5-E Classroom STEM Activity: Measuring Mars

Dr. Alexandra Owens

Manufacturing a Clearer View of Mars and Beyond

By Dorothy Crouch

Working with colleagues who have different backgrounds and expertise to make products that help people learn more is one of the most important aspects of manufacturing.

Optimax President Mike Mandina and optical coating technician Tsion Teklemarim have very different jobs, but they depend on each other to make sure important projects—such as creating the optics for NASA's Mars Rovers—are successful.

While Mike is now the leader at Optimax, he started in manufacturing in the same way many other kids find themselves interested in the field—taking things apart and trying to rebuild them at home.

"I liked to tinker with things to see how they worked. I remember disassembling my sister's toy piano to see how it made sound," remembers Mike. "Unfortunately, I could not get it back together. That was not a good day for me!"

When looking back on her start in manufacturing, Tsion realized she had the same spark.

"I was always interested in how things work, what they were made from and how they operate, which led me to be more involved in the manufacturing world," she says.

Though Mike has been working in the field much longer than Tsion, they are both proud of the accomplishments of their company and the work they continue to do with NASA. Optimax created optics for the different Mar Rovers, including the first that landed on Mars in 1997 and the New Horizons spacecraft that traveled to the solar system's edge, but also photographed Pluto during the trip, according to Mike.

"It was a privilege to be asked by NASA to manufacture more optics for the 2020 Rover," he says. "We feel tremendous pride in participating in projects like this that will ultimately benefit mankind."

Working with NASA is exciting, but it means that many different manufacturing specialists are needed to finish these important projects. As part of the team that makes optics for the 2020 Rover, Tsion relies on her coworkers and they rely on her specialized work.

"The 2020 Rover project is a result of so many hands. My involvement in this project is delivering the specific coating design by monitoring the machines' outcome and ensuring the results," she says, but her role involves additional responsibilities including troubleshooting and maintenance.

When thinking about the future of manufacturing, Tsion sees an expanding industry for today's students. For students who have a strong desire to learn, she sees a lot of opportunities to grow and succeed as new needs will bring about more jobs in the field.

"The manufacturing industry has a great impact in society today and continues to grow fast with human needs," she says. "There will be a lot of innovation and new career paths in the future in this field."

As the leader of the largest optics manufacturing company in the United States, Mike believes the future of manufacturing is in automation, but there will be a need for educated professionals who specialize in process engineering, quality control, optics manufacturing, technical coating, purchasing, training, sales, information technology (IT), and finance.

While he doesn't recommend kids start taking apart everything in their houses—especially without a parent's permission—he advises students to begin taking coursework in technology, humanities, and business, and finding part-time jobs in the field.

"Students, counselors, and parents should all understand that entry-level manufacturing jobs are a powerful gateway to enjoyable and living-wage sustainable careers," says Mike. "I started grinding lenses on a night shift and ended up owning an optics company with more than 300 employees."

MIKE MANDINA
PRESIDENT, OPTIMAX SYSTEMS, INC.
DEGREES:
- ASSOCIATE DEGREE IN OPTICAL ENGINEERING TECHNOLOGY & SCIENCE
- BACHELOR'S IN APPLIED PHYSICS
- EXECUTIVE MASTER'S OF BUSINESS ADMINISTRATION

YEARS IN THE INDUSTRY: 45
STEM TYPE: MAKER

TSION TEKLEMARIM
OPTICAL COATING TECHNICIAN
TRAINING: PRECISION TOOLING AND MACHINING CERTIFICATE
YEARS IN THE INDUSTRY: 2
STEM TYPE: EXPLORER

Photo: provided by Optimax Systems, Inc.

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Here are some ideas for how high school teachers could use this story as a launching point for integrated STEM learning. Our activities follow the 5-E Learning Cycle Model.

Part 1: Engage

1. Ask students what they know about Mars. How have scientists been able to gather data about Mars?
2. Have students read the article "Manufacturing a Clearer View of Mars and Beyond" in *STEM Jobs* magazine. Discuss the following questions:
   a. Have you ever taken something apart to see how it works?
   b. How are optics used for the Mars Rovers and other space missions?
   c. Even with the rise in automation, how will the manufacturing field still grow?
   d. What are some ways to prepare for a career in manufacturing?
3. Show the video "The Next Mission to Mars: Mars 2020" found at edu.STEMjobs.com/teacher-resources. Stop at 3:48 as an introduction, or play the entire video for an in depth scientific explanation of the evidence collected in prior missions, and plans for Mars 2020.
4. If time, also show the video "NASA Begins Building Next Mars Rover Mission" to give an overview of the mission itself.

Part 2: Explore

1. Break students into small groups of three or four. Ask students to consider what data they think should be collected from Mars during the Mars 2020 mission. What makes this data important? How can this data be collected?
2. Present the challenge to the students: Design an instrument that should be included on the Mars 2020 Rover. Your instrument should contribute to the overall mission of Mars 2020 by collecting samples that will provide data pertinent to determining if there is or was life on Mars.
3. Encourage students to research instruments used on past Mars missions, including the optics described in the article. As a teacher reference only, a description of the instruments currently included on the Mars 2020 Rover can be found on the website "Mars 2020 Instruments - A Plan for Sample Return" available at edu.STEMjobs.com/teacher-resources.
4. Provide time for students to research and design their instrument. Students may draw their design by hand, or if desired, allow groups to utilize free CAD software to create a digital design. If this software is not available on your school computers, use a free online resource listed at edu.STEMjobs.com/teacher-resources.
5. Have groups create a presentation to share their instrument design for feedback.

Part 3: Explain

1. Pair groups so each can present their instrument design to another group in class. Students should share their research, design, and a description of data collection using presentation software such as PowerPoint or Google Slides if personal devices are available. Students should explain their instrument and how their instrument contributes to the Mars 2020 mission.
2. Encourage groups to ask questions and provide constructive critique following the presentation. Feedback will be essential for the next part of the lesson.

Part 4: Elaborate

1. Present an extension to the student challenge: NASA can only select a few instruments to include on the rover due to restricted size, weight, and budget requirements. They are now accepting proposals from teams of scientists for consideration. Create a proposal to NASA for your instrument to be part of the Mars 2020 Rover. The proposal should include a description of the instrument (including its size and cost), how samples are collected, and its contribution to the overall Mars 2020 mission.
2. Provide time for students to create their proposal while considering the feedback provided from their partner group. Additional research may be needed to determine costs.
3. Have students share their final proposals with a class presentation. Invite school administration, space science faculty, and community members (like those working in the manufacturing industry) to attend.

Part 5: Evaluate

Students will be evaluated for their design, presentation and proposal using the following rubric. Provide the rubric at the beginning of the lesson to clarify expectations and objectives. Each group will be graded, therefore all students in the group will receive the same score.

Scoring Rubric

____/20 Design Presentation

Was research on Mars Rovers and instruments completed?
Did they consider this in their design?
Did the presentation summarize the design and its contributions?

____/20 Proposal

Did the proposal include a description of the instrument, how samples are collected, and its contribution to the Mars 2020 mission?
Was the presentation clean and easy to understand?

____/10 Participation

Did each student contribute to the design and proposal?
Did each student assist in providing and responding to group feedback?

____/50 Total

Standards Addressed:

Common Core State Standards - Math

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.
CCSS.MATH.PRACTICE.MP4 Model with mathematics.

Common Core State Standards - ELA

CCSS.ELA-LITERACY.RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
CCSS.ELA-LITERACY.RST.9-10.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g. quantitative data, video, multimedia) in order to address a question or solve a problem.
CCSS.ELA-LITERACY.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
CCSS.ELA-LITERACY.SL.9-10/11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10/11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.
CCSS.ELA-LITERACY.WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
CCSS.ELA-LITERACY.WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Next Generation Science Standards

Possible Standards Include:
ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
Science and Engineering Practices
Asking Questions and Defining Problems. Analyze complex real-world problems by specifying criteria and constraints for successful solutions.
Disciplinary Core Ideas
ETS1.A: Defining and Delimiting Engineering Problems
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
Crosscutting Concepts
Influence of Science, Engineering, and Technology on Society and the Natural World
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
Science and Engineering Practices
Constructing Explanations and Designing Solutions. Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Disciplinary Core Ideas
ETS1.B: Developing Possible Solutions
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
Science and Engineering Practices
Constructing Explanations and Designing Solutions. Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
Disciplinary Core Ideas
PS1.B: Chemical Reactions
The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Standards Addressed (Cont.):

Next Generation Science Standards (Cont.):

HS-PS1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
Science and Engineering Practices
Constructing Explanations and Designing Solutions. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Disciplinary Core Ideas
ETS1.C: Optimizing the Design Solution
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
Crosscutting Concepts
Stability and Change. Much of science deals with constructing explanations of how things change and how they remain stable.

HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
Science and Engineering Practices
Constructing Explanations and Designing Solutions. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Disciplinary Core Ideas
PS3.A: Definitions of Energy
At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
PS3.D: Energy in Chemical Processes
Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.
ETS1.A: Defining and Delimiting an Engineering Problem
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
Crosscutting Concepts
Influence of Science, Engineering and Technology on Society and the Natural World. Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
Science and Engineering Practices
Obtaining, Evaluating, and Communicating Information. Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
Disciplinary Core Ideas
PS4.A: Wave Properties
Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
PS4.C: Information Technologies and Instrumentation
Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
Crosscutting Concepts
Cause and Effect. Systems can be designed to cause a desired effect.
Interdependence of Science, Engineering, and Technology. Science and engineering complement each other in the cycle known as research and development (R&D).
Influence of Engineering, Technology, and Science on Society and the Natural World. Modern civilization depends on major technological systems.

HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
Science and Engineering Practices
Developing and Using Models. Develop a model based on evidence to illustrate the relationships between systems or between components of a system.
Disciplinary Core Ideas
ESS2.A: Earth Materials and Systems
Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
Crosscutting Concepts
Stability and Change. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

HS-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.
Science and Engineering Practices
Engaging in Argument from Evidence. Construct an oral and written argument or counter-arguments based on data and evidence.
Disciplinary Core Ideas
ESS2.D: Weather and Climate
Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
ESS2.E Biogeology
The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.
Crosscutting Concepts
Stability and Change. Much of science deals with constructing explanations of how things change and how they remain stable.

Standards Addressed (Cont.):

ISTE Standards for Students

1d Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.
4b Students select and use digital tools to plan and manage a design process that considers design constraints and calculated risks.
4c Students develop, test and refine prototypes as part of a cyclical design process.
6a Students choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.
6b Students create original works or responsibly repurpose or remix digital resources into new creations.
6c Students communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations.
6d Students publish or present content that customizes the message and medium for their intended audiences.

Texas Essential Knowledge and Skills- Math

A.1.A apply mathematics to problems arising in everyday life, society, and the workplace.
A.1.B use a problem-solving model that incorporates analyzing given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution.
A.1.D communicate mathematical ideas, reasoning, and their implications using multiple representations, including symbols, diagrams, graphs, and language as appropriate.
A.1.E create and use representations to organize, record, and communicate mathematical ideas.

Texas Essential Knowledge and Skills- Science

Possible Standards Include:
B.3, C.3, P.3 The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom.
C.4.A Differentiate between physical and chemical changes and properties.
C.11.A Describe energy and its forms, including kinetic, potential, chemical, and thermal energies.
C.12.A Describe the characteristics of alpha, beta, and gamma radioactive decay processes in terms of balanced nuclear equations.
P.7.C Compare characteristics and behaviors of transverse waves, including electromagnetic waves and the electromagnetic spectrum, and characteristics and behaviors of longitudinal waves, including sound waves.