Materials World Modules

Meeting the New Core Standards through Scientific Inquiry & Engineering Design

Alignment to the New Core Standards

MWM is directly aligned with the newly published "Next Generation Science Standards" (NGSS), which emphasize three dimensions of learning:

Dimension 1: Practices

The new standards call for more hands-on practice – a tall order when curricula are already so crowded! ***MWM's inquiry[i] and design[ii] methodology simultaneously develops all eight of the science and engineering practices outlined in the standards*** **(right),** making it a quick and flexible way to incorporate hands-on science and engineering practices into your curriculum! For example:

Manipulation of Light in the Nanoworld prompts students to ask questions about how photons interact with matter (*Practice 1A*) and how this behavior can be used to improve signal (information) processing and other applications (*Practice 1B.*) Students make a CD-ROM spectroscope and use online simulations to study the behavior of different light sources upon interaction with structured matter (*Practices 2&3.*) They work on teams to collect, analyze, and interpret data (*Practices 4&5)* to explain the scattering, diffraction, and reflection of light (*Practices 6A, 7, 8.)* Then they design a photonic crystal to solve the problem of reflecting and transmiting light of particular wavelengths (*Practice 6B*), using an online simulation (*Practice 2)* to vary the **structure** of the photonic crystal, the wavelength, and the angle of incidence to optimize its performance (*Practices 4, 5, 7, 8.)* After performing tests and making improvements *(Practice 6B),* they make presentations describing their designs and the foundational concepts involved *(Practice 8.)*

Dimension 2: Cross-Cutting Elements

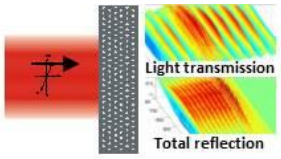
The new standards prescribe a new type of interdisciplinarity – one that prepares students to synthesize STEM concepts and apply them to diverse situations. MWM is ideal for teaching STEM in this integrated way! Our topics come from the inherently cross-cutting field of materials science and engineering. which naturally incorporates chemistry, biology, physics, applied math and engineering and has direct relevance to 21st century challenges like energy, environment, health and security. As a result, our modules naturally address all of the cross-cutting concepts outlined in the standards (right)

Dimension 1: NGSS Practices

1. A) Asking questions (science) and B) defining problems (engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. A) Constructing explanations (for science) and B) designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information



Light diffracts from CD grooves



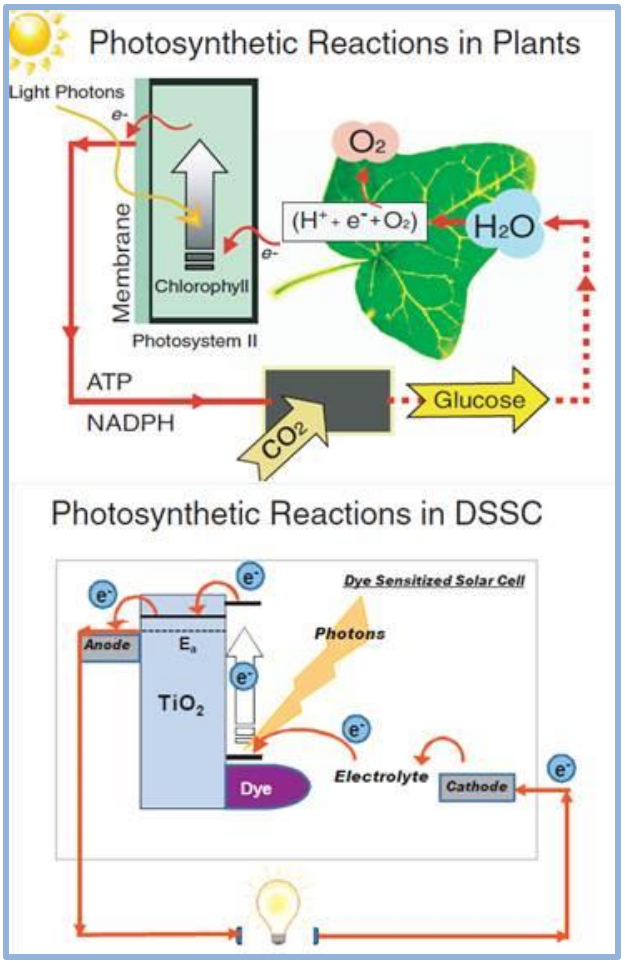
Design opals from structural simulations

Cross-Cutting Concept	*MWM Modules*
1. Patterns	All Modules, esp. Nano-patterning
2. Cause and Effect	All Modules
3. Scale, Proportion, and Quantity	All Modules, esp. the Nano modules
4. Systems and Systems Models	Solar Cells, Food Packaging, Sports Materials
5. Energy and Matter	Solar Cells, Manipulation of Light, Environmental Catalysis
6. Structure and Function	All Modules
7. Stability and Change	Biodegradable Materials, Biosensors

Dimension 3: Core Disciplinary Ideas

MWM is comprised of 16 interdisciplinary modules that focus on topics with high societal relevance. As a result, modules cover many of the specific core disciplinary ideas – not as rote learning, however, but within the framework of an engineering problem and design challenge. Modules can be easily inserted into an existing curriculum, or combined into classes that address engineering design and the role of technology in society.

Importantly, the modules do not just teach content, they guide students through the process of designing an experiment to test a potential solution. From ***identifying the problem***, to ***considering possibilities*** based on what they've learned, putting a ***prototype*** together, and then ***designing a process to evaluate the success*** of that product, MWM introduces students to the process of scientific discovery and real-world engineering principles. For example:



In the ***Polymers*** module, students learn that different chemical structures of polyethylene confer different properties to a bulk substance, including strength, viscosity and absorption (*PS1-3*), with the goal of applying that knowledge to the design of a humidity sensor, or novel polymer product.

Similarly, in geosciences and astronomy, using light spectra is all important for discovery. This includes the concept of reflection, refraction, and scattering of light (*EBS1-A*), which is thoroughly discussed using simulations and hands-on experiments in the ***Manipulation of Light in the Nanoworld*** and ***Nanotechnology*** modules.

In the ***Food Packaging*** module, students are asked to optimize packaging that leaves a minimal impact on the environment (*ESS3-4*), while still ensuring that food is safe for consumption. Questions of the impact of humans on weather, life cycles, and climate change (*ESS3*) are evaluated in the ***Environmental Catalysis*** modules. In the ***Biosensors*** module, students learn about bioluminescence and are asked to consider what advantages it may give to an organism (*LS1-4*). As we'll discuss in depth below, the ***Dye-Sensitized Solar Cell*** module uses principles of photosynthesis (*LS1-6*) to discuss and design a device that translates energy from solar to electric (*PS3-3,* right).

Focus on Engineering Design:

MWM modules were designed by engineers and teachers to introduce students to the design process and help develop the next generation of engineers. Consequently, these modules are a natural fit for the new standards in Engineering Design (ETS1). The modules provide background information on how engineering has contributed to a wide-range of subjects, and then ask students to design their own solution to a problem. Importantly, the process doesn't stop there. Students are then asked to test their design, and optimize it through an iterative process, having students answer questions like:

- Which aspects of the design worked?
- Which material was the "weak link" and how do you strengthen or mitigate that weakness?
- Is there a point when further improvement to one aspect of a product is no longer beneficial to the whole?

An example of how MWM can help your curriculum meet the new NGSS standards:

MWM and Engineering Design	*Example from Dye-Sensitized Solar Cell Module*
Each module has design projects options. Working as a team, students come up with their own design of a product or a process with a **given set of constraints and criteria**, such as cost, utility, safety, and/or time to produce. In addition, each module has at least one design project that asks the design team to meet given specifications. Each module and design project has **relevance to societal needs and/or solving a global problem relating to health, energy, security, or environment.** *MS/HS ETS1-1*	The DSSC module asks students to design a solar cell that has a maximum absorption spectrum using natural dyes and pigments obtained from things like berries or leaves. There are several components that need to be individually optimized, and then optimized as a group in order to create the most efficient DSSC: 1. Choice of a good dye – how broad of a spectrum does it absorb vs. the energy output. 2. Optimization of TiO_2 coating – the thickness affects how much dye can be bonded and the packing density of particles, which will alter the access of the electrolyte to the TiO_2 particles. 3. Size of the conductive glass plate – more surface area can be useful, but it is costly.
In most modules, especially those relating to nanotechnology, student teams are asked to **consider the choice of each component and part to be used in the system** (the final product). *MS/HS ETS1-2*	Before building their own solar cell, students perform chromatography experiments to identify pigments in a spinach leaf and learn about the spectrum of light absorbed by each pigment to determine which pigments for different kinds of light. Students also learn how to assess the limits of their equipment by measuring the internal resistance of their solar cell.
Once the product is developed students will **make measurements** to see how close they have come to the optimal solution of their design, within the given constraints. Students are asked **to improve their design models and compare those of the other teams** to adopt components from couple different models to obtain the overall ultimate design. *MS/HS ETS1-3*	After the design project, students are asked to present their project to the class, using data to support their claims, and evaluate which parts of the design were most and least successful. Classes then have the option to compare multiple solar cell designs in order to evaluate their efficiency and choose components that can work optimally together.
With further **simulation and modeling**, an iterative design process will be carried out. *MS/HS ETS1-4*	As a part of the module, students can use a simulation that allows them to understand the relationship between different dye molecules and their absorption spectra. The simulation adds in the factor of cost, as well, to encourage students to consider the practicality of implementing their designs.

[i] Drayton, Brian and Falk, Joni. Inquiry-Oriented Science As a Feature of Your School System: What Does It Take? *Science Educator*, v11 n1 p9-17 Spr (2002)
Khishfe, Rola; Abd-El-Khalick, Fouad, Influence of Explicit and Reflective versus Implicit Inquiry-Oriented Instruction on Sixth Graders' Views of Nature of Science. *Journal of Research in Science Teaching*, v39 n7 p551-78 Sep (2002)

[ii] Garmire, Elsa, The EngineeringDesign Method. *Technology Teacher*, v62 n4 p22-28 Dec 2002-Jan (2003)
Sadler, Phillip, Coyle, Harold P., Schwartz, Marc, Engineering Competitions in the Middle School Classroom: Key Elements in Developing Effective Design Challenges. *Journal of the Learning Sciences*, v9 n3 p299-327 (2000)