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Engaging Students in STEM Careers Through the Mars Rover Challenge: Bridging Barriers through Multimodal Informal Learning

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Abstract: *This paper presents a framework for implementing informal learning events through a multi-modal event. A specific example is provided using the Mars LEGO Robotics challenge during the global pandemic Novel-coronavirus-19 (COVID). Students in grades 4-6 typically develop Lego Mars Rovers and compete in a face-to-face large competition in three primary regions across the state of Idaho. Competitions typically include n= 200-300 children and n =100-200 adults. This year the competition will be held using multimedia posters and competition notebooks that accompany a virtual presentation and competition over an Internet-based platform. A mixed methods design is described as a methodology to collect data using a case study design and pretest/posttest survey. The paper concludes with implications and recommendations.*

Key Words: Informal Learning, LEGO, Students with Disabilities, Technology

INTRODUCTION

Across the globe, women, members of historically marginalized racial and ethnic groups, and individuals with disabilities continue to be underrepresented across STEM disciplines (National Science Foundation, 2019; Griffith, 2010). Informal learning opportunities that focus on STEM have long been a vehicle for developing and sustaining interest in STEM. In order to address the need for more science, technology, engineering, and mathematics (STEM) opportunities for students to explore, engage, and participate in, is critical to support the shortage of individuals moving into STEM-related careers (Ayar, 2015). As an effort to develop interest in STEM, the Idaho Teaching Engineering to Children (TECH) project has provided informal STEM experiences to Idaho students in grades 4 - 6 by way of the NASA LEGO Mars Rover Challenge. Recently, building on the legacy of Idaho TECH, Idaho TECH-plus (TECH+) was developed to increase the diversity in students participating by recruiting teams with students, who have disabilities (Autism, learning disability, attention deficit disorder, or other high-incidence learning disability), are from rural and remote areas, from culturally and linguistically diverse backgrounds, and students from lower-socioeconomic backgrounds (National Science Foundation, 2019; Wei, Yu, Shattuck, McCracken, & Blackorby, 2013).

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In the wake of COVID-19, overnight, students were removed from school, sports activities, clubs, and informal learning opportunities. Educators, coaches, and other informal mentors were confronted with a reality for which they were not prepared or had not previously considered when supporting students outside of the traditional school setting. This is, in part, due to the nature of many informal learning programs requiring a heavy face-to-face component. This new reality presents a gap in program delivery to students on a national level. The continued gap in programs for youth highlights a need for programs to make the shift to fully distance or multi-modal. Therefore, this year, the Mars Rover Informal Learning opportunity that culminates in a competition, will be multimodal and include Internet-based platforms. This new program design will support students during the Novel-Coronavirus-19 (COVID-19) as well as other potential natural disasters. The newly developed method of providing informal learning opportunities during COVID-19 can also support the inclusion of marginalized students particularly those residing in more rural and remote settings. Today, there are very few programs offering informal learning using multi-modal delivery. Additionally, there is limited research on how to design and deliver an efficacious program in an informal setting; therefore, the purpose of this paper is to present a theoretical framework and implementation guideline for a multimodal informal learning STEM program. This paper concludes with implications and future recommendations to help meet our long-term goal to increase interest in STEM careers for individuals from underrepresented populations and increase the number of individuals pursuing STEM careers to fill an ongoing need in the U.S.

Overview of STEM and the Workforce

It is well known that there are not enough students matriculating to careers in science, technology, engineering and mathematics (STEM) in the United States (US) (Sass, 2015). Sass (2015) noted large differences in mathematics achievement across racial, gender, and disability groups. These gaps begin as early as elementary and persist through high school. Further, these achievement gaps lead to higher dropout rates and lower postsecondary enrollment. The persistent underrepresentation of minorities (this includes those with disabilities, women, and different races) contributes to the growing challenge of the United States not producing enough STEM graduates to remain globally competitive. Available data confirm that there is an increase in demand for individuals to fill STEM jobs and there is a skill-gap as the U.S. labor force does not have enough individuals with highly specialized training; therefore, annually, the U.S. government begins accepting applications for the H-1B program, a temporary visa program designed to bring in high-skilled workers from abroad. Informal learning opportunities exist to build and advance the informal STEM education field and provide multiple pathways for broadening access to, and engagement in, STEM learning experiences. It is known that in an informal learning environment, students have the opportunity to freely explore, engage, and develop an interest in STEM (Dailey et al., 2018). Interest in STEM is cultivated overtime through opportunities for children to engage with activities that are exciting and challenging. One way to introduce STEM and generate interest and belief that students can be successful in STEM is through play-based learning in the elementary years. Children have a strong interest in play and vivid imagination that can be harnessed through structured activities to introduce and nurture interest in a given subject.

Supporting STEM Engagement through Play-based Learning

Imagination is a critical component of play-based learning (Adbo & Carulla, 2020). An essential part of learning is allowing students to utilize their creativity which allows them to imagine what cannot be seen, conceptualize what they hear from others, and think about things that have not been explored (Fleer, 2015 p. 39). Play-based learning has been defined by Siraj-Blatchfor (2009) as the teacher having a participatory role in play as the mediator by engaging in play with the students, and finding common ground, and creating shared meaning from the play experiences. To support play-based learning, teachers include science words, concepts, and discussion referred to as conceptual play (Fleer, 2011). The Idaho TECH program incorporates play through the construction of a Mars Rover by testing the rover through structured play activities such as the hill climb or rock collection activities. The team coach introduces STEM concepts, language, and habits of mind as they sustain dialogue about the design, development, and testing of the Mars Rover through play in an informal learning setting.

OVERVIEW OF IDAHO TECH

Idaho TECH is an informal STEM Education program that has been in existence for over 20 years. The program has historically been sponsored by the NASA Idaho Space Grant Consortium (ISGC). Students design and construct Mars Rover models using specified LEGO and non-LEGO components, which are then tested in concert with, and against, other teams at regional Engineering Design Competitions (EDCs). The EDCs allow teams to display their design and demonstrate their rover capabilities on Martian Test Courses. Students also have the opportunity to examine the design and performance of Mars Rover models constructed by other engineering teams, engage in dialogue, and collaborate across their region. Furthermore, hands-on and informational activities such as robotics exploration, coding, and invited speaker presentations, in addition to the focused competition, are open to all participants and attendees at the EDC.

Idaho TECH is an intensive program which requires a high level of both teacher and student dedication. Parental and community support is key to the Idaho TECH team's success as students learn to work together with their team through dedicated build and test times over several weeks. By including parents, teachers, and students in a meaningful, hands-on education activity, Idaho TECH seeks to demonstrate schooling as a collaborative and experiential venture among parents, teachers, and students.

IMPORTANCE AND PURPOSE OF INFORMAL LEARNING WITH LEGO

Making a shift to a multi-modal setting with significant virtual components is essential during a crisis or in the immediate aftermath of disruptive events such as hurricanes, earthquakes, floods, and, more recently, the COVID-19 pandemic. Therefore, this year the Mars Rover challenge will include virtual components to allow students the opportunity to participate in the informal learning through the Mars Rover Challenge and will include opportunities for state-wide collaborations rather than regional collaborations. Multiple events will be held across the state of Idaho using multimedia virtual tools and limited in-person connections. Not only is the development and implementation of a multimodal competition addressing the challenges presented by COVID-19; a multi-modal competition allows for students in more rural and remote regions to have an opportunity to participate in, and share their learning experiences, with other students across the state and beyond their region. This new format allows for connections to be developed across the entire state.

METHODOLOGY

We proposed the development and implementation of a multimodal competition to take place using virtual platforms for interaction, virtual posters and notebooks, and limited interaction between participants using multiple locations across multiple days. The development of the multi-modal program was informed by an understanding of social, cognitive, and information processing theories in learning (Meichenbaum, 1997). The multi-modal informal learning program is intended to support collective experiences in STEM across the state of Idaho. The overall objective for this competition was to develop a program that can be implemented in an informal setting, across multiple platforms, and that harnessed the power of virtual mediums.

PROGRAM DESIGN

The program is comprised of three main elements: 1) virtual interactive posters to be displayed in a Google Classroom and presented over Zoom, 2) virtual interactive notebooks that are added to by each participant using a Google+ documents and presented over Zoom, and 3) Zoom links set up in each competition room for each individual team to test their rover over the Martian Terrains. Table 1 includes a series considerations for program development specific to Idaho TECH and that can be used when planning other informal learning multi-modal event.

PROJECT IMPLEMENTATION

The Idaho TECH project has three primary phases culminating in the final phase of competing with the Mars Rover. The first phase is preparation and recruiting. During this phase, the project leader and coordinator contact schools in designated regions across the state of Idaho to recruit teams. Teams are often recruited through school contacts, flyers, and teacher interest. Teams that identify as having a student with a disability will become part of the TECH+ program where additional data will be collected. Once the teams have been identified, LEGO kits are delivered to the teams via the U.S. Mail or physical delivery depending on proximity to the team. For each of the three competitions approximately 25 – 40 teams will participate and attend each competition.

The second phase is Rover Designing and Testing. In this phase, the team sponsors for the participating schools, will act as mentors for their student teams. The students will design, build, test, and improve their rover designs over the course of 8-10 weeks. Typically, students meet one to two times a week every week and follow the engineering design process outlined in the Idaho TECH handbook (available by request through the authors). The design process is iterative and through each phase students record their thinking, collaboration, process, successes, and challenges in an individual notebook will continue until the third and final phase. Protocols for safety have been established and include mask wearing, hand sanitizer, and sanitization protocols for equipment and rooms, prior to attending a team build session.

The project leader and coordinator remain in contact with the team leaders to assure that the teams are on schedule for the competitions. Further, the team leaders have access to a database of lesson plans, developed over multiple years, to assist their mentorship of the students. The milepost for this phase of the project is the number of teams with operable rovers that attend the multimodal competitions in phase three. The final phase is the EDC which has been typically held in the student's region; however, now will have all of the events inclusive of virtual pieces so students across the state can see each of the teams compete.

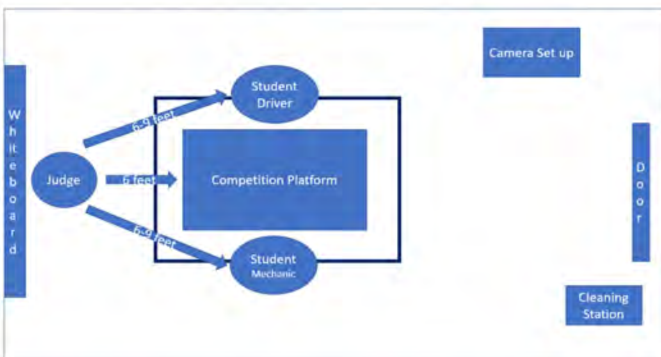
Table 1
Program Development Considerations

Preparation and Recruitment	Program Design and Delivery	Judging and Inclusion of Participants Across the State
Accessibility to tools for students and mentors: Does a specific location have barriers to available Internet access?	**Program components**: Each element of the program should be considered for alternative methods of delivery such as moving the poster development to a virtual poster presentation.	**Access to events and presentations:** Student poster presentations, notebooks, and formal presentations should be developed using virtual protocols. All presentations should be done over a virtual platform such as Zoom which allows for recordings and other teams and community members to view the event live. This allows for all students, judges, and community members to remain distanced.
Development of teams: Protocols should be developed for teams to consider an in-person limited interactions plan and should be shared during the recruitment phase.	**Team interactions:** Teams or individual groups should utilize the suggested interactions plan and work with the program coordinator to help ensure current guidelines are met.	**In-person events with the Martian Terrain or other necessary interactions**: Any in person events should limit the number of individuals required to engage with tools, cleaning protocols should be in place, and rotations for teams to minimize interactions. These should be posted around the event building as well as on the Internet.
Navigation for in-person EDC: Room layouts and rotations should be developed and shared during the recruitment phase.	**Program Layout and EDC event**: A phased delivery plan should be developed to meet the current guidelines for safety. For example, plan A would include more in-person, plan B would include limited in person with more rotations of events, and plan C would include interactions with only 1 team at a time and using mostly Internet-based platforms.	**EDC room layout**: A sample room layout has been provided (see image 1). Room layouts should indicate location of individuals, judges (if needed), clearing stations, and cameras to broadcast the event to other teams and locations. A space should be dedicated for those who have not given permission to have their photo or video taken and shared out.

Phase three is the final testing of the Mars Rover during a competition. Competitions have been held across three major locations in Idaho in the month of April. This year, three competitions will be held in three sites, each divided into morning and afternoon sessions. Each includes limited contact with the test course and will use Internet based interactions to include additional team members and provide viewing opportunities for other teams. All participants compete in seven categories and are recognized for their efforts and persistence. The categories include; 1) hill climb, 2) blind driving, 3) speed test, 4) rock collection, 5) weight, 6) poster 7) notebook presentation, and 8) formal team presentation. Room set up and design have been created to manage social distancing for the hill climb, blind driving, speed test, and rock collection (see Figure 1). Posters, notebook presentations, and formal team presentations will be delivered using Internet based platforms such as Zoom (refer to Table 1). All students will be asked to sign a media release, spaces for those who do not wish to participate in photos or videos will be identified as "off camera areas". Rover weights will be recorded by the mentor and reported to the program lead.

Figure 1

Sample Room Layout for in-person events



PARTICIPANTS

For the Idaho TECH Mars Rover challenge, participants will include students in grades four through six enrolled in the NASA Mars Rover Challenge. Diversity of participation will be increased by recruiting teams with students from underrepresented populations in STEM such as, students with disabilities, students from rural and remote areas, and students who are from lower-socioeconomic backgrounds. It is anticipated that *n* = 300 students will participate across all competitions.

DATA COLLECTION

We recommend collecting data through self-study, case study design, and survey data, there is no method that is appropriate for all contexts and situations. The Idaho TECH program will collect data using a survey to assess multiple social, psychological and educational factors influencing the STEM-related academic and career choice will be used to gather data from participating students. Data gathered will assess the effectiveness of the multi-modal competition across several factors. The factors assessed will include interest in STEM, knowledge of STEM and STEM careers, self-efficacy, outcome expectations, perceived behavior, attitudes/beliefs, choice-intentions, perceived feasibility, complexity, and system support related to STEM education and careers. Additionally, data will be collected on the use of the virtual platforms, readiness to utilize 21st century tools (i.e. Zoom, Google+ documents, Google Classroom, Internet presentations, virtual product development) and their perceived improvement on the use of the tools as well as how the use potentially prepared the students to be ready for 21st century interactions in STEM careers. A copy of the survey may be requested by contacting the authors as the survey can be adapted for many STEM informal learning events.

Additionally, qualitative data will be collected through interviews to develop a case study design will be conducted to describe and understand the student perceptions of the experiences behind the program. The researchers seek to describe in depth the relationship between the social, emotional, and personal growth as well as self-perceptions of belief in self and interest in STEM as a result of the Idaho TECH competition. A case study design was chosen to provide concrete, contextual, in-depth knowledge about the collective shared experiences through the multi-modal competition.

FUTURE IMPLICATIONS

While there is no protocol that is appropriate for all contexts and situations, the suggested program design and implementation, utilizing multi-modal components, serve as a starting place for informal learning events that can bridge geospatial barriers and continue to support students in STEM experiences during, or in the aftermath of a natural disaster. Likewise, there are other implications to consider when shifting to, or including multi-modal components for an informal learning experience.

First, a multi-modal event can eliminate or reduce physical interactions, travel, and benefit students in more rural and remote areas. As such, informal learning becomes more flexible and equitable for students, teachers, mentors, and community members. An EDC can now leverage the expertise from individuals who may serve as speakers who are in a STEM field such as a NASA engineer. Additionally, geographically remote and rural teams have the opportunity to meet and interact with others not only from their region, but also, across the state and potentially the global community. Such contexts offer a wealth of learning experiences for students, teachers, mentors, and community members alike, that may otherwise be impossible in traditional, face-to-face, more urban contexts.

Next, while a direct response to current events (COVID-19), the implementation of a multi-modal competition may have efficacy beyond our current circumstances. For example, many opportunities for K-12 online education exist, while most informal learning opportunities require all face-to-face components. Lessons learned as a result of the current COVID-19 pandemic can assist those who traditionally serve students through informal learning opportunities. Largely, it is important to realize the impact that a lack of social engagement, interactions with other students, and missed opportunities to enhance traditional education might have. Understanding how to design, develop, and deliver better ways to address the continued needs of K-12 children may hold the potential to reach and connect students on a national level and ultimately impact the STEM pipeline.

FUTURE RESEARCH

The program design and implementation can offer a level of flexibility to benefit students by providing them increased opportunities to collaborate with others and be on a team across multiple districts. Further, we recommend running the initial implementation of an informal learning opportunity as a pilot program to understand and reflect on program specific needs. The impact on students missed experiences through informal learning has been profound and needs further attention to better support the STEM pipeline.

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