

# Challenges in STEM Education

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Arlington, VA



# Outline of the presentation

- What is being projected 30 years from now?
- What are some of challenges in STEM education?
- What is Materials World Modules program doing?
- The need for integration!

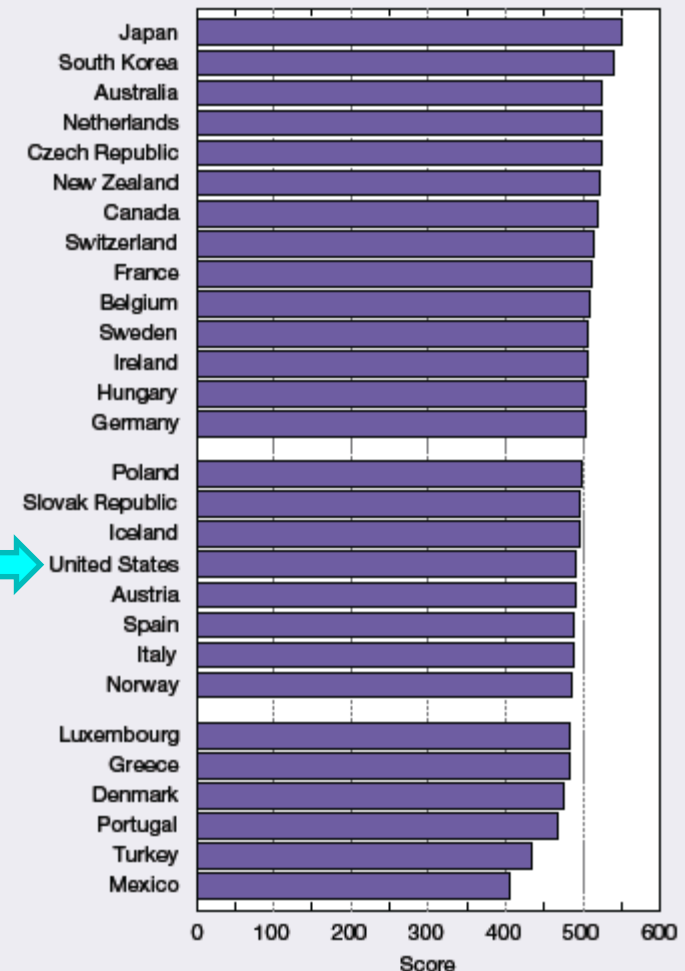
# 30 years from now

- Oil production will peak
- Consequences of Global warming
- Global economic impact/Competition for natural resources
- Change in the US demographics
- Others???

# Challenges for U.S. in the 21<sup>st</sup> Century

- Educating our young people in the context of building knowledge-intensive economies
- Continued global achievement gap between U.S. students—even our top performing students—and their international peers

Figure O-38  
Average science literacy score of 15-year-old students, by country: 2003

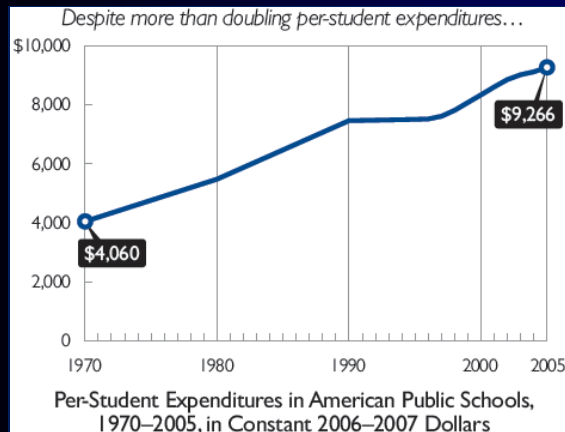


# Basic Challenges in K-12 STEM Education

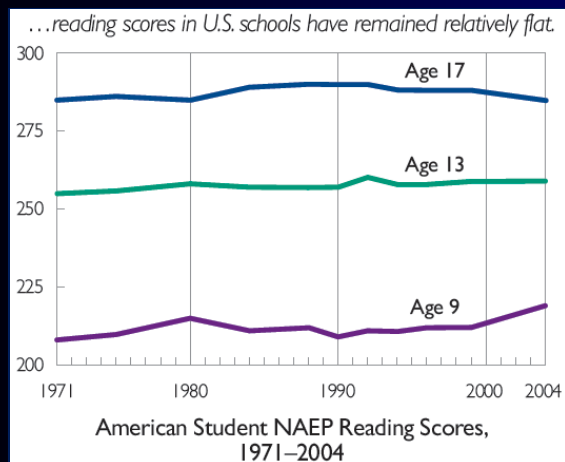
- **The need to produce a globally literate citizenry** is critical to the nation's continued success in the global economy
  - Human capital is key to continuing S&T and S&E developments
- **The need for secondary institutions to adapt** to a world altered by technology, changing demographics and globalization
  - Several national studies confirm the insufficient preparation of high school graduates for *either college-level work or the changing needs of the workforce*.
  - Low proficiency performance level, only 1/3 of 4<sup>th</sup> and 8<sup>th</sup> grade, and even fewer 12<sup>th</sup> grade students, reached the proficient level for their grades

# Funding Challenges in K-12 STEM Education

- **Spending increases have not corresponded to increase in high school achievement rates**



1. US spending at all-time high – 49% increase over past 20 years
2. Since 1985, real federal spending on K-12 education has increased by 138%
3. Only 17 percent of seniors are considered proficient in mathematics
4. Only 36 percent are proficient in reading



# Teacher Challenges in K-12 STEM Education

- A paucity of teachers who have the necessary knowledge and skills to effectively teach these subjects
  - Nationally, in academic year 2002—between 17-28% of public high school science and math teachers lack full certification
  - In academic year 1999, between 23-29% of middle and high school science and math teachers did not have a college major or minor in their teaching field
- Inadequate teacher compensation and professional development to attract, prepare and retain high-quality teachers
- Compartmentalized subjects taught by teachers isolated within and across departments

# Student Challenges in K-12 STEM Education

- Students generally lack motivation and have low self confidence in learning STEM subjects
- Persistent achievement gaps in science and math among many student subgroups
  - Disparities starting as early as kindergarten, continue across grades, and widening over time
  - Substantial performance gaps exists between racial/ethnic groups
  - Sex differences were small but favored males in most cases
- Sweeping demographic changes will exacerbate the gaps
  - Racial and ethnic minorities will comprise the majority of the nation's population by 2042



# The Demand for a 21<sup>st</sup> Century Education and Skills

- “The best employers the world over will be looking for the most competent, most creative, and most innovative people on the face of the earth and will be willing to pay them top dollar for their services.
- This will be true not just for the top professionals and managers, but up and down the length and breadth of the workforce.
- Those countries that produce the most important new products and services can capture a premium in world markets that will enable them to pay high wages to their citizens.”  
--The New Commission on the Skills of the American Workforce,  
National Center on Education and the Economy, 2007

# 21<sup>st</sup> Century Curriculum and Instruction

- Curriculum must go beyond content knowledge to include a strong emphasis on 21<sup>st</sup> century skills development
- Use an integrative approach to curriculum—one that unites core academic subject matter, interdisciplinary themes, and essential skills
  - Solve open-ended problems (design-based)
  - Promote cooperative learning
  - Use real-world contexts
  - Take advantage of advanced technologies
  - Adopt effective assessment strategies
- Provide a pathway for learning to help students succeed in college, work and life

--Adapted from Partnership for 21<sup>st</sup> Century Skills, 2007

# Components of a 21<sup>st</sup> Century STEM Curriculum and Instruction

- Thinking critically and making judgments
- Solving complex, multidisciplinary, open-ended problems
- Creative and entrepreneurial thinking
- Communicating and collaborating
- Making innovative use of knowledge, information and opportunities
- Taking charge of civic responsibilities

# MWM—a Highly Effective STEM Curriculum

Nationwide study show student acquisition of many of the characteristics associated with learning :

- Exceptional gain in new content knowledge among all student subgroups; female is slightly favored
- In depth learning of STEM concepts
- Critical thinking and problem solving skills
- Improved teamwork; sharing responsibilities
- Overcoming a fear of failure
- Improved student self-esteem in science learning

- Understand concepts as opposed to memorize them
- Willing to take risks in order to advance an idea
- Willing to pursue a new direction; look for a “best solution”
- Apply learned content knowledge in a new context
- Make decisions based on criteria and data
- Develop the skills of innovation
- Think in unconstrained ways or "outside the box"

# Materials World Modules

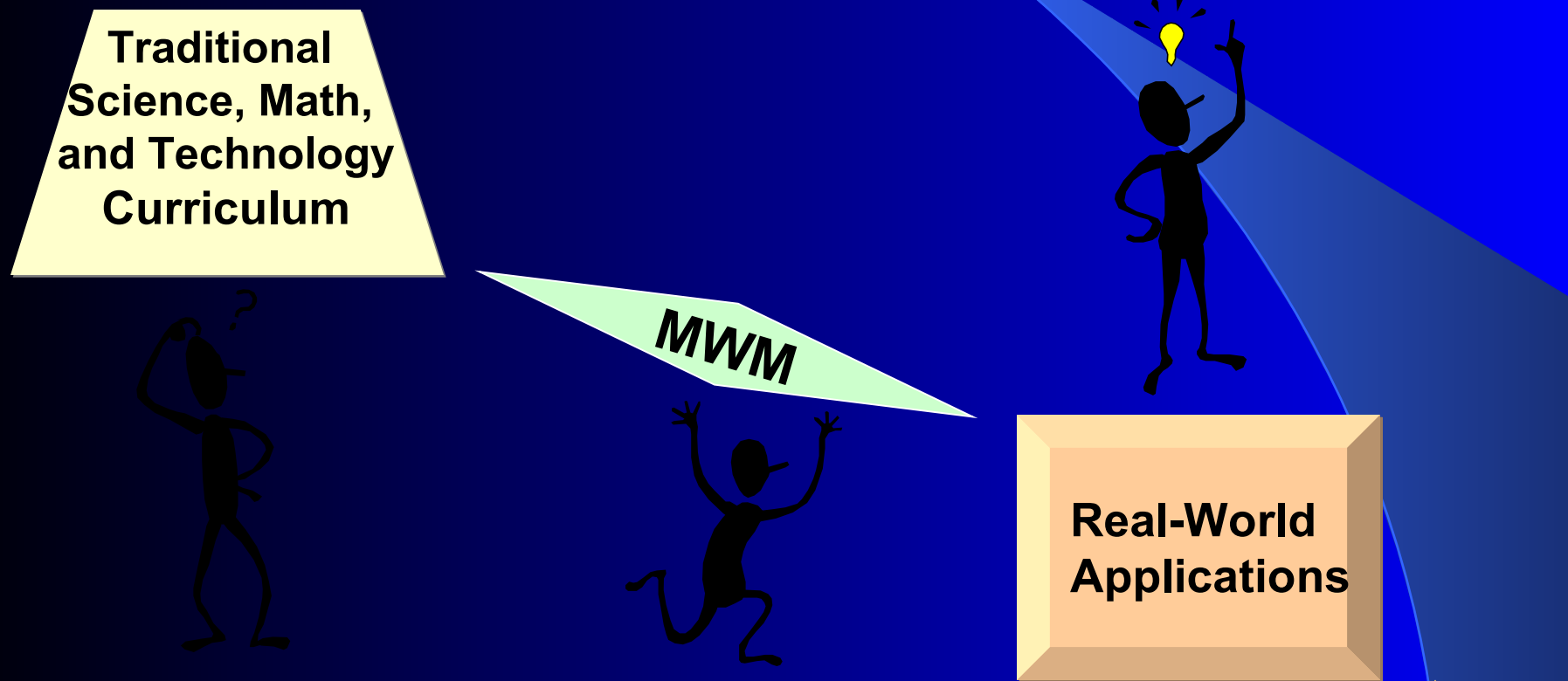
An NSF Inquiry & Design based  
(STEM) Education Program

R.P.H. Chang

Northwestern University



# Materials World Modules Program Connects Science and Math Curricula to the Real World



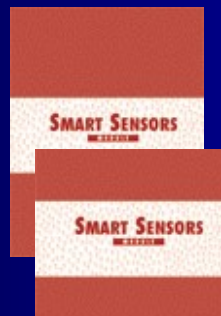
# Materials World Modules

## Published Modules

- Composites
- Concrete
- Sports Mat'ls
- Biodeg. Mat'ls
- Biosensors
- Food Pkging Mat'ls
- Ceramics
- Polymers
- Smart Sensors

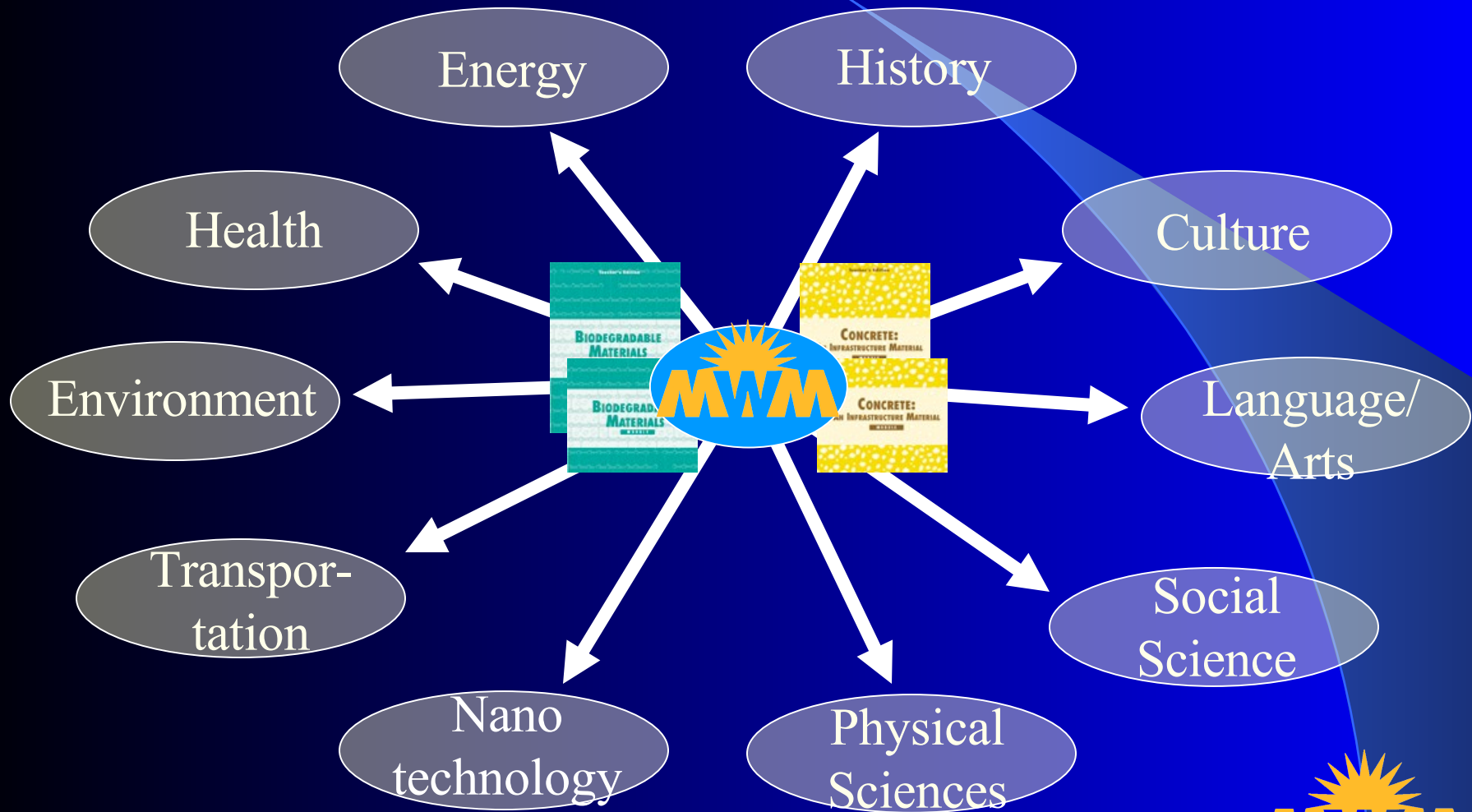
## Coming Soon!

- Environ. Catalysis
- Nanotechnology Module



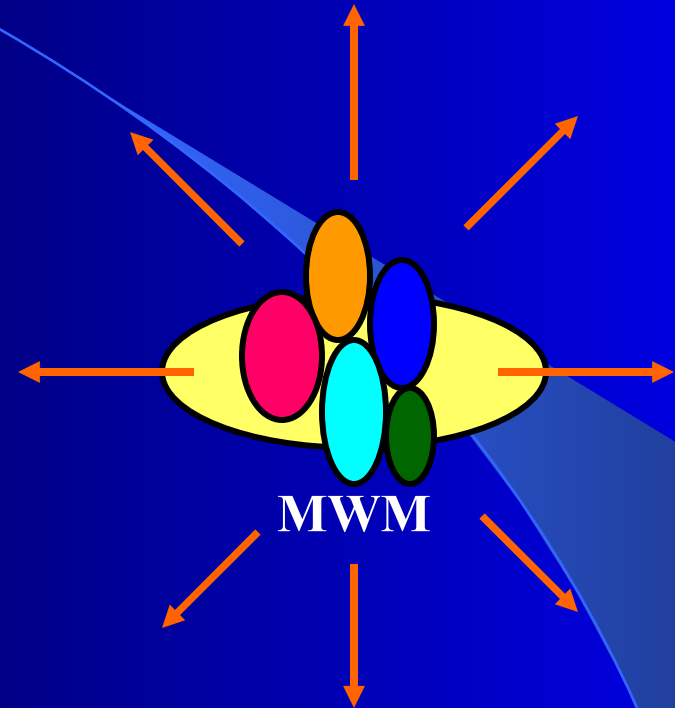
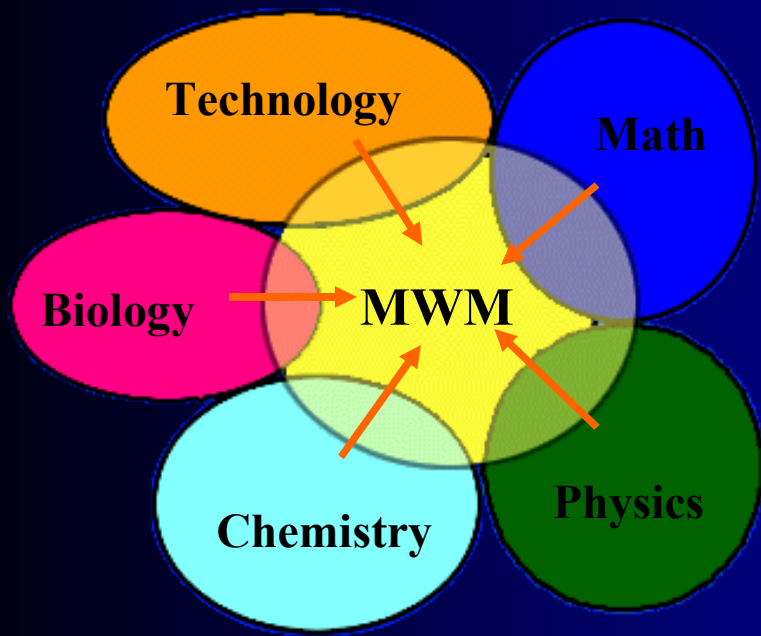


# Creating Interdisciplinary & Globally & Socially Relevant Modules



# MWM Promotes Integrated Learning

Materials World Modules (MWM )  
provides interdisciplinary science  
teaching.



MWM provides an  
integrated science and math  
learning experience.

# Development of Materials World Modules

Secondary  
School Science,  
Math, and  
Technology  
Teachers

Northwestern  
University  
Scientists &  
Researchers

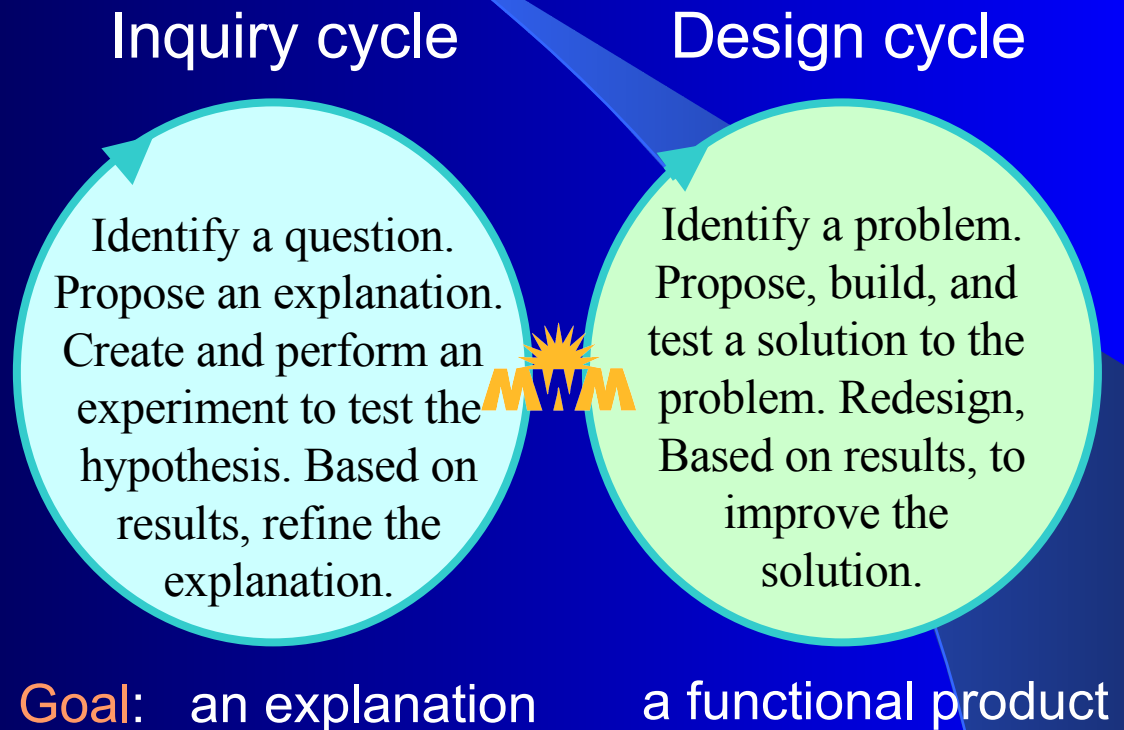


Northwestern  
University  
Educational  
Researchers

Professional  
Editors, Designers,  
Graphic Artists, etc.

# MWM's Model: Inquiry and Design

- Students complete a series of hands-on, ***inquiry-based*** activities
- Each module culminates in ***design challenges***
- Students simulate the work of ***scientists*** (*through activities that foster inquiry*) and ***engineers*** (*through design*)



# Main Components of MWM

Piques student interest in the topic

The Hook

Provides students with background and concepts central to the topic

Staging Activities

Challenges students to apply what they have learned to create a functional design

Design Challenge

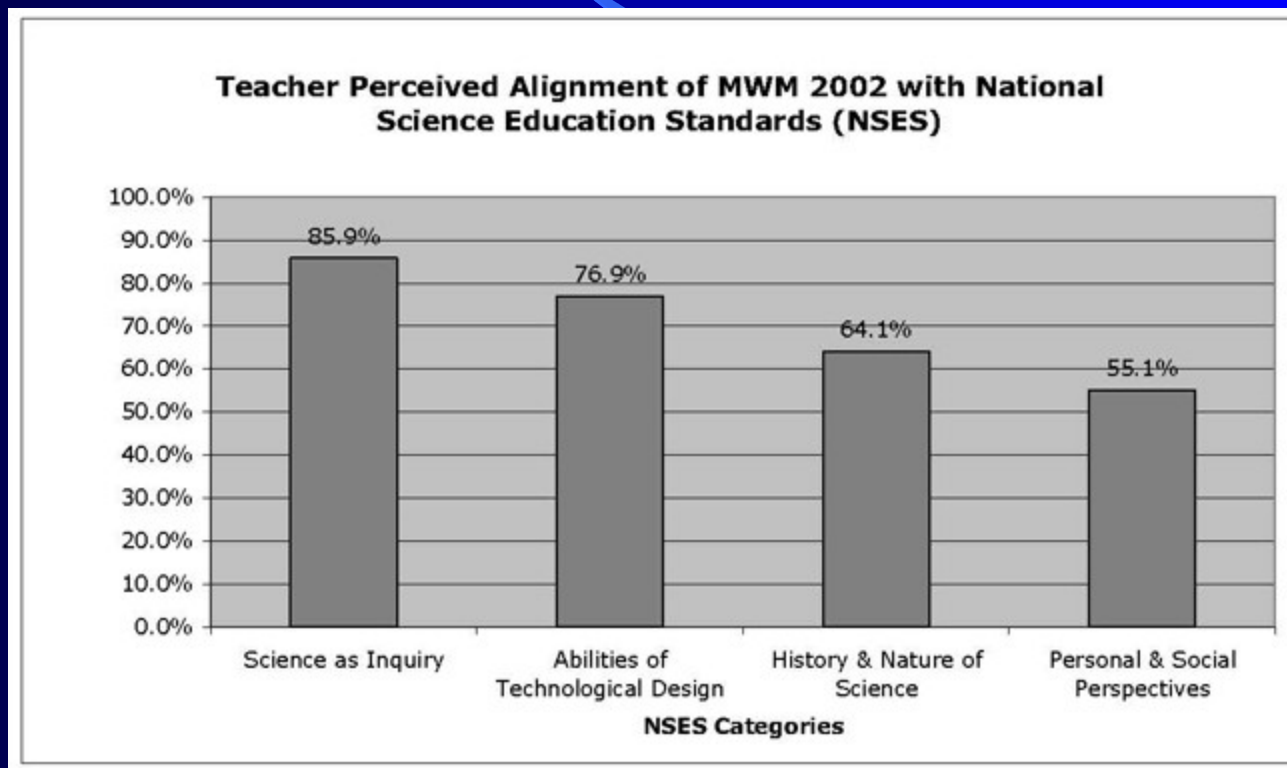
Revisits steps in the design process to make adjustments to improve the initial designs

Redesign

# MWM Helps To Meet Standards

**MWM Links to the following National Science Education Standards:**

- Unifying concepts and processes in science
- Science as inquiry
- Physical science
- Life science
- Earth and space science
- Science and technology
- Science in personal and social perspective



AAAS Benchmark Standards	
Sports Materials Module	
Grades 9-12	Module Alignment
<b>1. The Nature of Science</b>	
A. The Scientific world view	✓
B. Scientific inquiry	✓
C. The Scientific enterprise	✓
<b>2. The Nature of Mathematics</b>	
A. Patterns and relationships	
B. Mathematics, science, and technology	✓
C. Mathematical inquiry	
<b>3. The Nature of Technology</b>	
A. Technology and science	✓
B. Design and systems	✓
C. Issues in technology	
<b>4. The Physical Setting</b>	
A. The universe	
B. The earth	
C. Processes that shape the earth	
D. Structure of matter	✓
E. Energy transformations	✓
F. Motion	✓
G. Forces of nature	

## Alignment to the National Standards

- The American Association for the Advancement of Sciences Benchmarks
- National Science Education Standards

NSES Standards	
Sports Material Module	
Grades 9-12	Module Alignment
<b>Unifying Concepts and Processes</b>	
1. Systems, order, and organization	
2. Evidence, models, and explanation	✓
3. Constancy, change, and measurement	✓
4. Evolution and equilibrium	
5. Form and function	✓
<b>A. Science as Inquiry</b>	
1. Ability to do scientific inquiry	✓
2. Understanding scientific inquiry	✓
<b>B. Physical Science</b>	
1. Structure of atoms	
2. Structure and properties of matter	✓
3. Chemical reactions	
4. Motions and forces	✓
5. Conservation of energy	✓
6. Interactions of energy and matter	✓

# Sports Materials Module

## Alignment with NJ & CA State Standards

### ***New Jersey—Physical Science / Physics / B. Energy Transformations***

- ☒ • Explain that while energy can be transformed from one form to another, the total energy of a closed system is constant.
- ☒ • Recognize that whenever mechanical energy is transformed, some heat is dissipated and is therefore unavailable for use.
- ☒ • Explain the nature of electromagnetic radiation and compare the components of the electromagnetic spectrum from radio waves to gamma rays.
- Explain how the various forms of energy (heat, electricity, sound, light) move through materials and identify the factors that affect that movement.

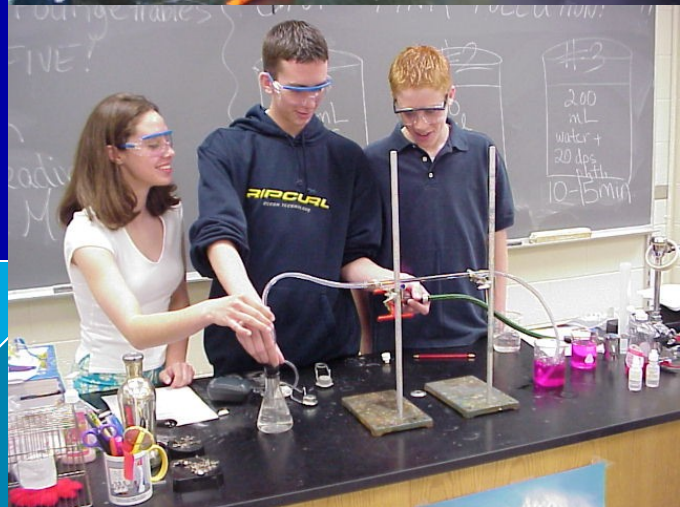
### ***California—Physics / Conservation of Energy and Momentum***

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept:

- ☒ • Students know how to calculate kinetic energy by using the formula  $E = (1/2)mv^2$ .
- ☒ • Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy)  $= mgh$  (h is the change in the elevation).
- ☒ • Students know how to solve problems involving conservation of energy in simple systems, such as falling objects.
  - Students know how to calculate momentum as the product  $mv$ .
  - Students know momentum is a separately conserved quantity different from energy.
  - Students know an unbalanced force on an object produces a change in its momentum.
- ☒ • Students know how to solve problems involving elastic and inelastic collisions in one dimension by using the principles of conservation of momentum and energy.
- ☒ • \* Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs.



# MWM: A Total Educational Program



**Network  
of  
Teachers**

**Web Support  
for students  
& teachers**

**11 Hands-on,  
inquiry-based  
Modules**

**Module  
Booklets &  
Activity Kits**

**Training/  
Workshops  
for Teachers**

# MWM Activity Kits

- Starter and refill kits are available for each module
- Kits contain enough materials for a class of 24 - 32 students
- Kits range in price depending upon the materials they contain



# Workshops/Teacher Training

During workshops, module developers and master teachers of MWM work with new teachers to help them:

- Learn about MWM's philosophy of inquiry through design
- Experiment with module activities and design challenges
- Discuss practical and theoretical issues regarding the implementation of MWM into the classroom
- Establish a network of MWM resources within their school and area, as well as with NU





# Evaluations & Assessments Improve MWM



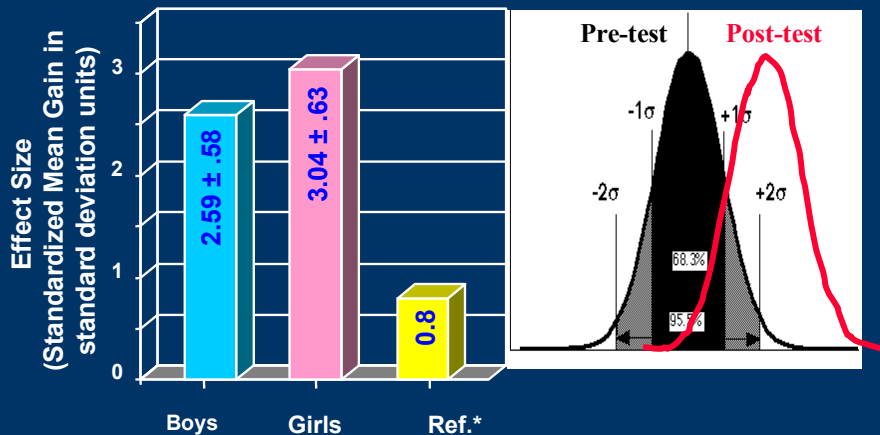
# MWM Produces Results

**Field-test results indicate that with MWM:**

- **Girls** acquire more science knowledge than boys
- Students of **all races and socioeconomic status** excel
- Teachers of **all experience levels** can participate
- Curriculum meets **National Science Education Standards**

## Positive Student Gains

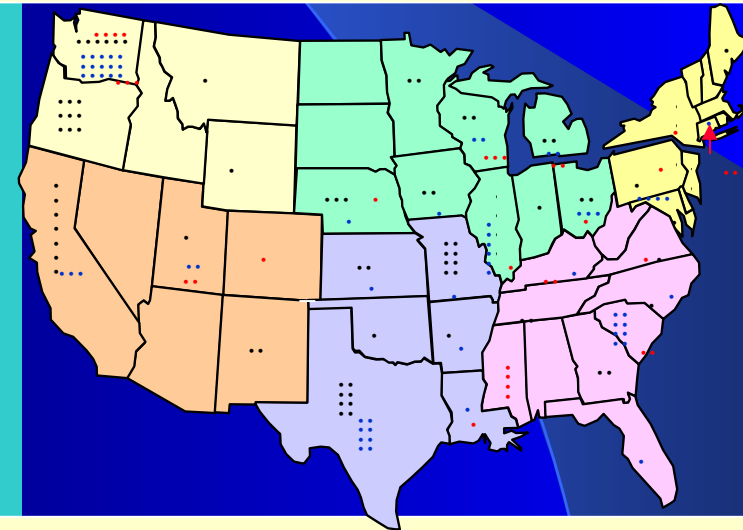
Results for BOYS and GIRLS were avg. over all 5 field test modules



\* Traditionally, 0.8 is considered a large effect.



**48 states across the US**



**~ 40,000 students**



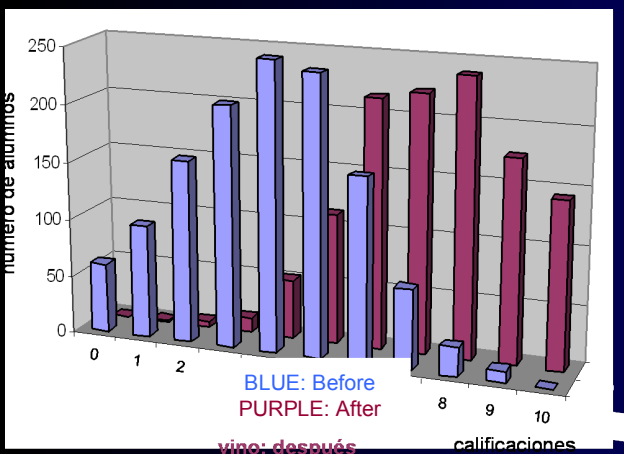
# Materials World Modules - Spanish

## Expands to Chihuahua, Mexico and Puerto Rico



The Materials World Modules Program (MWM) has recently translated five of its modules into Spanish. In 2005, the Centro De Investigacio en Materiales Avanzados and the Department of Education & Culture for the state of Chihuahua provided support to train 50 high school teachers in **Chihuahua, Mexico**.

Since the 2005 Workshop, MWM has been used by 35 schools, including 120 teachers, 1200 students, and 7 cities and towns, in the state of Chihuahua. Results indicate that these modules helped to improve science achievement with these students.



In February, 2007, MWM worked with professors at the **University of Puerto Rico** to train lead STEM teachers in Puerto Rico on four modules, which will be disseminated to schools around the Island.



# Why Integration?

- **Train more scientists and engineers** who are highly-skilled and globally-engaged
- **Increase science literacy** across all sectors of society
- **Build capacity to address global challenges** in energy, environment, health, communications, and security.
- **Create relevance** for students - strong connections between science concepts and their real-world applications.

# Rationale

## Why Materials Science?

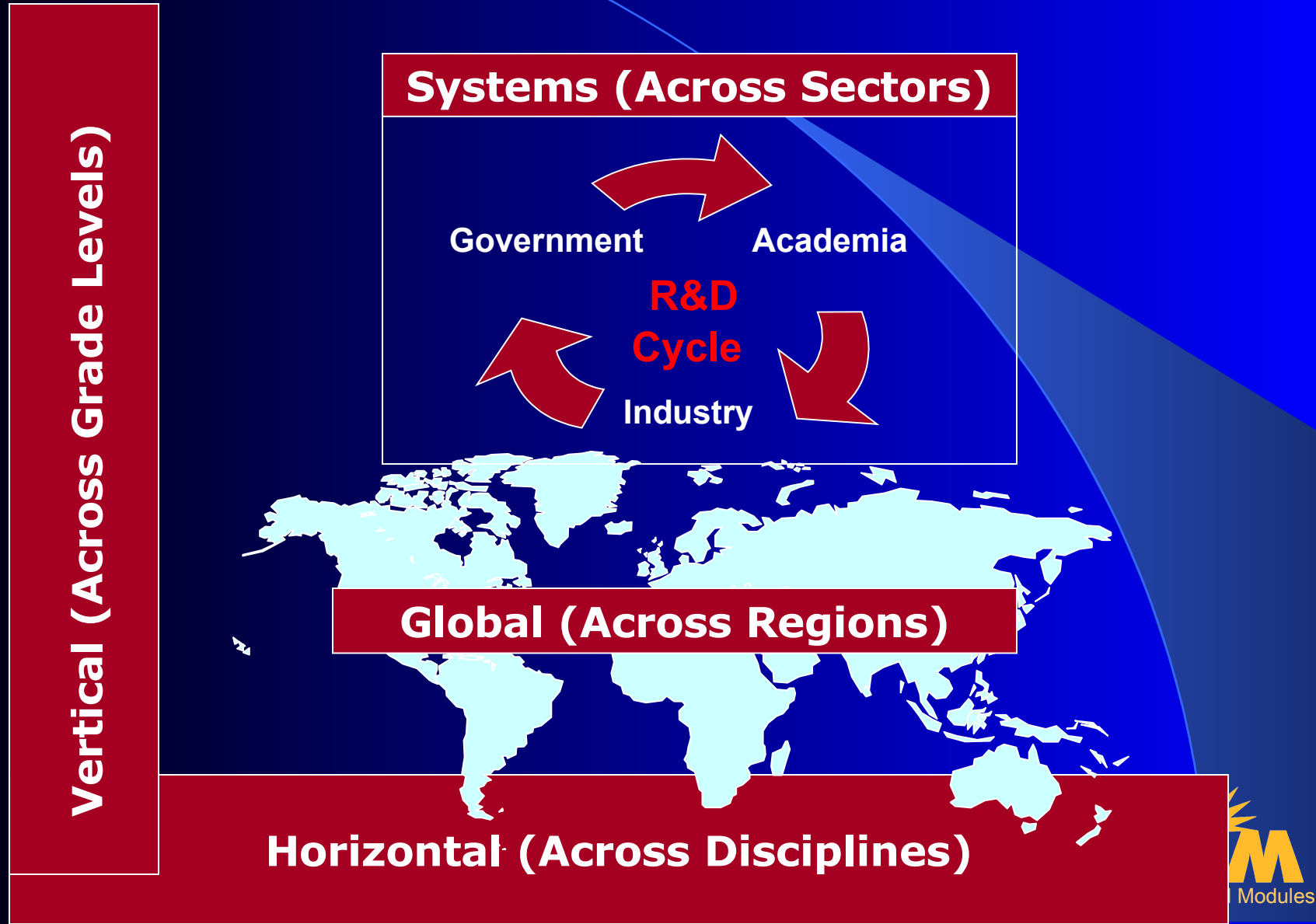
- **Materials and their properties are the basis for all technology**, including emerging areas such as bio- and nano- technologies.
- **New materials are vital to:**
  - Industrial development
  - Energy efficiency
  - Environmental stewardship
  - Medicine
  - Information systems
  - Civil infrastructures
  - Global security, etc.
- **MSE combines the best of science and engineering**

## Why Materials Education?

- **Excellent Integrator**
- **Fosters creative problem-solving**
- **Improves science literacy** for all citizens
- **Creates relevance for students** – i.e. strong connections to everyday life
- **Workforce development** for all sectors
- **Preparation for global challenges**



# Paradigm for Integration



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**Materials World Modules**  
 An Inquiry & Design-Based Science, Technology, Engineering, and Mathematics (STEM) Educational Program

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*MWM promotes professional development*

MWM MODULES	MWM PEDAGOGY	MWM USER SUPPORT	PROFESSIONAL DEVELOPMENT
<ul style="list-style-type: none"> <li>• <a href="#">Components</a></li> <li>• <a href="#">List of Modules</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Inquiry &amp; Design</a></li> <li>• <a href="#">Interdisciplinary Approach</a></li> <li>• <a href="#">Learning Goals</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Integrating Inquiry</a></li> <li>• <a href="#">Assessing Learning</a></li> <li>• <a href="#">Linking to NSES</a></li> <li>• <a href="#">FAQ</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Workshops</a></li> <li>• <a href="#">Research Programs</a></li> </ul>
CLASSROOM EXHIBITS	SUCCESS STORIES	MEDIA GALLERY	RESOURCES LINKS
<ul style="list-style-type: none"> <li>• <a href="#">View Design Projects</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Teachers</a></li> <li>• <a href="#">Students</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Photo Gallery</a></li> <li>• <a href="#">Video Gallery</a></li> </ul>	<ul style="list-style-type: none"> <li>• <a href="#">Materials Science</a></li> <li>• <a href="#">Nanoscience</a></li> <li>• <a href="#">Others</a></li> </ul>


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