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The NASA Spaceward Bound field training curriculum

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ABSTRACT

A comprehensive field training curriculum was developed and tested during the 2006, 2008, 2009, and 2010 National Aeronautics and Space Administration (NASA) Spaceward Bound missions at the Mars Desert Research Station (MDRS). The curriculum was developed to train teachers and students in fundamentals of Moon and Mars analog station operations, logistics, field work, and scientific investigation. The curriculum is composed of background content, directions, lesson plans, suggestions, protocols, images, diagrams, figures, checklists, worksheets, experiments, field missions, and references. To date, 48 individuals have participated in Spaceward Bound missions at MDRS, and 18 have successfully tested the curriculum. Based on our analysis and student feedback, we conclude that the Spaceward Bound curriculum is highly useful in training teachers and students in aspects of astrobiology, field science, and Mars exploration, and that MDRS is an ideal location for its use.

INTRODUCTION

Since the fall of 2001, the Mars Desert Research Station (MDRS) near Hanksville, Utah, has enabled Moon and Mars analog field research activities for nearly 100 crews of scientists, engineers, and space enthusiasts (Fig. 1). Crews use MDRS to simulate human missions on Mars and to perform field investigations that will help support future Mars exploration. In addition to providing opportunities for professional researchers, MDRS has also been used like a classroom to train crew members in the fundamentals of Moon and Mars analog station operations (Rask et al., 2007; McKay et al., 2007). To help in the standardization of the training process and to develop a training curriculum, the National Aeronautics and Space Administration (NASA) Spaceward Bound educational program at NASA Ames Research Center supported the recruitment, selection, and training of nine crews during the 2006–2007, 2008–2009, and 2009–2010 field seasons. This paper

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Figure 1. Crews 86 and 87 at the Mars Desert Research Station in December 2009. Participants (from left to right) included Jon Rask, Jessica Watkins, Donna Viola, Raechel Harnoto, Mary Beth Wilhelm, Heather Bradshaw, Grier Wilt, Josh Nelson, Clara McCrossin, Denise Wood, Justin Brannan, and Laura Meyer.

describes the many efforts made to develop the curriculum and reports feedback from the students that participated in its field testing.

THE SPACEWARD BOUND PROGRAM

The NASA Ames Spaceward Bound program enables students and teachers to participate with NASA scientists and engineers in the exploration of Earth-based Moon and Mars analogs of scientific interest. One of the main goals of Spaceward Bound is to help NASA attract and retain students in science, technology, engineering, and mathematics (STEM) disciplines, by providing educational opportunities for undergraduate and graduate students in STEM education programs, for preservice and in-service STEM K–12 teachers, and for STEM education faculty. Through field expeditions and Moon and Mars exploration simulations, Spaceward Bound has inspired, engaged, and educated members of the STEM education pipeline (Coe et al., 2010), and it has involved them in field training opportunities in the Mojave, Atacama, Namibian, and Australian deserts (Smith et al., 2008; Allner et al., 2010; McKay et al., 2007; West et al., 2010), at Pavilion Lake (Lim et al., 2010), in the relic glacial terrains of North Dakota (Rask et al., 2010), and in the Canadian Arctic (Williamson et al., 2008). More information about the Spaceward Bound program can be found online at http://quest.nasa.gov/projects/spacewardbound/.

SPACEWARD BOUND MDRS

Recognizing that MDRS is a valuable and unique facility that can be used to train and inspire the next generation of explorers, the NASA Spaceward Bound Program created NASA-sponsored field training opportunities for teachers, graduate students, and undergraduate students at MDRS. The program solicited for applications, and offered travel stipends for individuals that were selected to participate in the program. The main goals of the Spaceward Bound missions at MDRS were to train teachers and students in the fundamentals of Moon and Mars analog station operations, logistics, field work, and scientific investigation, and to support the development and testing of the Spaceward Bound field training curriculum.

All Spaceward Bound crews were composed of volunteers with a wide variety of scientific knowledge and skills. Following a crew model used in past missions at MDRS, each Spaceward Bound crew included a commander, an executive officer, a health and safety officer, a crew geologist, a crew biologist, and a chief engineer.

For the four 2006–2007 Spaceward Bound crews that participated in the curriculum development (MDRS crews 52, 53, 54, and 55), an MDRS-experienced scientist commanded each crew, and the remaining crew positions were populated with outstanding teachers, undergraduate students, and graduate students with interests and skills relevant to space exploration. By using this approach, the crews were provided with an experienced commander who could support their training, as well as the development and editing of the curriculum content that each crew created. The crews also worked collaboratively and prepared for the missions via the NASA Ames Distance Learning Network prior to the simulations. Crews 52, 53, 54, and 55 each carried out a full 2 wk mission, and their reports can be viewed online at http://desert.marssociety.org/MDRS/.

The 2008–2009 Spaceward Bound crews (MDRS crews 73 and 74) (Fig. 2) were composed of both undergraduate and graduate students without MDRS experience, and they were trained by an MDRS-experienced guide, who was stationed in Hanksville (Fig. 3). The 2009–2010 Spaceward Bound Crews (MDRS crews 86 and 87) (Wilhelm et al., 2010) were composed of mostly MDRS-experienced students, and they were also trained by a guide who was stationed in Hanksville (Fig. 1). Crews 73, 74, 86, and 87 each carried out a 1 wk mission and tested the curriculum. Their reports can be viewed online at http://desert.marssociety.org/MDRS/.

Figure 2. Mars Desert Research Station (MDRS) crews 73 and 74 who tested the Spaceward Bound field training curriculum in December 2008 and January 2009. Participants (from left to right) included Josh Nelson, Mary Beth Wilhelm, Michael Borden, Emily Calandrelli, Clara McCrossin, Thomas Franklin, Raechel Harnoto, Jessica Hill, Heather Bradshaw, Rachel Forman, Jon Mihaly, Michael Hrynyk, and Jon Rask (not pictured).

Figure 3. The Spaceward Bound guide training students in the field at the Mars Desert Research Station (MDRS).

CURRICULUM DEVELOPMENT PROCESS

The Spaceward Bound field training curriculum was designed to be a university-level course of study held at MDRS for undergraduate and graduate students. The curriculum engages students in outdoor lectures and trainings and requires them to demonstrate knowledge and skill in a variety of disciplines, including geology, biology, planetary science, and analog studies. The document that describes and outlines the curriculum was written, edited, and tested over the course of three separate field seasons. Crews 52, 53, 54, and 55 drafted the first version of the curriculum, and crews 73, 74, 86, and 87 each tested and edited the curriculum. The core content of the curriculum consists of seven modules that familiarize students with scientific concepts and skills needed to successfully perform field science at MDRS. The modules cover navigation and use of global position systems (GPS) at MDRS, all-terrain vehicle (ATV) use, MDRS habitat (Hab) engineering, extravehicular activities (EVA) and spacesuit simulators, field geology, field biology, and astronomy. Each module contains activities and tasks that students are required to complete.

CURRICULUM ACTIVITIES

To ensure that students complete all the current activities in the curriculum, checklists were created to guide students through the required training within each module. For example, the navigation checklist requires students to become familiarized with the MDRS waypoint database. It requires students to download waypoints from a computer to a GPS unit, to navigate to a waypoint of interest using the GPS, to create a waypoint on the GPS unit, and to upload a waypoint from the GPS to the waypoint database. The EVA training checklist requires students to gain a working knowledge of the ATVs, spacesuit simulators, and the mission simulation. The checklist ensures that students become familiar with the suit and simulation by requiring the following: suit donning and doffing; communicating with the MDRS habitat using two-way radios that are built into the suits; entering and exiting the habitat; and performing EVAs both on foot and on ATVs. The checklist also requires students to become familiarized with ATV operation and maintenance. Students first become familiar with ATVs outside of the simulation, and then eventually repeat the same ATV checklist while in the simulated environment (with spacesuit simulators donned). Students are also required to navigate and scout for field sites while on ATVs in simulation (Fig. 4). The biology checklist requires students to collect soil samples (Fig. 5), make media, culture soil microbes, count colonies, and characterize the microbial colonies (Fig. 6). Finally, the geology checklist requires students to complete several field lessons that train them in fundamentals of geology, such as rock types, the principle of superposition, and sedimentary and erosion processes. With help from the guide, students are trained to interpret a geologic setting and describe the environmental conditions that formed local features such as Habitat ridge, White Rock Canyon, box canyons on Muddy Creek, and Skyline Rim. They are also trained to navigate with GPS to field sites of astrobiological and geological interest, and they are trained to distinguish the differences between the Jurassic- and Cretaceous-era formations that are around MDRS. Students are also required to deploy environmental data loggers and use them to gather temperature and humidity data (Fig. 7). Other field missions that are included in the geology checklist require students to bury a cache and mark the waypoint location with GPS, navigate to a cache and retrieve it, and retrieve samples from field sites that are relevant to Mars exploration, such as in gullies, sedimentary formations, concretion sites, dune fields, dry stream beds, and rocks rich in endolithic or hypolithic algae. Each of these field sites and many others are described in the *Lovely Planet Guide*

Figure 4. Spaceward Bound students learning to use all-terrain vehicles (ATVs) and global positioning system (GPS) to navigate to field sites of geologic and biologic interest.

Figure 5. Gathering samples during the simulation at scientifically interesting field sites.

Figure 6. Spaceward Bound students processing and analyzing field specimens in the Mars Desert Research Station (MDRS) laboratory.

Figure 7. Students performed tasks while wearing spacesuit simulators during field training missions at Mars Desert Research Station (MDRS).

to Science and Field Sites at MDRS. The *Lovely Planet Guide* is a series of minireviews, descriptions, and images for each field site or scientific topic of research at MDRS. Both the curriculum and the *Lovely Planet Guide* are considered living documents, are not yet complete, and will continue to be updated and expanded.

CURRICULUM FIELD TESTING PROCESS

During the second Spaceward Bound field season, crews 73 and 74 tested the original version of the curriculum, provided comments, and edited the document. The goal of this effort was to determine if a crew without MDRS experience could successfully use the curriculum "as written," and determine if it was accurate, organized, and relevant to MDRS. In the third Spaceward Bound field season, crews 86 and 87 tested and edited the updated version of the curriculum.

To organize the crew missions and testing of the curriculum, an electronic version of the curriculum was provided to the crews prior to their arrival to the MDRS, and teleconferences were held to facilitate discussions. The initial approach for crews 73 and 74 was to have them engage remotely via e-mail with the guide during the testing phase. Problems with the Internet communications system at the habitat prevented the guide from communicating with the crews electronically, and thus in-person meetings and trainings were performed on a daily basis for crew 73. Crew 74 also successfully tested the curriculum, but with fewer in-person training sessions with the guide. This was done to help improve the fidelity of the mission simulation. Both crews demonstrated that the checklist could be followed, and the field missions could be accomplished by following the curriculum as written. Student learning was assessed during face-to-face morning meetings between the guide and the crews. Discussions regarding the purpose of each item in the checklist were held to ensure that students understood the relevance of each task.

SUMMARY OF STUDENT FEEDBACK

To help improve the curriculum and gather data about the experiences of students, we solicited feedback from the students that participated in the curriculum field testing process. The questionnaire provided to crews 73, 74, 86, and 87 asked the students to rate their training experience and curriculum features as "exceeds expectations," "satisfactory," or "needs improvement." Student feedback and comments were used to evaluate the organization of content, the quality of instruction, relevance to Moon exploration, relevance to Mars exploration, relevance to astrobiology, level of rigor, the training missions, the field missions, biology content, geology content, engineering content, NASA involvement, and Mars Society involvement (Fig. 8). Students were asked if they would recommend others to participate in a Spaceward Bound crew, if they had found their MDRS experience to be useful to their current work, and if they were able to receive university credit for their experience. The questionnaire also encouraged the students to provide any other feedback they felt should be communicated.

RECOMMENDATIONS AND DISCUSSION

Every student that used the Spaceward Bound curriculum at MDRS indicated they would recommend the training experience to other students interested in space exploration. Sixteen of eighteen students reported their experience was useful in their current research and or work. All students reported that the curriculum was satisfactory or exceeded their expectations with regard to Mars Society involvement. However, students recommended that the organization and flow of the curriculum should be improved, along with the structure and design of the training missions, as well as the engineering, geology, and biology content. They noted that although the curriculum contained highly useful information and the training could be completed by following the document as written, the current version was somewhat scattered, and did not flow well in all modules. Students reported that having a guide stationed in Hanksville to help them with the training was well received and should be repeated in future Spaceward Bound training missions. Students also recommended that the curriculum's relevance to astrobiology and Moon exploration could be improved by adding a specific module that discusses these topics, and by including remote-sensing imagery of the MDRS area, the Moon, and Mars. Additionally, the students suggested that the modules should include more training on how to interpret samples collected in the field. Students that tested the curriculum emphasized that premission teleconferences were very helpful, and more would be useful to better prepare the crew. Only two of the students reported that they were able to receive credit from their academic institution for their experience at MDRS. It should be noted, however, that with advanced planning, it

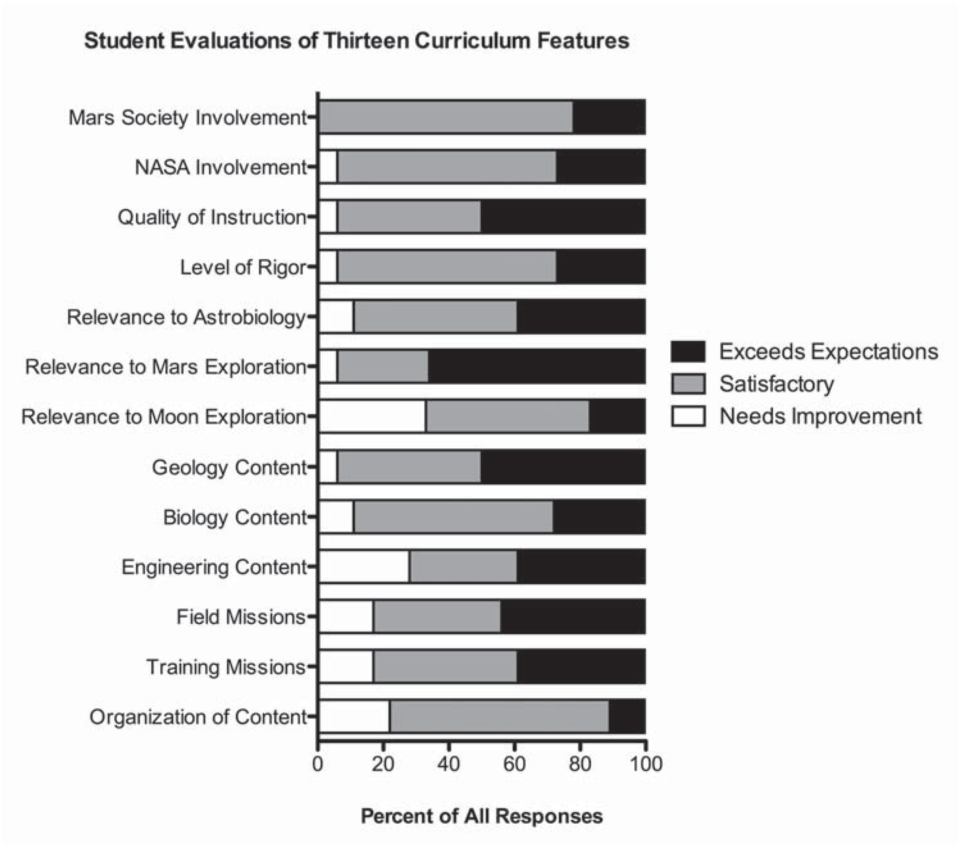

Figure 8. Feedback provided by students to the National Aeronautics and Space Administration about their experience in using Spaceward Bound field training curriculum at the Mars Desert Research Station (MDRS).

may be possible for all students to receive credit. Therefore, it is recommend that prospective students investigate this possibility early in the application process, or that NASA and the Mars Society work together to identify an academic institution that can provide all future Spaceward Bound crews university credit for the training they receive at MDRS. Additionally, it was observed that a 1 wk period is adequate for the Spaceward Bound training at MDRS. A training period that is longer would be highly useful, but it may reduce the pool of potential students because it is difficult for students to get more than 1 wk of time off during the school year. In general, the curriculum testing results from all four crews were similar. However, crews that were composed of more experienced students were able to progress more rapidly in some cases, whereas crews with less experienced students required more guidance.

CONCLUSIONS

A curriculum to train students in Moon and Mars analog station operations has been developed and successfully tested at MDRS. Although there are some areas in the curriculum that need improvement and revision, the majority of feedback from the questionnaires indicates that the curriculum either met or exceeded student expectations. In total, 48 individuals have participated in Spaceward Bound crews at MDRS, and 18 of them have used and tested the Spaceward Bound field training curriculum. The development and testing of the curriculum have inspired, engaged, and educated members of the STEM education pipeline and successfully provided educational opportunities for teachers, undergraduate students, and graduate students. Based on our analysis and student feedback, we conclude that the Spaceward Bound field training curriculum is a highly useful tool for training teachers and students in aspects of astrobiology, field science, and Mars exploration, and that MDRS is an ideal location for the training.

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