the deleted word or words. For the practical experience of learning to write, the MST journal may be a loose-leaf three-ring binder. With a binder, students can add extra pages and classroom handouts, or they can take out a specific page and turn it in to the teacher to be read.

Keep in mind that the purpose of the journal is a learning tool. Clear writing promotes clear thinking. The emphasis of writing to learn is on learning content, not on writing skills themselves, although writing skills are likely to improve through practice. In reading student journals, you should not dwell on grammar, spelling, or other technical aspects of language. The general rule should be: “If it does not interfere with clarity of meaning, ignore it.”

As students become more familiar with their ability to use their journal, and as they observe other students organizing, writing, and outlining, they will develop an intrinsic sense for the usefulness of their writing and their ability to clearly present what they have learned. The journal will then become for them a reference for following a procedure and for showing other students and the teacher what’s been taking place in the classroom and laboratory as well as in a specific experiment. Successful student notebooks are an accountable indication of accomplishment when students have finished the course.

Some MST teachers have emphasized the importance of the journal by assigning a portion of the student’s grade to this activity. The journal has also been used in open-book quizzes. Students are a little more motivated to use their journals daily when testing and grading are emphasized as part of the process.

It is essential that you check student journals a minimum of once every other week. Make sure you provide students with written feedback, comments, or advice on their thinking/learning progress.

Benefits of Using the Laboratory Journal

Student Benefits

• Enlarges students’ understanding of materials science and technology.

• Encourages participation through a success-oriented activity.

• Helps develop clear thinking.

• Encourages and illustrates the importance of writing across the curriculum.

• Provides an open and risk-free communication with the teacher.

• Provides accountability to teacher for work done.

• Emphasizes the importance of writing whether now or in the real world.
Creating an MST Environment

• Can be used as a resource in an open-journal test.
• Gives students a reason to write.

**Teacher Benefits**

• Breeds success in the course, encourages teachers.
• Provides insight into students as individuals and their understanding of materials.
• Provides optimum teaching opportunity, i.e., if the students can write about and clearly explain something, teachers know they have taught beyond memorization for a test.
• Promotes “active” teaching; forces teachers to examine course work and their efforts more closely.
• Builds rapport between teacher and student; makes learning a joint effort.
• Provides a future resource for teacher, student, and classmates.
• Provides an effective communication source to encourage students.
• Provides accountability for teacher evaluation for individual students and the entire class.

**Journal Writing Activities**

You will need to promote using the laboratory journal because many students have learned to think of writing as a difficult task. Daily writing is essential in the MST class for students. A number of activities follow that can be used to stimulate student writing.

**Journal Write.** *The purpose of this exercise is to get as much information and as many questions onto paper as quickly as possible. Some information may be facts students want to remember, or questions students would like to have answered because an article they read had insufficient information, or the student didn’t have sufficient background to understand it.*

• Distribute a short article (1-2 pages) from a current materials periodical to each student (a list of periodicals is provided in the Appendix). Give students a specified period of time (i.e., 5 minutes) to read the article. At the end of the time period, tell students to stop reading, even if they all haven’t finished the article, and have them begin to write, again, for a specific time period. To help students start writing, give them some writing prompts (see sidebar). You can use an overhead projector, the chalkboard, or hand out the prompts on paper. When time is up, have students count the number of words they wrote, and record them at the bottom of the page.
“Journal Write” Prompts

1. What did you see?
2. What did you read that you didn’t know or understand?
3. If you had one question to ask the author, what would it be and why?
4. Why were particular materials used to construct this product?
5. Write down what is bugging you.
6. What things have you seen around you that remind you of this product?
7. What did this article make you think of?
8. What did you learn from this article that you didn’t know before?
9. Do you agree or disagree with the article?
10. What would you have done if you had discovered this product?
11. What was the most useful thing you heard in the last 30 minutes?
12. Why do you suppose society wants you to know this stuff?
13. What puzzles you about this article?
14. What made sense to you about this article?

- After a journal write, have students exchange notebooks with a partner. Partners read each other’s journals and make comments on the page about the writing (i.e., “Looks good!” or “I wish I could organize my thoughts as well as you did,” or “I found the answer to your question a little later in the article”).

- Have partners discuss the article or their writing for a short time. These partner activities allow students to learn from other students’ strengths and insights as to how they accomplished the task.

- Have the whole class discuss the article and writing experience. Students could be inspired by the article, and learning about a scientific concept or technological process would be a group motivator.

- Use questions evolving from the journal write for student research. Have students find a resource in the community to answer a particular question, or invite a local “expert” to come to class and talk about the question.

- To vary the journal write activity, have students jot down what they already think they know about a topic or article they will read. They can also write questions they hope the article will answer or predict the author’s major points. After reading the article, students can then respond to what they wrote.

**Daily Write.** The purpose of this activity is to get students to write their thoughts and ideas in the journal. It is also an activity for teaching “thinking on paper,” so students become aware of thoughts that occur to them day to day and the thought patterns that might be forming.

- Ask students to answer the following questions: 1) What did I do in class last time we met? 2) What did I see or learn about MST since the last time we met? 3) If I could ask only one question related to MST, what would it be? Challenge students to find answers to their questions by talking to a local expert or by consulting a resource book such as an encyclopedia, or watching periodicals for a topic on the subject. When the question is sufficiently answered, have students write this information in their journal.

**Weekly Summary.** During these weekly reviews, students may discover what learning is taking place over time or what process continues to be a problem. They can sort out some variables of a recurring problem and refocus on a specific answer to a problem (i.e., my glass process continues to be plagued with cracking. I need to learn more about annealing so I can pour uncracked glass). These summaries can also zero in on specific item(s) that may warrant teacher attention.

- Have students spend 10 minutes each week summarizing their week’s work. Use the following journal prompts:
Creating an MST Environment

- What did you do this week?
- How did it go, good or bad, and why?
- Who did you work with, and what was the result?
- What did you learn from your work?
- What do you now anticipate? (next steps, needed materials or resources)?
- What are your frustrations and your successes and why?

**Writing to Describe a Process.** This kind of writing involves recording the experiment, project, or process in the journal. Students need lots of practice because as they get more involved in making something, they forget to record each step.

- Have students record all details of a lab they are working on. See sidebar for prompts to help describe a process. Have someone familiar with the process read student entries and make suggestions for how to more accurately describe what has been written.

**Resources**


Working in Small Groups

Working in small groups is an essential element of a successful MST program. Small groups develop teamwork and cooperative learning skills, and promote student interactions that allow students with experience and knowledge in specific areas to lead or share with other students.

For example, when a specific experiment requires numbers to calculate chemical batches or explain the chemical bonds, the college preparatory students quickly shine, but typically, the students who learn by doing or applying what they learn do better manipulating and processing materials. In this kind of learning environment, students end up coaching each other, and in the process, learn to respect each other’s abilities, and their own (see box).

Working in small groups also gives students a sense of how the “real” work world functions. Often, as we attempt to solve problems, it is not uncommon to find ourselves in content areas with which we are not familiar. Learning to ask for someone’s help in solving a problem is a necessary skill in our increasingly complex society.

Building Teams

Bill Howl, an MST student from Olympia, Washington, has had minimal success in school. He still does not read, and he cannot write. Bill chose to make metallic parts from powdered metals as his MST project. He learns best by working with his hands and learning from his mistakes as he worked through the press and sintering processes of making powdered metal parts. When the MST class began working on the powdered metal unit, Bill already knew the process well. So, the students looked to him for help and advice as they learned the procedure. Pretty soon, other students began to recognize Bill as the powdered metal expert, which boosted his self esteem to a level he had never encountered in his school career.
Developing Handiness

“Handiness,” as we define it, is the ability to solve materials-related problems with available or limited resources. When presented with a problem, without the usual materials to solve it, “handy” people can use their creativity, imagination, and problem-solving skills to come up with a solution that allows them to get a job done.

Handiness is an important component of the MST course. Today, many students are not handy. They lack the ability to solve developmental problems because they don’t understand how to use alternative materials if what they need is not available. The MST course helps students overcome these obstacles by systematically examining many diverse materials, their characteristics, properties, and subsequent uses. By working hands-on with the materials in classroom experiments and on projects, students learn not only about materials, but also techniques to manipulate them—handiness.

A Success Story

The term handiness was coined by Eugene Eschbach, Manager of Innovation and Technology at Battelle. Gene learned to be handy growing up on the family ranch near Yakima, Washington. Gene’s father raised cattle on the open range and was not at home with mechanical things. So, when ranch work was automated, Gene’s brothers had to buy and repair all the machinery.

In the late 1920s, the Eschbach family developed part of their ranch as an amusement park. But Gene’s brothers left the ranch for the military, so Gene had to shoulder many of the responsibilities for fixing things. The park was isolated, a long way from a repair shop, so Gene learned to repair electro-mechanical and electronic devices of all sorts—automated violins, automatic phonographs, and later, the slot machine. He says, “. . . I had an outlet for my creativity, and I was able to reinforce it because the equipment had to work. I was able to implement my ideas, and if I made a mistake, I could fix it without feeling badly because no one noticed my mistakes.”

Gene kept the equipment running, sometimes under much duress, but the work motivated him to be the first in his family to attend college. Even before Gene finished his degree, RCA Laboratories hired him. At RCA, he intensely studied the properties and forming of glass, metals, and ceramics. He was associated with developing what then were highly novel methods of fabricating components. He also helped develop the first large-diameter television picture tube envelope that could be made through mass production techniques. Later, this same design was the foundation of the color television industry. Over the years, Gene has accumulated several patents and hundreds of invention reports. These successes come, in part, from the handiness skills he learned on the ranch as a young boy.
Fostering Creativity

Setting up a classroom/laboratory environment where the focus of learning is discovery and exploration provides a unique opportunity for students to develop and enhance their creativity. The MST course’s inquiry approach to problem solving, the experimental design model with open-ended experimentation, and projects all help students use their creative skills.

All students are capable of being creative, but their creativity generally has not been tapped and at times has been stifled by our formal educational process. The standard learning approaches—passively reading textbooks, listening to lectures, and doing cookbook-style labs with “set” results that guarantee the right answer—have created “fearful” students, who are not willing to take risks because they might get the wrong results.

Part of fostering the creative process is letting students make mistakes. Because the MST program emphasizes the learning process over right answers, it takes the pressure off students of always having to be right. The learning environment provides them instead a freedom to experiment with their own hypotheses, make some mistakes, and learn from their failures. Making mistakes means acknowledging unexpected results or unpredicted scientific outcomes. It doesn’t mean sloppy experimentation or poor safety practices, ignoring materials or processes that would lead to an injury, fire, or explosion.

Learning from mistakes is key to the scientific process. Battelle’s Gene Eschbach is first to admit and reinforce this concept. In an article Gene wrote about his early work experience at RCA Laboratories, he describes his experience related to making mistakes (see box, next page).

Tips for Fostering Creativity

• Create an atmosphere where students are willing to risk and feel it is okay to make mistakes.

• Develop a rapport with students that gives them a feeling of acceptance, trust, and team spirit.

• Remember that some students will be able to express their creativity rapidly, which can stimulate other students whose skills may take a while to surface. At the smallest sign of a creative idea, encourage these students, and let them see they do have abilities.

• Recognize that making mistakes is an acceptable tool for learning within the classroom. But, be very careful in distinguishing between using the mistake as a learning tool and introducing scientific concepts that are erroneous. Continually check your knowledge of scientific concepts, and likewise, be attentive to what students are learning by checking their journals, listening to their discussions, and clarifying the important scientific concepts being developed in the units of materials study.
“Several years ago, a chemistry teacher stopped by the auto shop to ask if I would give a demonstration on the operation of an air conditioning system to sophomore chemistry students. “Sure! What for?” I said with moderate suspicion. (After all, how often do science teachers mix with shop teachers? The science teacher’s response to my question was the genesis of a new direction in philosophy and curriculum in our school toward technology.)”

— Robert Gauger, Chairperson, Technology Department
Oak Park and River Forest High School, Oak Park, Illinois

An Honor to Err

That it’s OK to err during an investigation or during a learning process was brought home to me again and again by my most illustrious mentor, Dr. Lloyd Preston Garner of RCA. The laboratory by his design was indistinguishable from its support function, namely: the instrument makers, tool and die makers, electricians, and electronics experts, who were all housed among aspiring scientists.

Dr. Garner told all of us on many occasions not to hide our errors but to share them with others because he believed that “our errors are our greatest teachers.” One day he found in a wastebasket a part from an experiment that was damaged. He grabbed the part, called everyone to an informal meeting, and asked who had thrown the part away and why? Then he asked why the rest of our group was not made aware of the error and the mistake. Dr. Garner went on to say that an error was, first, an opportunity to learn, and second, an indication of a possible shortcoming. Moreover, that it was usually a manifestation that “Mother Nature was trying to tell us something,” and not an oversight to be covered up. From then on, Dr. Garner said it would be an honor to err. A 20-ft-long trophy case was placed in his office exhibiting all errors and surprises after they were analyzed.

I was privileged to be with Dr. Garner for 4-1/2 years. And during that time I filled 4 of the 5 shelves with errors, unusual events, and an occasional triumph. “Errors” included events where an experiment did not “come out” as we expected or predicted. Many such “errors” became “happy accidents.” A few years ago I visited Dr. Garner (in his late eighties now), and within 5 minutes of our visit he said (and I was after all in my sixties), “Gene, errors are our greatest teachers, don’t hide your errors, and more importantly, run fast enough to still make them.”

— Eugene Eschbach,
Manager of Innovation and Technology, Battelle

Teaching in Teams

Combining science and technology is an integral element of the MST program. So, we recommend the course be taught by both a science and a technology teacher. Because materials science and technology is a new field of science, bringing with it some unexplored areas in traditional science and technology education, the combined expertise of two teachers enhances student learning, particularly where science concepts are heavily combined with materials processes and application (technology per se).

Students learn from the diversity of teaching styles and from the strengths of each teacher. Teachers also benefit from the interaction, learning from each other’s strengths. We have found that some of the most successful MST courses have been taught with this combination.
Using Community Resources

Community resources are important to the MST program, helping to bring reality to the classroom. Ways to use community resources can vary from inviting local materials experts to visit the classroom and taking field trips to local cement plants, jewelry workshops, and specialized materials application sites to forming local MST advisory committees and developing mentors and partnerships. Remember, anyone who makes “stuff” is a potential resource. The local telephone directory is an excellent tool for locating resources.

Community volunteers can be wonderful mentors if they are properly instructed to help students, guiding them toward the solution to a problem. Mentors should be motivators, answering students’ questions, perhaps with another question, or giving students clues as to where to direct themselves to solve a problem, or showing students a process they know will help them better conduct an experiment or project.

Richland High School MST teacher Steve Piippo, who first developed the MST approach with scientists at Pacific Northwest National Laboratory, describes below how he developed an important relationship with local goldsmith/artisan Paul Howard in the box below.

Community Mentor

About 1985 while teaching in the laboratory a man walked in and very casually asked, “Can I be of any help to you or your students?” The man turned out to be local goldsmith Paul Howard. Paul is an artisan who now volunteers his time in the MST laboratory. He arrives at school without standard teacher attire, attendance responsibilities, or grading responsibility. He looks at each student as an individual who is motivated to create a precious metals project (metal alloys) and experience the feeling of accomplishment and success. Paul requires that each student record questions, ideas, and information in a learning log and that each question be the result of a previous application of research. Paul does not fall into the “tell me what to do next” trap. Each student’s question is followed with, “What do you have in your log,” “Have you checked this reference,” or “What do you think would work?” Students quickly learn that Paul does not regurgitate the answer but makes them derive their own individual solutions and apply their ideas as a solution. Every community has businesses that would provide a mentor, if asked. Try calling artisans, rock hounds, model airplane builders, dental technicians, American Society of Materials members, and members of the Society of Mechanical Engineers, Society of Plastics Engineers, junior college or university artisans, boat builders, ceramic and stained glass businesses, and other local businesses.

—Steve Piippo, Richland High School MST teacher
Building a School/Community Advisory Committee

An ideal MST advisory committee membership comprises teachers, administrators, curriculum directors, vocational directors, and representatives from local MST-related industries, who meet monthly to find out such things as 1) what is happening in the MST course, 2) what equipment might be needed, 3) ways local business/industry can assist teachers/students in laboratory activities or arrange field trips to their businesses, 4) and future activities in which students will be involved.

Advisory committee members can help students understand MST and also help teachers stay current in MST by sharing experience, knowledge, journals, information, and videos. Meetings can be held either at a place of business or in the MST lab.

Getting the Advisory Committee Started

We have found several ways that work well to get a local advisory committee started. A few suggestions follow.

1. Have students write an autobiographical sketch that includes what their parents do for a living and for special hobbies. Some parents will have jobs and hobbies that fit in well with the content of MST. Then ask those parents whose jobs/hobbies match your units of study if they would like to be part of your committee. Most people will be motivated to help since they have a vested interest (their son or daughter) in the class.

2. Look through the yellow pages and find any possible MST-related businesses/industries. Call or write a letter to any that sound interesting, inviting them to participate in the advisory committee.

3. Visit local industries, ask for a tour, get acquainted with the people, and tell them about your program. Occasionally, you will get a negative response, but most of the time people want to help their local school system. The following are examples of MST kinds of businesses in your area.

   Plastics:
   - Tub, spa, and swimming pool manufacturers
   - Boat builder
   - Plumber
   - Auto repair
   - Injection molding corporations
   - Toy manufacturers
“At first, starting an MST course is really intimidating. It’s like jumping on the highway without a map. Then you begin to become fairly competent.”

— Andy Nydam, Olympia High School MST Teacher

Glass and Ceramics
Artists
Stained glass
Blown glass
Pottery
Glass manufacturer
Bottle recycler
Dental lab
Glass shop
Concrete plant

Metals
Metals shop
Metal fabricating shop
Sheet metal union
Jeweler
Sculptor
Local college or high school metals instructors
Auto body shop
Tool & die shop

Composites
Recreation supply
Sporting goods
Airplane manufacturers
Automotive supply

Woods
Lumber yard
Wood supplier
Paper mill
Plywood mill
Saw mill
Finish carpenter

4. Don’t forget state, regional, and national professional societies, such as the Materials Research Council, Society of Plastic Engineers, the American Ceramic Society, and the American Society of Materials.
Setting Up The MST Classroom and Laboratory

To best facilitate the MST multi-instructional approach, you need two types of facilities: a classroom and a laboratory. A classroom and separate laboratory would be the ideal facility, but, in many places this is impossible. Figure 2.5 shows a design for a typical MST facility.

The classroom provides a formal place for class discussions, instruction, lecture, safety meetings and guest speakers, a traditional school classroom, with desks, chalkboard, bulletin boards, and book shelves. The classroom also should provide a quiet place for students to record journal entries and study complex concepts.

The MST laboratory provides a much different atmosphere. With multiple activities occurring, you hear the chatter of students discussing problems, projects, or the latest news in recent MST periodicals. You hear the buzz of a diamond cut-off saw, the clatter of spatulas, and the growl of the oxyacetylene torch, all common sounds for the MST laboratory setting.

The teacher is the key to helping and training students to work in this open environment, where learning takes place amidst constant busyness. Students learn much through this designed-discovery process. But teachers also need to be sensitive in motivating students who may be frustrated with a problem or insecure in the open-ended MST process. Most importantly, you must maintain accountability in a system that demands students cooperate with each other and at the same time work with safety as a key concern.

In setting up an MST laboratory, don’t forget to consider proper storage space. Chemicals, materials, and equipment used periodically or once a year need to be stored in locked cabinets or a storage room. Also consider storage needs for chemicals that must be separated and stored in specific areas because of their flammability or incompatibility.

The design of the facility must provide a safe learning atmosphere. There has to be sufficient space and openness to allow students to freely move around work areas without crowding those who are performing laboratory experiments. It is also important for the teacher to be able to scan the laboratory quickly to assess the safety and performance of all students.

Also, ventilation of specific work locations such as an exhaust canopy over the furnaces and the area where students solder are important considerations. Heat and flammable materials must be properly separated to meet building and safety code. Chemical hazards must also be addressed to ensure students are protected from potential injury.

“The technology education laboratory provides a setting that abounds with opportunities for a broad range of learning activities extending from the concrete to the abstract.”

— International Technology Education Association
A Storage  
B Hood  
C Desk  
D Sink  
E Work station  
F Counter  
G Burn out oven  
H Furnace  
I Sander  
J Plastic injection molder  
K Dremel table saw  
L Dremel drill press  
M Rolling mill  
N Rockwell tester  
O Grinder  
P Buffer  
Q Drill press  
R Glass grinder

Figure 2.5. Design of a Typical MST Facility
Laboratory Safety

Before beginning any experiment/demonstration, you must discuss safety with students and establish laboratory rules. To perform laboratory procedures without considering student safety can endanger all people in the laboratory. For some students, the MST experiments are their first experience working with testing materials, using laboratory tools, and working in the same space with other students.

You must be aware of your state’s safety rules or guidelines for laboratory safety. Training students in how to safely perform laboratory procedures and operate tools and equipment used to conduct experiments and complete their projects is of utmost importance. Please consider the following items when developing laboratory rules.

- **Protect your eyes and students’ eyes.** Whenever the classroom is set up in a working (laboratory) mode, or your facility has a dedicated MST laboratory, the first thing students should do is put on their safety glasses—even before setting up the experiment. Those visiting or walking through the laboratory must also wear safety glasses. At first, some students may feel awkward about wearing the glasses, but once everyone wears them, they feel more comfortable and learn the importance of protecting their eyes. Getting into the habit of wearing safety glasses also reminds students to be more safety conscious.

- Ensure that other body parts are protected from possible hazards. Wear gloves, aprons, chemical goggles, and masks, when necessary. Use tongs and other protective equipment, when necessary. Wear long pants (i.e., blue jeans) and leather shoes while working with molten material.

- Students need to know the differences between safety glasses and chemical goggles and use them appropriately. This means they need to have access to both kinds of eye protection.

- Adequately ventilate the laboratory. Make sure vents are not near building intakes.

- Most vaporized metals are health hazards, and exposure should be limited.

- Ensure correct safety labels are attached and safety signs posted in appropriate places. Explain all signs and emergency equipment; do not assume they are self-explanatory.

- Be aware and have a working knowledge of materials safety data sheets (MSDS) reports for materials used in the laboratory.

- Ensure that students working in the laboratory give each other consideration and distance. Make sure students moving from one work area to another are conscious of their surroundings and avoid bumping into other students.
Creating an MST Environment

- Make sure students clean up after completing each experiment or day’s work.
- Avoid contaminating chemicals or surfaces.
- **Horseplay must not be allowed in the laboratory at any time.** Students need to know the seriousness and consequences of horseplay. Accidents don’t happen. They are caused by carelessness.
- Emphasize wearing “proper” clothing. Shorts and open-toed shoes are not appropriate in a laboratory setting. Panty hose can be readily dissolved by acids and/or solvents, causing chemical burns. Long hair should be tied back. Loose clothing should not be worn. Have alternative activities ready for students not appropriately dressed. A study area where these students can work during laboratory time is useful. Or, keep extra safety apparel on hand that students can borrow for the class period.