Mars Exploration Through Project Based Learning

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Introduction

American Academy of Innovation is a new public charter school in the Daybreak area of South Jordan, Utah. Our mission is to ignite a passion in students through project-based learning (PBL) in science, technology, engineering, art, and mathematics (STEAM) courses.

We began our first school-wide project at the start of second semester, which provided sufficient time for students to learn how project-based education works and for teachers to prepare. We chose four possible themes for our projects and put these to a student vote at in October 2016. The students overwhelmingly chose the theme of Mars Exploration.

The first phase occurred during the last four weeks of first semester. We modified our schedule to accommodate a weekly hour-long Mars Seminar, where each teacher ran classes on different aspects of exploring Mars in order to bring students up to speed and to instill excitement and anticipation for the main project. Some seminar topics included the history of Mars, using 3D altitude data, building Mars rovers from candy, keeping humans healthy, Mars in popular culture and science fiction, and Dumb Ways to Die on Mars.

During this time, various individual courses created in-class projects related to Mars, such as our STEAM It Up class designing and building a model Mars colony out of junk and repurposed items and our Astronomy students creating a 3D animation of a space habitat and spaceship that will carry astronauts to Mars. They also learned about the relative orbits of Earth and Mars and why round-trip missions take up to 30 months through a human orrery project.

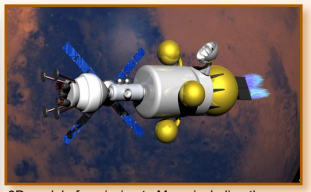
At the start of second semester, students wrote proposals for group projects they wished to lead, along with timelines and objectives. Thirteen proposals were submitted and approved. Remaining students applied for which teams they wanted to join by writing cover letters and resumes and signing up for interviews. The team leaders and assistants then interviewed the candidates and made final selections. Each team consisted of from 10 to 15 students and was assigned a faculty mentor. Those students who did not apply or who were not selected for a team were required to complete individual Mars projects of their own design. 155 out of 220 students were chosen for teams; of the 65 students doing individual projects, many of them self-organized into smaller teams of 4-5 members.

Student teams have been meeting for one hour each Friday since Feb. 27th to implement their projects. This poster reports on their progress and what we have learned about project-based learning so far in the context of Mars exploration.

Project Based Learning

Effective project-based learning (PBL) teaches key knowledge of content standards and the 21st Century success skills of collaboration, communication, creativity, critical thinking, problem solving, leadership, and project management. "Gold Standard" PBL has seven essential characteristics according to the Buck Institute for Education (Larmer, Mergendoller, and Boss; 2015):

1. **A Challenging Problem or Question:** This driving question should be interesting to students so that they will pursue it out of a need to know, not because it is simply assigned to them. It should be open ended, challenging without being intimidating, and involve creativity and problem-solving skills.
2. **Sustained Inquiry**: The question should lead to active investigation through research, data gathering and analysis, and critical thinking. It should involve primary sources, field research, and expert interviews.
3. **Authenticity**: The project should be meaningful to students with real-world applications that solve local issues. It should relate to the students' everyday lives and be intrinsically motivating.
4. **Student Voice and Choice**: Students need to help choose the final project theme and how they carry out the overall project. These choices should allow for personal interests and recognize the legitimacy of multiple approaches and perspectives.
5. **Reflection:** Students should continuously evaluate what, how, and why they are learning and whether or not their projects are meeting design parameters and audience needs. These are formative assessments that help the students change course.
6. **Critique and Revision:** Projects should be held to a high standard of excellence and given official critiques and chances for revision. As the projects develop, they need to be evaluated by students and teachers to make sure they adhere to the groups' design criteria.
7. **Public Product:** A product can be a presentation, an action, a physical object, or a well-conceived solution to a problem. They have to show something for their efforts, and in front of a public audience.



3D model of a mission to Mars, including the Orion spaceship, a space habitat, a VASIMR drive, and a lander.

Students conducting a human orrery activity to learn the orbits of Earth and Mars.

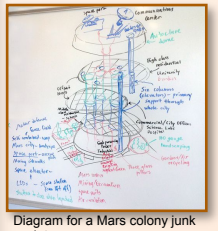
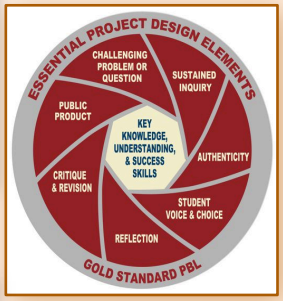


Diagram for a Mars colony junk sculpture.

Building the base of the Mars colony sculpture using autoclave parts.



The Mars colony sculpture nearing completion.

Applying PBL to the Mars Project

- Sending humans to Mars provides a broad yet challenging problem that allows for student interpretation and in-depth inquiry.
- Students were given a choice between four possible project themes, and chose Mars Exploration.
- Students showed initiative by proposing their own projects related to Mars. We received a wide variety of proposals across many subject areas.
- Students applied for the team projects they most wanted to join, and were asked to write cover letters and resumes, then interview for the job.
- Team leaders reflect on their progress through frequent written progress reports and personal interviews with teachers. Several teams adjusted course based on our discussions and made their projects more realistic.
- Most of the team project members are engaged and contributing well, although some adjustments have been necessary.
- Initial formal assessments will occur March 31 as mentor teachers provide detailed feedback to their teams. Teams will make revisions and stay on track for completion.
- Team leaders received training on leadership and project management, including the relationship between quality and time and the 20-80 Rule.
- Student teams will demonstrate their final products and make presentations before the whole school and a panel of industry judges on April 28th and receive feedback. Individual projects will be displayed.
- Team leaders are traveling to Houston for the Lunar and Planetary Science Conference to present a poster of their progress on March 21.
- Remaining team leaders are raising funds to travel to Washington, D.C. on May 8-11 for the Humans to Mars Summit, where they will present their final projects before an audience of NASA scientists, engineers, and Mars policy experts.

Student Project Descriptions

Mars Habitat:

Two teams are building Mars habitats, which they will live inside for two days and one night. They wish to test that factors that contribute to the mental and physical health of the Mars explorers, including the isolation of delayed communications from Earth and not being able to go outside for fresh air.

Mars Soil Simulation:

Two teams are growing radishes and endive in simulated Mars regolith, complete with known contaminants (chlorates and peroxides, heavy metals), which they purchased from a NASA supplier..

Mars 3D Lander Animation:

This team is creating an animation of a landing craft descending from the orbiting space ship and landing on Mars using real 3D altitude data from the Mars Global Surveyor MOLA instrument.

Mars Science Fiction Novella:

This team is creating a novella about three generations of Mars colonists. They have worked out the complete story arc, are nearly done with the first draft, and are creating illustrations of characters.

Mars Video Game:

This group is using the Unity game engine to create a Mars survival game where an expedition is stranded on Mars due to a devastating war on Earth and must survive on supplies they brought and in-situ resources they can obtain

Mars Nova Ball Sport:

Two students are leading a team to plan out and practice a sporting event called Nova Ball that can be played in the reduced gravity of Mars or in free fall.

Mars Illustrations:

This team is creating illustrations and paintings of life on Mars and what a colony or city would look like.

Mars: Past, Present, and Future:

This group is researching and reporting on the history of Mars exploration by creating a poster and presentation. They have finished the poster and are now working on a short story about Mars.

Mars Simulation:

This team has planned an interactive role-playing simulation of several days in the life of a Mars colony, complete with crises to overcome. They have ran the simulation as a team twice to work out the bugs, and are now ready to run the entire school through the simulation.

Mousetronaut:

This team has purchased a D-engine class two-stage rocket and are building the launch ignition system and gantry now. They are designing an acceleration couch and harness to launch a mouse up to 2500 feet and recovery it safely.

Mars Video Documentary:

These students are photographing and videotaping the other projects. Each student is embedded in another group, similar to war correspondents, and are recording interviews with students and team leaders. We will edit the footage into a final 30-minute video and a 2-minute trailer for YouTube.

Individual Projects:

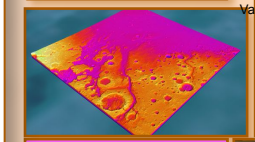
Those students not chosen for a team project are working on individual and small group projects such as creating Minecraft mods and programming a Scratch game about Mars, building 3D printouts of Mars terrains, etc. Most of the 65 students doing individual projects are engaged and working well, but there are about 15 students that are undermotivated.

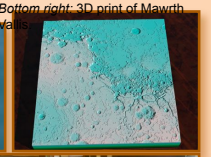
Classroom Projects:

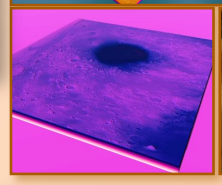
Specific classes are continuing to create Mars related projects, such as a video tutorial on using Mars MOLA Data for the 3D Modeling and Media Design classes (on YouTube at: https://youtu.be/kzdO9PANu_8). The Astronomy class is designing travel brochures, exploration timelines, solar system scale models, and building candy and paper space probes.

Upper Left: Building the Mars habitat; *Upper Right:* Collecting plant data; *Left:* Making candy space probes.

Student-Created Mars Images:
Below Left: Chryse Planitia; *Below Right:* Protonilus Mensae; *Bottom Left:* Hellas Basin; *Bottom right:* 3D print of Mawrth Vallis







What We've Learned So Far

This is our first school-wide attempt at PBL, although individual teachers have implemented projects in their own classrooms. Here is a list of points we have learned and practical ideas for our next attempts:

- The chosen theme or topic must have general appeal and we need to work at promoting the theme to ensure student and teacher buy-in.
- We need a plan for managing those who do not participate or are undermotivated. As a PBL charter school, we need to be sure to advertise to prospective students that this is how we operate. If they do not like (or will not participate in) projects, they can choose a different school.
- Prospective team leaders need training in project management and leadership before they submit proposals, so that they can be more realistic in their expectations. They have done very well for a first attempt, but more can be done to train them beforehand. Overall they have had great experiences and are still enthusiastic about their projects.
- We need more project proposals. Thirteen was a good start, but it has required that 10-12 people be in teach team and that is too many. Teams of 6-8 would be more ideal, to avoid the "free rider" problem of students relying on others to get the work done. More teams would also avoid having too many individual projects and ensure greater student participation.
- We need to increase the percentage of students participating in teams from about 70% to 90%.
- We should collect more data in the form of pre and post tests, so we can see changes in knowledge, skills, and attitudes more accurately.
- We need to raise funds through sponsors before starting a school-wide project so that our budgets are guaranteed and can't be frozen midway.
- Students should start paying installments from the start of the year for trips to present their work.
- Teachers need additional training on the characteristics of effective project-based learning, including research on its effectiveness and how to implement projects inside classrooms, between classes, and across the entire school. Site visits to effective PBL schools would be useful.
- With more students in the school next year, we will need more computers, printers, and other technology. Right now we have a 2:1 student to computer ratio; that needs to improve to almost 1:1 for project-based learning to really work.
- We should budget more time. One hour per week for 2/3 of a semester has not been enough. We will probably increase the Mars time as we approach April 28, but we needed more time from the start. Now that the teams are working well, they can handle more time. Next year, they will come in already knowing what to do.
- Having student leaders and winning teams travel to actual professional conferences to present has been very motivational, but we need to raise funds well beforehand or have the students raise their own.

Bibliography

J. Larmer, J. Mergendoller, S. Boss: *Gold Standard PBL: Essential Project Design Elements*, Buck Institute for Education, 2015