Developed at Northwestern University (NU) and propelled by an initial grant from the National Science Foundation in 1994, the Materials World Modules (MWM) Program has developed a series of inquiry and design modules that encourage students to discover the interconnections between science, technology, and society.

Focusing on materials that we use every day, a team of NU professors, high school science teachers, professional editors and designers created a series of nine modules each featuring a separate materials topic. The modules are designed for use in middle and high school science, engineering and technology classes. They have been extensively field-tested by teachers in a wide array of subjects, including chemistry, physics, biology, earth science, technology, engineering, and mathematics.

Why do science teachers use MWM?
✓ Active, hands-on learning
✓ Students of all abilities can relate science to real world applications
✓ Cutting edge research topics
✓ Professional development workshops and seminars
✓ Summer research opportunities
✓ Free resources, curricula and design ideas
✓ Ease of use for experienced and new teachers
✓ Meets National Science Education Standards and State Standards

What do students say?
Students who used MWM related a perceived improvement in their science process and technological design skills in key areas such as: working as a team, connecting science to the real world, planning a design project, and analyzing data and understanding science concepts – to name a few. Student surveys indicated that after using MWM there was a positive change in their perceptions about science. They related that: science classes are interesting; they talked about science among friends; they looked up science information on their own; and they considered going into science as a career.

Each module contains:
Teacher Edition: Divided into three user-friendly sections [introduction, planning guide, & appendix] to provide teachers with comprehensive instructions as well as troubleshooting and teaching tips.

Student Edition: Structured into three parts: an introduction that inspires inquiry; exploratory activities that provide background & concept information central to the topic; and design projects that challenge students to apply what they have learned by creating a functional prototype product from the materials at hand.

Kits: Contain the basic materials that a class of 24 to 32 students (eight groups of three students or four students) will need to run the activities and design projects outlined in the modules.

Current Modules:
- Biodegradable Materials
- Biosensors
- Ceramics
- Composites
- Concrete
- Dye Sensitized Solar Cells
- Environmental Catalysis
- Food Packaging
- Intro to the Nanoscale
- Manipulation of Light
- Nanopatterning
- Nanoscale Drug Delivery
- Nanotechnology
- Polymers
- Smart Sensors
- Sports Materials

Materials World Modules
Northwestern University
1801 Maple Avenue, Suite 2431, Evanston, IL 60201
847-467-2489 www.materialsworldmodules.org
THE MATERIALS WORLD MODULES PROGRAM

R.P.H. Chang and Matthew Hsu

Materials Research Institute, Northwestern University, Evanston, IL, 60201; rphchang@gmail.com

ABSTRACT

This article presents an overview of the philosophy, development, evaluation and assessment of the Materials World Module (MWM) program. Launched at Northwestern University in 1991, MWM develops modular instructional content to supplement pre-college STEM curricula. Thirteen modules have been published to date on materials-related topics ranging from Composites to Sports Materials and Nanotechnology. MWM modules employ the methodology of inquiry and design, which enables students to perform the work of scientists and engineers in their classrooms. The next four articles in this issue of the Journal of Materials Education describe the quantitative assessment of data gathered from a large field test of the program (Pellegrini), a detailed study of the classroom-based technology (engineering) design process (Heroux et al.), the personal experience of a veteran teacher who has participated in the program since the very beginning (Turner), and a report on MWM in Mexico (Fuentes et al.).

BACKGROUND

In 1991, when the author was serving as the director of the NSF-funded Materials Research Laboratory at Northwestern University, an NSF program director posed a challenging question: “How have the activities of your Center benefited U.S. society?” This question is clearly relevant today and, I believe, should be asked of any research center or institution. At that time, it was not yet obvious that those working in universities should help to improve pre-college science education. However, there were several factors that drove us in that direction: 1) Our materials science and engineering department was not getting any direct freshman applications; 2) Our own children were not interested in pursuing science or engineering as a career choice; and 3) We noticed a large communication gap between university faculty and precollege science teachers – two communities that should be cooperating closely in the interest of national science and technology education.

Based on these initial observations and the challenge set forth by NSF, we launched two NSF-funded programs in 1993. Both were designed to quickly transfer the latest multidisciplinary research content from our laboratories into precollege STEM classrooms. The first - Research Experience for Teachers (RET) invited science teachers to perform research at Northwestern laboratories, which equipped them first-hand research experience to carry back to their classrooms. The second program-
Materials World Modules (MWM) set out to develop supplemental modular instructional content that would enable students to perform research and design projects related to their STEM coursework. Today, both programs have become national in scope. The following is a historical perspective of MWM and its future vision for improving STEM education in the U.S. and around the world.

THE MWM PHILOSOPHY

MWM is designed to supplement existing STEM curricula with short, easy-to-use modules that are pre-aligned with national learning standards and benchmarks. Each module lasts about 2 weeks and consists of a series of inquiry-based learning activities culminating in a design project. Modules are designed for a wide range of school districts and teacher experience levels.

In our experience as materials researchers, interesting science usually occurs where disciplines intersect. Materials science and nanotechnology are excellent examples. Both fields are inherently transdisciplinary and have direct relevance to industrial, societal, and global needs. Research knowledge in these areas has been expanding exponentially in recent years, and it has become imperative to bring these ideas into the classroom as quickly as possible. MWM module topics are selected with a view to preparing students for future careers in industries and technologies that will be relevant 10 or 20 years from now. Therefore modules address materials and nanotechnology-based applications to industry, society and global challenges such as energy, environment, health/medicine, and security.

Modules published to date include:
- Ceramics
- Composites
- Concrete
- Polymers
- Sports Materials
- Biodegradable Materials
- Biosensors
- Environmental Catalysis
- Food Packaging Materials
- Smart Sensors
- Introduction to the Nanoscale
- Manipulation of Light in the Nanoworld
- Nanotechnology

For ease of use by teachers and students, modules include a teacher edition, a student edition, and a kit of supplies for 24 students, a user’s guide, minipedia and links to useful websites. Recent modules also include web-based animations, simulations, and games. Workshops and webcasts are available to prepare teachers to use the modules effectively.

The program website (www.materialsworldmodules.org) includes an introduction of each module, videos illustrating how the modules are being used, an online store where modules and classroom kits can be purchased, and a MWM community where teachers and students can share their MWM experiences, design projects, discussion and collaborations.

MWM METHODOLOGY AND DEVELOPMENT

Module development is driven by the needs of students and teachers. Students need modules to enhance their learning of science and
engineering concepts, build their confidence in applying these concepts, and prepare and inspire them to enter science and technology-related careers. Teachers need modules to be safe for use in the classrooms, inexpensive, relevant to concepts taught in physical and biological curricula and closely linked to state and national science standards and benchmarks. Modules must also be designed for use in incremental classroom sessions, not to exceed a total of two week period.

The inquiry and design methodology has proven very effective in meeting these needs. Students gain exciting hands-on experience working as scientists (inquiry) and engineers (design) that stirs their natural curiosity and motivates them to learn. Teachers receive help in linking science and engineering concepts to real-world applications that students can appreciate.

The module development process is very rigorous. Great care is taken to ensure that content is relevant and up-to-date, and that student have a “wow” experience. All modules start with a demonstration of an intriguing phenomenon that piques the interest of the students, followed by a series of inquiry-based activities that teach the concepts emphasized in the module. At the end of the module, students team-up to th a design project to show how much the students have really grasped the concepts. Students work in teams and communicate their findings through written and oral presentations. All elements of the module are thoroughly tested in classrooms before the module enters final development. Small scale classroom assessments are performed during the development phase to ensure maximum classroom impact.

A unique aspect of MWM development is its emphasis on vertically-integrated development teams. University research faculty and their students work closely with pre-college science teachers in physics, chemistry, biology, and technology to ensure that modules are appealing to students, properly aligned with standards, and used effectively in the classroom. The program also provides professional development for teachers in the form of workshops and summer research. This close partnership with teachers has been very effective in vertically integrating STEM learning across levels.

In 1999, the MWM program launched the MWM-2002 project for the purpose of performing nationwide field tests. Eight cross-cutting modules (e.g. bonding and polarity; motions and forces; properties of solutions; conductivity, light and color; etc.) were developed using content from various prior modules. Each module was offered in three levels of difficulties. Teachers across the country were able to go online to download files for use in their classrooms and upload assessment questions and evaluation comments for analysis by our external evaluator and assessor. A detailed report is presented in the following article by Pellegrini. This nationwide study showed significant impact of MWM on student knowledge gain despite the fact that the amount of time spent was very limited - no more than ten percent per semester in most cases.

In 2005, researchers at the Centro de Investigación en Materiales Avanzados (CIMAV) in Chihuahua, Mexico began working with local teachers and the State of Chihuahua to translate and adapt MWM modules for use in Mexican high schools. Mexican developers worked closely with Northwestern and followed the same content development and professional training process described above. This effort is described in the article by Luis Fuentes.
CONCLUSIONS AND FUTURE VISION

Investment in science and engineering education is the key to a nation’s economic development. This investment is long-term and requires at least 16 years before it pays dividends. A well planned strategy is essential to save time and resources. We must ask ourselves how we can prepare students for lives and careers that will change with new technological and economical developments and how can we provide opportunities for all citizens to learn about the exciting fields of STEM?

To date the MWM program has reached more than forty thousand students in 48 U.S. states and thousands more in Mexico. The program has demonstrated that the insertion of trans-disciplinary materials science and nanotechnology concepts can positively impact national STEM education. It is also clear that supplemental modular approach and inquiry and design methodology employed by MWM significantly benefits school teachers and students alike.

The four new MWM modules for publication: “Drug Delivery at the Nanoscale”, “Dye-Sensitized Solar Cells,” “Nanopatterning,” and “Nano Surfaces” address a range of exciting nanoscale science and engineering concepts with applications to global needs. Going forward, MWM is encouraging school districts around the country to adopt MWM as an integral part of their STEM curricula. The adoption of MWM by each state will do much to address the urgent need for improving the US STEM education and its global economic strength and leadership. The articles that follow in this issue of the Journal of Materials Education provide additional perspective on MWM activities in the US and Mexico.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the sustaining support of the MWM program by the National Science Foundation.

Journal of Materials Education Vol.32 (5-6)
MATERIALS WORLD MODULES: 
A VIEW FROM THE SCIENCE CLASSROOM

Ken Turner
Science Teacher, Schaumburg High School, Schaumburg, IL; kturner@d211.org

ABSTRACT
This article describes the experiences of a high school science teacher who was an early collaborator in the Materials World Modules (MWM) program. He attended the first organizational meeting in 1991 and he has remained deeply involved ever since. In this article, he looks back over these many years and reflects on his increased use of MWM, discussing the ways in which his classroom teaching style has changed for the better, the ways in which his students have learned to produce design projects with increased sophistication, and above all, the ways in which he has become an active participant in making science education a more exciting and rewarding field.

INTRODUCTION
At what point does one allow high school students to experience science? When are they considered to have a sufficient knowledge foundation to design and execute their own experiment? Is it appropriate for them to attempt to design something of their own that might require background research, significant testing and re-design? Is there a type of learning, or of motivation, that requires a deeper assessment than a standardized test? Against the backdrop of developing National Science Education Standards, and more recently of the No Child Left Behind Act (2001), the MWM program initiated a unique collaborative effort between university researchers and high school science teachers to bring cutting-edge, hands-on, student-centered units to the classroom while placing the student in the role of scientist/engineer.

BEGINNINGS
In 1991, R.P.H. Chang, Director of the Materials Research Institute at Northwestern University invited Chicago area science teachers to attend an informational meeting on the MWM project. Chang expressed concern for the direction of education - too few students were enjoying science and choosing science and engineering fields. He proposed increasing
student excitement by demonstrating the relevance of doing science and asked for our help to develop instructional materials that would transfer the latest materials science and engineering concepts from Northwestern laboratories into high school science classrooms. Much of that meeting escapes my memory now, but two distinct themes will always be with me: (1) What is materials science? and (2) Chang's desire to partner with high school teachers.

Like the vast majority of high school teachers in 1991, I had never heard of materials science but as Chang explained this new initiative, I wanted to learn more. As for the partnership, he used this analogy: We want to bake you (meaning us science teachers) cookies, but we don’t want to make you sugar cookies, if what you really want is chocolate chip cookies. Chang made it clear that he wanted science teachers to provide input right from the start. That was an unusual statement for a scientist to make! More meetings followed.

EARLY MODULE DEVELOPMENT

A fellow teacher and I volunteered to work with Matthew Hsu, a materials scientist from Northwestern, to create the first module. The composite module began with a quick lab that demonstrated the strength of paper-reinforced ice. After developing a few other possible module activities, I recall the students making fiberglass reinforced epoxy beams that were tested in a complex three-point bend apparatus. When enough water for weight had been added to break the beam, a circuit was completed and the water flow was shut off automatically. Although innovative, and worthy of study, the epoxy resin created havoc with the ventilation systems of most high schools; and the testing, while very accurate, was not suited for high school students or budgets, The 3-point bend apparatus was too expensive for most schools to purchase. A good beginning had been made, but it was time for re-design.

REDESIGN

The redesign phase is one of the continuing threads of each module. Students design, build, and test something, and then improve upon it through re-design. Re-design occurs in all facets of the modern world. Gates did not stop at Windows version 1. Skis, airplanes, car engines, telephones, hip replacements, etc. - it would be hard to imagine a product that has not undergone almost continuous re-design. As it is in the real-world, so it was with our first efforts. We kept the original ice/fiber composite demo and followed it with guided activities illustrating concepts such as “What is a composite?” and “How are strength and stiffness related?” We also added guided research on composites and the culminating design project: a fishing pole prototype. The fiberglass-reinforced epoxy was scrapped in favor of more student-friendly and cheaper designs of fishing poles or other composite structures. In my experience, once students have seen examples of designs developed by other teams, they seem more eager to go back to the drawing board and give it another try.
Their new designs invariably eclipse the marks set by their first designs. So it was with our new Composites module. We achieved a highly adaptable set of activities that fit easily into many courses. It was easy to lead, easy to use, easy to adapt, and the materials were inexpensive. I am very proud of the work we did with that module.

BUILDING ON COMPOSITES

Composites became the successful template for all subsequent MWM modules, including Biodegradable Materials, Biosensors, Ceramics, Food Packaging, Concrete, Polymers, and Smart Sensors. Each module follows the organizational pattern and scaffolding that was first laid out in Composites. One begins with a captivating demonstration or “hook” — something that piques the interest of the students and encourages them to ask questions. Activities and labs help students to gain new content and see how the concepts being presented connect with the opening “hook” activity and relate to the culminating design project. Activities and labs include pre-lab and post-lab reading assignments and questions for students, as most will have no experience with these materials. Fortunately, MWM has developed more elaborate guides for the teachers, as they, too, may have little experience with the topic.

CLASSROOM EFFECTS OF MWM

I place a little MWM in my curriculum every year because from start, I have liked the difference that it makes in my classroom. Students enjoy the freedom to ask questions and seek answers to their questions. Students see the relevance of the topics and are curious about them. With its focus on hands-on activities, cutting edge technologies, and student design, MWM makes my classroom more “team” focused. Instead of being the boss at the front of the room, I become a collaborator. I ask questions, I direct, I probe, I check—these are still things that I do as a teacher. But my students are so much more active; asking their own questions, proposing to continue a lab in a new direction, seeking further information on a topic on their own, without any direction from me. In a short two week period, students gain enough insight into a new material to design/build/test/present/redesign something with that material. Rather than simply memorizing some organized step system of scientific method, they have engaged in authentic scientific inquiry and technological design.

Every year, MWM helps a few more kids get excited about being in Science class. Have all my students decided to become engineers and scientists? No. But I can say that all of them have had a positive experience with a novel, relevant material that has made them consider—a little more thoughtfully—how the world is put together. The next time a new plasma TV, fuel cell car, or graphite bike comes along they will be better able to evaluate the design and appreciate the research and engineering that brought it about. Using MWM has helped me to keep my classroom a learning community; where students have freedom to ask, to seek, to discover, to grow. This impact, this orientation to student learning, this change in perspective is important to my students and me.

OPPORTUNITIES FOR OUTREACH AND PROFESSIONAL DEVELOPMENT

MWM was designed to be teacher friendly and very adaptable. Teachers may choose to use a single 15-minute demonstration or an entire module that lasts two weeks or more. Teachers
have used it with virtual every secondary science class currently being offered. It has also been adapted for the middle school and college levels. I was part of the original presentation team that brought MWM to many National Science Teacher Association (NSTA) conferences, from one coast to the other. Teachers began to use our materials all over the country. Our team presented many times regionally, and ran workshops in many states. Department of Defense schools sponsored a workshop to train their teachers to use our materials. Today, MWM modules are used in many states across this country and states in Mexico.

MWM has also gotten me very excited about materials science. I spent two summers performing research at Northwestern, where Chang designed the first Research Experience for Teachers (RET) program. Although high school science teachers teach about research, most have little or no experience in research. RET is designed to give teachers a taste of the research experience so that they can teach from an experiential framework. Imagine a science teacher who can answer questions about what a scientist does from the perspective of a scientist! It is no wonder that the RET program has become a staple outreach program at nearly all research institutions.

As my love of materials science grew, I pursued all sorts of topics in my readings. Eventually, I won grant support from Toyota Tapestry to simultaneously launch several research topics in various classes at our high school. Students were experimenting with composites, dendrimers, piezoelectrics, memory alloys, high temperature superconductors, diamond thin-film, humidity sensing polymers, lighter than air biodegradables, and more. Some of these continue in my classes to this day. My perspective on the teaching/learning relationship that was so influenced by MWM also helped me to earn my National Board Certification, the highest certification a teacher can earn.

CONCLUSION

My students and I have gained much from my relationship with MWM. The program has given me insight into materials science - a field that I did not know existed, an ongoing, collaborative relationship with materials and education researchers, and a real taste of scientific research and the role it plays in society. Most importantly, it has provided the ultimate in professional development and made me a much better teacher. My students have greatly enjoyed learning exciting materials science content and the opportunity to do the work of researchers, designers, and engineers in the classroom.

REFERENCES

About the Materials World Modules (MWM)

Sixteen classroom modules have been published to date (right). Each includes a set of printed student manuals, a teacher’s guide with assessment items and a kit of basic supplies for a class of 25 students (below). The program has been successfully used by more than 50,000 students in 47 states. National field tests have demonstrated its effectiveness in a wide range of classroom settings.

Key elements of MWM Design:

**Supplement rather than Replace:** Because MWM is designed to supplement rather than replace existing STEM curricula, it is a fast, effective and affordable means of boosting student achievement and improving student dispositions toward STEM.

**Easy to Implement:** Modules are designed for students of varying abilities and levels, from 5th to 12th grade. Because the modules take about 2 weeks to teach, they are easy to insert into a range of STEM courses including chemistry, math, biology (life science), physics (physical science), and earth (space science).

**Teacher Friendly:** Modules are easy for teachers to use because they were developed in partnership with teachers. National field test results have demonstrated that the modules are equally effective with experienced and inexperienced teachers. Teacher’s editions include: background on how the topic and basic science concepts are linked to societal needs, new technologies and careers; connections to STEM curricula and science standards; guidelines for implementing the inquiry and design methodology; an assessment guide; safety guidelines; and links to learning technologies (i.e. simulations, animations, and games.)

**Methodology and Alignment with Standards:** Modules employ the principles of scientific inquiry and engineering design to offer students exciting hands-on learning and deepen their understanding of STEM. Module methodology is not only aligned with existing national and state science standards but is also in direct alignment with the new science education framework recently released by the National Research Council\(^1\), which emphasizes the following three “dimensions” of STEM learning:

**Dimension 1: Core Disciplinary Ideas** - MWM links the STEM concepts already being taught in middle and high school to current laboratory research, technological applications, natural phenomena, and global challenges.

**Dimension 2: Cross-Cutting Elements** - MWM teaches STEM in an integrated or “cross-cutting” manner by addressing cross-cutting concepts such as Form and Function, Cause and Effect, Scale, Proportion, and Quantity, Systems and Systems Models, Cooperative and Discrete Phenomena, etc. The modules also link math concepts to science and engineering applications, which is of critical importance for the viability of U.S. undergraduate science and engineering programs.

---

\(^1\) This framework is scheduled for adoption by a majority of states in 2012 and will serve as the basis for new national science standards.
**Dimension 3: Scientific and Engineering Practices**—Based on the principles of scientific inquiry and engineering design, each module is designed with developmental coherence, beginning with a hook activity to captivate student interest in a foundational concept, followed by a series of learning activities (below) that culminate in a creative design project such as the atomic force microscope project (right). The design process incorporates teamwork, communication, and competition, as well as testing and redesign, so students can learn from what didn’t work, as well as from what did!²

<table>
<thead>
<tr>
<th>Activity 1: Unusual Size Dependent Properties</th>
<th>Activity 2: Nano Applications around Us</th>
<th>Activity 3: Fabricating Nano-Sized Objects</th>
<th>Activity 4: Imaging Nano-Sized Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce objects sizes to the nanoscale affects their physical &amp; chemical properties.</td>
<td>Use Internet search engine to find ‘hot’ nanoscience concepts &amp; applications.</td>
<td>Use plastic spheres &amp; glitter to model Nanosphere Lithography.</td>
<td>Use laser deflection to amplify movement in nanoscale to the macroscale.</td>
</tr>
<tr>
<td>Why does gold appear to have different colors?</td>
<td>Where to find nanotech applications?</td>
<td>How to make nanoparticles?</td>
<td>How to detect it?</td>
</tr>
</tbody>
</table>

**Professional Development and Content Support**

MWM offers coordinated professional development designed to:

1. Equip teachers with a basic understanding of materials and nanoscale science and engineering;
2. Prepare teachers to use the classroom modules effectively and implement the inquiry and design methodology in their classrooms;
3. Allow teachers to exchange best practices; and
4. Enable teachers to participate in the iterative improvement of module content.

Professional development activities include:

- Workshops where teachers engage in hands-on inquiry and design activities (top right);
- Web-based Content Demonstrations of module activities (center right);
- Content Lectures: University researchers offer web-based lectures on key concepts and their applications;
- Membership in an Online Community, where teachers can create and maintain their own profiles, join discussions, and collaborate with each other (bottom right).

---

Do you know the attributes and advantages of biodegradable materials?

Students make, test, and evaluate biodegradable films and gels. They use their knowledge to design devices that release a dye in a controlled manner as they degrade.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

Activities
- Comparing Packing Materials
- Hunting for Biodegradable Objects
- Processing and Comparing Their Mechanical Properties
- Measuring Degradation Rates
- Researching Biodegradable Materials

Design Project
- Designing a Medicine Delivery Device
- Designing a New Biodegradable Product

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Biosensors – basic biological processes transformed into sophisticated advances in biotechnology.

Students investigate the use of biological molecules as materials and use enzymes as chemical sensors in the design of diagnostic tests for peroxide, cholesterol, and glucose.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

**Module At-a-Glance:**

**Activities**
- Investigating Biological Molecules and Bioluminescence
- Investigating Enzymes
- Making a Peroxide Biosensor
- Testing a Cholesterol Biosensor
- Evaluating a Home-Use Cholesterol Biosensor

**Design Project**
- Designing a Glucose Biosensor

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

**MWM’s key ingredients**

- **Interdisciplinary**
  Integrates science & non-science subjects

- **Flexible**
  Modify to your teaching style, students’ ability and class time

- **Hands-on**
  Contains activities that lead up to inquiry-centered design projects

- **Cutting-edge**
  Introduces issues on the forefront of technological research

**for improving STEM education**

Science • Technology • Engineering • Math

---

**Chemistry**
- Chemiluminescence
- Enzymes
- Catalysts
- Chemical Reactions
- Reaction rates
- Proteins
- Oxidation-reduction Reactions
- Paper Chromatography
- Making Sequential Dilutions
- Solubility and concentrations
- Lipids

**Biology & Life Sciences**
- Bioluminescence
- Biological Molecules
- Enzymes
- Linked Enzymatic Reactions
- Proteins
- Sensing Light and Color
- Cholesterol
- Atherosclerosis

**Mathematics**
- Calculating Ratios
- Slope-intercept Formula
- Interpreting Graphs
- Calculating Concentrations

**Physics & Physical Sciences**
- Light
- Color
- Luminescent Indicators
- Electromagnetic Spectrum
- Colorimetric Indicators
- Atomic Structure and Energy States

**Health**
- Cholesterol in the Diet
- Cardiovascular Disease
- Lowering Cholesterol Levels
- Health-care Technology

**Career Education**
- Careers in Health Care

**Language Arts**
- Writing a Report
- Public Speaking

---

**Materials World Modules**

An Inquiry & Design Based STEM Education Program
Northwestern University  www.materialsworldmodules.org
847-467-2489  mwm@northwestern.edu
Dinnerware, tile, sidewalks...radar-absorbing paint for military aircrafts. From the common to the extraordinary, ceramics are everywhere.

Students study the science of compacting ultra small ceramic particles. They evaluate the evolution of density and microstructure of ceramics as they are synthesized at high temperatures. They then use ceramics to make a voltage-protecting device.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

Activities
■ Comparing Properties to Identify Materials
■ Searching for Ceramics
■ Exploring ZnO Powder
■ Reducing Porosity and Slip Casting
■ Sintering Ceramics
■ Making a Varistor

Design Project
■ Designing a Low-Clamping Voltage Suppressor
■ Synthesizing a High-Temperature Superconductor

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Tires, sports equipment, formica, and cardboard. Do you recognize other composite materials you use every day?

Students find out what composite materials are and test them to learn their advantages over pure materials. They design a prototype composite material to make a strong, lightweight fishing pole.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

**Module At-a-Glance:**

**Activities**
- Testing Different Kinds of Ice
- Hunting for Composite Materials
- Exploring the Difference Between Strength and Stiffness
- Testing a Foam Composite
- Researching Composites

**Design Project**
- Designing a Fishing Pole
- Designing a New Material

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University  ■  www.materialsworldmodules.org
847-467-2489  ■  mwm@northwestern.edu
Concrete vs. Cement. What makes them different?

Students learn how the components of concrete can be modified to alter its properties. They use their knowledge to make concrete roofing tiles that meet specific design and performance criteria.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

Activities
- Hunting for Objects Made of Concrete
- Comparing Different Kinds of Cements
- Comparing Different Concrete Formations
- Testing Properties of Concrete
- Reinforcing Concrete

Design Project
- Designing a Concrete Roofing Tile
- Designing a New Concrete Product

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Nanotechnology is applied to create targeted delivery of nanomedicine for localized treatment.

Students learn how nanotechnology is revolutionizing the approach to drug delivery and diagnostics. They are engaged in a simulated, as well as hands-on experience, in designing nanomedicine for targeted delivery. Students are challenged to design a nanodrug with an optimum time-release profile.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Nanotechnology for Energy Conversion
Can we harvest the sun’s vast energy using nanoparticles to fabricate inexpensive, next generation solar cell devices?

Students use nanotechnology and plant pigments to fabricate an artificial photosynthetic device for capturing the sun’s energy and convert it to electricity. They are then challenged to design the most efficient dye sensitized solar cell using vegetable or fruit dyes.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (ideally, approximately 10 hours) to complete.

Module At-a-Glance:

Activities
■ Investigating the Photosynthesis of Spinach Leaf Discs
■ Separating Leaf Pigments Using Paper Chromatography
■ Measuring Silicon Solar Cell’s Performance
■ Making a Spinach Dye Sensitized Solar Cell

Design Project
■ Designing a Dye Sensitized Solar Cell with Maximum Power Output

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

MWM is designed to improve STEM education
Science • Technology • Engineering • Math

Interdisciplinary
Integrates science & non-science subjects

Flexible
Can adapt to your teaching style, students’ ability and class time

Hands-on
Contains activities that lead up to inquiry-centered design projects

Cutting-edge
Examines issues on the forefront of technological research

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University • www.materialsworldmodules.org
847-467-2489 • mwm@northwestern.edu

Chemistry
Atomic Structure ■ Bonding ■ Polarity ■
Redox Reactions ■ Rates of Reactions ■
Chromatography ■ Solutions, Colloids, and Suspensions ■ Hydrocarbons ■ Catalyst ■
Electrochemistry

Biology & Life Sciences
Cell Processes ■ Photosynthesis ■
Energy Pathways ■ Ecosystems ■ Carbon Cycle ■ Food Web ■ Decomposition

Mathematics
Orders of Magnitude ■ Size and Scale ■
Surface-to-Volume Ratios ■ Graphing (Making, Reading and Interpreting) ■
Averages ■ Rates

Physics & Physical Sciences
Electromagnetic Waves ■ Colors and Light ■
Capillary Forces ■ Circuits ■ Electron Flow/Current ■ Photoelectric Effect ■
Energy, Work, and Power ■ Energy Source

Geology & Earth Science
Metals ■ Rocks and Minerals ■ Use of Natural Resources ■ Renewable and Nonrenewable Resources ■ Solar Energy

Technology/Engineering Education
Iterative Design ■ Building Prototypes ■
Optimization ■ Communications

Society
Ethics and Impact of Uses of Nanotechnology

Language Arts
Public Speaking ■ Writing a Scientific Paper
Catalysts are part of the solution to protecting the environment – developing new catalytic technologies with nanoscale materials provides for a promising tomorrow.

Students learn what a catalyst is, gain an idea of the scope of catalysis research today, and become aware of the effect of catalysis on environmental protection. Advances in nanotechnology are also discussed as a solution to eliminate environmental pollutants. Students are challenged to design an original solution to an environmental problem of their choice.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

**Module At-a-Glance:**

**Activities**

- Catalyzing with Platinum Black
- Searching for Catalysts
- Using a Heterogeneous Acid Catalysis
- Using a Metal Catalyst to Degrade an Air Pollutant
- Using Photocatalysis to Degrade a Water Pollutant

**Design Project**

- Designing a Catalytic System to Degrade a Pollutant
- Conceptual Design for Environmental Catalysis

MWM is designed to improve STEM education

Interdisciplinary
Integrates science & non-science subjects

Flexible
Can adapt to your teaching style, students’ ability and class time

Hands-on
Contains activities that lead up to inquiry-centered design projects

Cutting-edge
Examines issues on the forefront of technological research

Chemistry
Structure and Properties of Matter
- Conservation of Matter
- Oxidation-Reduction Reactions
- Catalysts
- Activation Energy
- Reaction Kinetics
- Biochemical Reactions
- Combustion
- Thermodynamics

Biology & Life Sciences
- Photosynthesis
- Enzymes
- Biochemistry

Mathematics
- Measuring
- Graphing (Making, Reading, and Interpreting)
- Computing
- Averages
- Rates

Physics & Physical Sciences
- Properties of Matter
- Physical and Chemical Changes
- Heat Energy
- Light Energy
- Energy Transformations

Geology & Earth Science
- Metals
- Use of Natural Resources
- Environmental Pollution Issues

Technical Education
- Designing
- Building Prototypes
- Communications

Language Arts
- Writing a Report
- Public Speaking

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University  ■  www.materialsworldmodules.org
847-467-2489  ■  mwm@northwestern.edu
Potato chips, soda, candy and frozen pizza. Your students’ four food groups or their next science lesson?

Students learn about the many functions of food packaging, besides protecting foods, and how food packaging materials affect the environment. Then they design their own environmentally friendly package for delivering a hot baked potato.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

Module At-a-Glance:

Activities
- Investigating Food Packaging
- Analyzing Food Packaging Materials
- Evaluating the Impact on the Environment
- Researching Materials
- Designing a Protective Package
- Comparing the Insulating Properties

Design Project
- Designing a Hot Potato Package
- Designing New Food Packaging

Module A-at-A-Glance:

Chemistry
- Acids and Bases
- Bonding
- Changing States of Matter
- Heat and Temperature
- Kinetic Energy of Molecules
- Polymers
- Properties of Matter

Biology & Life Sciences
- Biodegradation
- Decomposers
- Environmental Issues
- Microorganisms
- Plant Hormones
- Thermoregulatory Adaptations

Mathematics
- Computer Modeling
- Formulas
- Graphing
- Percentages
- Rates
- Ratios
- Volume
- Weights and Measurement

Physics & Physical Sciences
- Acceleration
- Forces
- Gravity
- Heat and Heat Transfer
- Insulation
- Mass
- Microwaves
- Newton’s Second Law of Motion
- Potential and Kinetic Energy
- Thermal Energy
- Volume and Capacity

Geology & Earth Science
- Mining

Technical Education
- Insulating Materials
- Microwave Ovens

Social Studies
- History of Food Preservation and Packaging Technology

Language Arts
- Describing a sequence
- Writing a report
- Public speaking

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University ■ www.materialsworldmodules.org
847-467-2489 ■ mwm@northwestern.edu
MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

Activities
- Size Dependent Properties
- Powers of 10 and Scale
- Surface Area and Volume
- Playing the Nano Concept Card Game “Nanocos”

Design Project
- Designing a Liquid Geyser

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

MWM is designed to improve STEM education

Science • Technology • Engineering • Math

Interdisciplinary
Integrates science & non-science subjects

Flexible
Can adapt to your teaching style, students’ ability and class time

Hands-on
Contains activities that lead up to inquiry-centered design projects

Cutting-edge
Examines issues on the forefront of technological research

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University • www.materialsworldmodules.org
847-467-2489 • mwm@northwestern.edu

Chemistry
- Chemical Reactions
- Food Chemistry
- Hydrogen Bonding Polarity
- Surface Chemistry/Catalysis

Biology & Life Sciences
- Size and Bone Strength
- Size and Skin Coverage
- Microscopy
- Allometry
- Size and Metabolic Rate
- Size and Thermoregulation

Mathematics
- Dimension
- 2-D and 3-D Geometric Shapes
- Scale
- Estimation/Approximation
- Powers of Ten
- Logarithm and Exponents
- Ratios and Proportions
- Length, Area, and Volume Measurement
- Surface Area to Volume Ratio
- Graphical Analysis

Physics & Physical Sciences
- Color
- Capillary Forces
- Energy Transfer
- Quantum Effects
- Size and Forces/Strength
- Size and Dominant Forces
- Size and Surface Tension
- Size and Terminal Speed
- Size and Thermal Radiation
- Types of Microscopes
- Astronomical Objects

Language Arts
- Writing a Report
- Public Speaking
- Giants and Tiny Creatures in Fantasy Stories
- Large and Small Scale Creatures/Devices in Science Fiction Stories
- Numbers and Magnitude in Literature
MANIPULATION OF LIGHT IN THE NANOWORLD

What makes opals so colorful? What can optical engineers learn from a peacock feather?

Students learn about how light interacts with matter at the nanoscale. They will fabricate, test, and evaluate their own photonic crystals.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

Chemistry
- Spectroscopy
- Structure of Atoms
- Pigments

Biology & Life Sciences
- Function of the Eye
- Organisms' Response to Light
- Resolution in Microscopes
- Color and Iridescence in Nature, Adaptation

Mathematics
- Angles and Arcs
- Measuring
- Sine and Cosine
- Dimension
- Wave Functions

Physics & Physical Sciences
- Electromagnetic Spectrum
- Energy Transfer
- Color
- Interaction of Energy and Matter
- Waves Diffraction and Interference
- Thin Films

Earth & Space Science
- Energy of the Sun
- Extraterrestrial Spectroscopy
- Solar Spectrum
- Resolution in Telescopes
- Crystalline Solids (Opals)

Language Arts
- Writing a Report
- Public Speaking

MWM is designed to improve STEM education
- Interdisciplinary
  Integrates science & non-science subjects

- Flexible
  Can adapt to your teaching style, students' ability and class time

- Hands-on
  Contains activities that lead up to inquiry-centered design projects

- Cutting-edge
  Examines issues on the forefront of technological research

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University | www.materialsworldmodules.org
847-467-2489 | mwm@northwestern.edu
Do you know how to make a nanoscale pattern?

Students learn multiple techniques for creating patterns at macro and nano scales. They use their knowledge to design ordered arrays (patterns) and analyze them by looking at the diffraction patterns.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found a solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Nanoscience — small particles with HUGE implications. Do your students understand the scientific principles behind this emerging field?

Students discover that physical and chemical properties of materials can depend on their size, investigate how nanoparticles can be made, and determine how to amplify small features at the nanoscale to the macroscopic scale. They are then challenged to design a working model of a nanoscale imaging apparatus or model a nanoscience phenomenon.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to use. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

**Activities**
- Changing the Properties of Materials by Changing Their Size
- Searching for Nanoscale Objects
- Nanopattering with Lithography
- Amplifying the Nanoscale to the Macroscale

**Design Project**
- Designing a Nanoscale Imaging Apparatus
- Modeling a Nanoscience Phenomenon

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.

MWM is designed to improve STEM education

- Science • Technology • Engineering • Math
- **Interdisciplinary**
  Integrates science & non-science subjects
- **Flexible**
  Can adapt to your teaching style, students’ ability and class time
- **Hands-on**
  Contains activities that lead up to inquiry-centered design projects
- **Cutting-edge**
  Examines issues on the forefront of technological research

Materials World Modules
An Inquiry & Design Based STEM Education Program
Northwestern University • www.materialsworldmodules.org
847-467-2489 • mwm@northwestern.edu

Chemistry
- Attractive Forces
- Catalysts
- Colors and Light
- Electrolyte Solutions
- Rates of Reactions
- Redox Reactions
- Solutions, Colloids, and Suspensions
- Physical and Chemical Properties
- Atom Arrangements in Solids
- Atomic Packing
- Hydrogen Bonding
- IR Spectroscopy
- Surface Structure
- Vibration of Molecules

Biology & Life Sciences
- Capillary Forces
- Hydrophilic/Hydrophobic Reactions
- Microscopy Techniques

Mathematics
- Orders of Magnitude
- Calculating Surface-to-Volume Ratios
- Geometry of Close-packed Structures
- Calibration Plots
- Metric System
- Spring-constant Calculations

Physics & Physical Sciences
- Colors and Light
- Capillary Forces
- Diffraction
- Electrostatics
- Using Mass to Determine Spring Constant

Society
- Ethics and Impact of Uses of Nanotechnology

Language Arts
- Public Speaking
- Word Derivations
- Writing a Scientific Paper
Compact discs, hair spray, and soft-drink bottles. What’s in your students’ lockers or your next lab activity?

Students examine viscoelastic, mechanical, and absorptive properties of polymers. They design and test a nonelectrical humidity sensor made of a polymer film.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

Module At-a-Glance:

Activities
- Changing Polymer Pellets
- Hunting for Polymers
- Comparing the Viscosity of Liquids
- Testing the Strength of Different Polymer Films
- Measuring Water Absorption by Different Polymer Films

Design Project
- Designing a Humidity Sensor
- Designing a New Polymer Product

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Microphones, interactive touch screens, light switches, and coin counters. Can you name other smart sensors?

Students investigate the behavior of pressure and heat sensitive piezoelectric films. They use these materials to make coin-counting and other smart sensing devices.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.
Today’s lesson: basketball, soccer, baseball, golf, and tennis – and this isn’t gym class!

Students explore the design and function of a wide variety of balls used in athletics, as well as test and analyze their interactions with many surfaces they come in contact during play. Then students design a suitable material for use in a newly invented game.

By incorporating everyday materials into science lessons, the Materials World Modules (MWM) program at Northwestern University has found the solution to getting students excited about learning science while helping teachers meet national and state education standards.

The modules are easy to organize and inexpensive to run. They can be incorporated into any science class because of the breadth of subjects covered in the Activity and Design Project sections. Each module is a supplemental science unit that takes 1-3 weeks of class time (approximately 10 hours) to complete.

MWM will give students an opportunity to understand the world around them in a way they have never experienced before. The modules promote an awareness of the roles science and technology play in society and guide students to take increased control of their work.