IBI* SERIES WINNER

Mars Student Imaging Project: Real Research by Secondary Students

The Mars Student Imaging Project, an IBI prize–winning module, provides student access to NASA scientists and spacecraft data.

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A group of scientists gather excitedly as their image arrives from the Thermal Emission Imaging System (THEMIS) camera on NASA's Mars Odyssey orbiter. They eagerly pore over the image they targeted to answer a scientific question about the Red Planet. Working together, the team measures, analyzes, and discusses relations among surface features, as they seek to answer their research question.

Sounds like Ph.D.'s in a NASA lab, but it isn't. Instead, it's a group of secondary students in their classroom learning how science is done by conducting research using real data they acquired from Mars. Funded by NASA's Mars Public Engagement Program and the NASA Mars Exploration Program Office, the Mars Student Imaging Project (MSIP) is led by the Arizona State University (ASU) Mars Education Program under the direction of the Principal Investigator of the THEMIS camera.

MSIP began in 2002, and more than 35,000 students have participated. With a focus on Mars, which appeals to many students, MSIP is an immersive and transformational way (*1*, *2*) for students in grades 5 through early college to learn the scientific process through authentic research experiences (*3*). The project is inquiry-based and student-centered, which means that students create and investigate their own research question about the Martian surface. This project engages them in the real process of science, replacing traditional worksheets with the collection and analysis of actual data from their own, targeted image of Mars.

The MSIP curriculum evolves to stay in step with the changing needs of science classrooms (*2*). Changes are based on feedback from teachers and students, professional evaluations, emerging national education standards (specifically the Next-Generation Science Standards), and changes in technology. MSIP reflects educational best practices and integrates education research. The lessons were developed to follow the Biological Sciences Curriculum Study (BSCS) 5E inquiry instructional model and enable teachers and students without deep knowledge of planetary geology to have successful experiences (*4*). The project is flexible and connects with the traditionally taught disciplines, such as earth science, biology, and chemistry (*3*). To support educators wishing to integrate MSIP into their teaching, the ASU Mars Education Team provides online training in the lesson components tailored to meet individual needs, and team members are available to educators through virtual office hours.

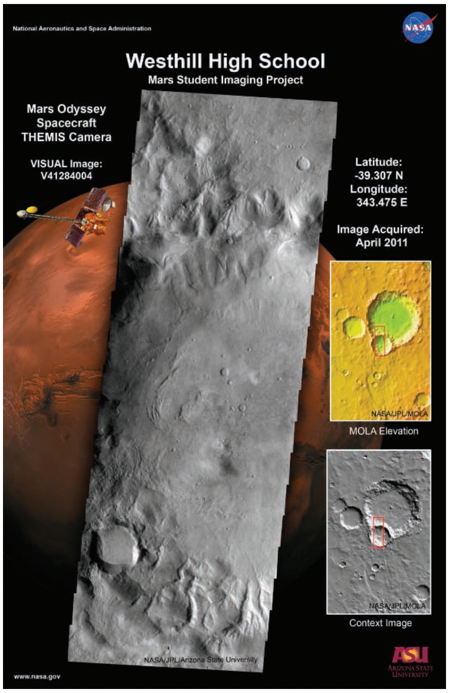
Students collaborating on Mars image analysis activity (phase 1 of the Mars Student Imaging Project).

MSIP students experience five main phases (*1*) in the project, beginning with the Mars image analysis phase (*1*, *2*, *4*). In this phase (see the photo, above), student teams work collaboratively with THEMIS images to identify common geologic features found on Mars and to develop a natural curiosity for these features and the processes that shaped them. This curiosity leads to student-generated ideas and questions shared with the entire team on topics such as wind streaks, landslides, collapsed lava tubes, dust devil tracks, lava flows, streamlined islands, chaotic terrain, channels, and dunes.

As students become engaged in the various observations, they become "student experts" in their topics of interest. They learn to make scientific observations while absorbing background information that can lead to measurable research questions (*4*). During the next phase, proposal development, each team develops a research question and articulates a testable hypothesis. This step is usually difficult because few have ever done it. The Question Mars activity was developed to aid this process. Student teams begin with a "big-picture question," such as "Why do some craters show the lobate debris aprons while others don't?"

Teachers are encouraged to help move from a general question by prompting them to develop working hypotheses. Next, the students collaborate to establish data-collection procedures, controls, and criteria. The team makes observations to determine where on Mars the features of interest occur, how measurements will be taken, what data will be recorded, and what tools will be needed.

The opportunity to struggle with these steps is crucial to inquiry learning (*1*–*3*). Students take ownership in developing their hypothesis, setting up procedures for data collection and analysis, and formulating their "why-this-is-compelling" discussion



MSIP student team's research image.

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into a formal proposal requesting THEMIS to take their image of Mars. Creating this proposal is an authentic scientific experience, as teams submit a proposal in a manner that parallels guest observers requesting time on NASA instruments.

Once the ASU Mars Education Program reviews, provides feedback, and accepts the team's proposal, the students enter the targeting phase, which consists of using the Java Mission-planning and Analysis for Remote Sensing (JMARS) tool to target (aim) the THEMIS camera at their chosen research location on Mars (see the photo, p. 920, bottom). JMARS is the same high-tech geographic information system platform used by the Mars science community to target research images and to study the martian surface. JMARS enables students to correlate their target area with other data sets in the same area taken during past or current Mars missions. Students look for surface features that connect to their research question, determine the exact location for their image, and communicate this information to the THEMIS mission planners. Student teams are given a specific number of orbits and target their image using JMARS and the actual orbit track of the Odyssey spacecraft. The student team typically assigns individual team members to collect data in a specific area pertaining to their focused research, which makes establishing criteria for data collection extremely important.

After the team receives its THEMIS image, they move on to the data analysis phase. Here, they interpret the image, collect additional data, display the data in graphical form, and draw conclusions.

As they analyze, the team is encouraged to use JMARS to obtain additional images relating to their research. The team then combines and reviews the data, identifies potential errors, and uses appropriate tools to visualize the data (e.g., graphs and tables). Teams are urged to create a wide variety of graph types to view their collected data, as this process may lead the team to discover other possible relationships in their data. Students are also asked to investigate "data outliers" that may extend the research in new directions.

Student-generated questions and research can lead to open-ended results, with many possible answers. The student team collaborates to determine the answer supported by their research and they must provide evidence from the research to support a claim. Typically, this step in the project is done in a collaborative, idea-sharing environment. The claim or evidence model is a necessary part of vetting results before the team presents the findings to Mars scientists at the symposium phase.

The project culminates when student teams interact with ASU Mars scientists during the final report and symposium phase. Because MSIP is offered in two formats, on-site and distance learning, students across the United States are able to participate in this phase. The on-site option is a 2-day program in which student teams complete their proposal and targeting at their own school. They then travel to ASU to work with Mars Education staff and scientists to finish the research and present their final project in a symposium to several Mars scientists face-to-face. The distance learning option involves a minimum of two live sessions: an online meeting to present the proposal and a final virtual meeting for the symposium with Mars scientists. Scientists involved in MSIP help the teams by vetting the students' approach and data. They probe the students' reasoning and discuss their findings. Some MSIP student projects have resulted in scientific discoveries (*5*), technical publications (*6*), and poster sessions at technical conferences (*7*).

MSIP provides an authentic research experience where students have access to real data sets from which many different questions can be asked. Working from a question they generate themselves, MSIP participants learn that, in science, it is the evidence and defensible interpretation through discourse that will determine the answer. Although the participating students are not Ph.D.'s in a NASA lab, they become scientists, nevertheless.

About the authors

Sheri Klug Boonstra is the director of the ASU Mars Education Program and the formal education lead for NASA's Mars Public Engagement Program. She is the precollege representative for NASA's Science Mission Directorate Planetary Science Education and Public Outreach Forum and served as the Education and Public Outreach representative on the Solar System Exploration Subcommittee for NASA Headquarters. She was the Universities Space Research Association principal investigator for NASA's Undergraduate Student Research Program and has experience as a classroom science teacher. Ms. Klug Boonstra has received several NASA group achievement awards for her participation in NASA missions and programs. **Philip Christensen** is a Regents' Professor of Geological Sciences in the School of Earth and Space Exploration at ASU. He is the principal investigator for THEMIS on NASA's Mars Odyssey orbiter. He is developing the OSIRIS-REx Thermal Emission Spectrometer for NASA's OSIRIS-REx asteroid sample-return mission, to launch 2016. He received NASA's Exceptional Scientific Achievement Medal in 2003 and its Public Service Medal in 2005. He was elected Fellow of the American Geophysical Union in 2004 and received the Geological Society of America's G. K. Gilbert Award in 2008.

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