AC 2011-1229: USING SPACE-INSPIRED EDUCATION TOOLS TO ENHANCE STEM LEARNING IN RURAL COMMUNITIES

Allison Anderson, Massachusetts Institute of Technology

Allison is a PhD student at the Massachusetts Institute of Technology. She received her undergraduate degree from the University of Southern California in Astronautics Engineering, and two masters degrees from the Massachusetts Institute of Technology in the Department of Aeronautics and Astronautics and the Technology Policy Program.

Guillermo Luis Trotti, Trotti & Asssociates, Inc.

Guillermo Trotti

Gui Trotti is an internationally recognized architect and industrial designer. His design thesis entitled ”Counterpoint: A Lunar Colony” is part of the Smithsonian’s Air and Space Museum permanent collection. Mr. Trotti has over 25 years of professional and academic experience. He has taught Space Architecture design at the College of Architecture at the University of Houston and Industrial Design courses for extreme environments at the Rhode Island School of Design. He is currently on the Board of Directors of Studio Arts Center International (SACI) in Florence, Italy. As founder and director of several space enterprises during his career he has been involved in the design of the International Space Station, many Space vehicles, Lunar and Mars surface Systems. As founder and president of two architecture / industrial design firms in Houston and Boston he has been responsible for the designed and construction of hospitality, mixed use, residential, industrial, and sustainable architectural projects as well as educational, commercial and military products, and space systems. Mr. Trotti is a co-founder and was the Associate Director of the Sasakawa International Center for Space Architecture (SICSA) at the University of Houston where he taught graduate courses in Experimental Architecture Design. He has extensive design and research experience in modular and inflatable structures, construction methods in Space, and space mission architectures. His design studio won the NSF/AIA National Competition for a new South Pole Station, utilizing many parallels and lessons learned from the design of Lunar and Mars bases. His current research involves design of self-sustaining environments for Earth, space, and sea. He is a passionate sailor, and circumnavigated spaceship Earth on his sailboat, Galatea.

He has a Masters of Architecture from Rice University, Houston, Texas. 1976. His thesis was entitled ”Rice University Space Station Study: An Investigation of the Needs and the Design of an Orbiting Space Station with Growth Capabilities” funded by a NASA fellowship.

His Bachelor of Architecture is from the University of Houston, Houston, Texas. 1974. His thesis entitled ”Counterpoint: A Lunar Colony” was selected as part of the Smithsonian’s Air and Space Museum permanent collection. The research was funded by The Houston Endowment and technically supported by NASA HQ and JSC.

Suzanne Marie Wilcox, ExplorationWorks: an Interactive Museum of Science and Culture
Dr. Elizabeth Perry Gundersen, ExplorationWorks Museum of Science and Culture, Helena MT

Retired pediatrician, currrenntly Science and Robotics Educator at ExplorationWorks Museum of Science and Culture, Helena MT

Dr. Dava J. Newman, Massachusetts Institute of Technology

Using Space-Inspired Education Tools to Enhance STEM Learning in Rural Communities

Introduction

As recently as 50 years ago, the outlook for rural education in the United States was not good. Many schools were underfunded, understaffed, under-enrolled, and lacked the resources and facilities to provide an education equivalent to their urban counterparts[1]. Informal education primarily came from utility based exposure directed toward a largely agrarian economy. Leisure opportunities for informal education, often enjoyed in urban environments, was sparser[2]. With improved communication, transportation, and focus on rural development, formal education has improved, yet not at the same level of more urban school systems[2, 3]. There is still a gap between the resources and courses available to rural students, and an exodus of more highly skilled workers toward urban environments[2-4]. Approximately one fifth of public school students in the United States live in rural communities, with about one in every three of those students living at or near the poverty line. This statistic is disproportionately shared by minorities[2, 5]. However, there are many institutions and organizations focused on improving quality and access to education for rural students, such as the Rural School and Community Trust, The Journal of Research in Rural Education, American Association for State and Local History, and the National Center for Research in Rural Education. The result has been a record decrease of rural adults without a high school education[3], roughly equivalent student performance on standardized tests, and improved teacher salaries and qualifications[5].

Informal education, or education that occurs outside the classroom in museums, aquariums, parks, or television programming to name a few, has not gained the same momentum as formalized education. The primary focus of rural informal education has been on library development[6], agrarian or job-based exposure to the natural environment[3], and museums dedicated to local issues and history[7]. These efforts have certainly improved student access to informal education, however rural students are not exposed to the same breadth of topics as urban students. Local and regional museums provide a valuable service to their visitors by keeping salient history, geology, and ecology accessible to those for whom it is most relevant, thereby preserving local culture[7, 8]. However, with small budgets, many of these museums have static exhibits. Developing new exhibits is expensive and requires large personnel commitments. This can be a challenge since many rural museums rely on volunteers for operations [7, 9]. Topics without a regional focus, such as space exploration, are not often covered in local museums. This is particularly true for science, technology, engineering, and math, or STEM subjects.

The value of informal education programs focused on STEM is undeniable. Informal education could do a great deal to supplement school STEM programs, which often lag when compared to urban school systems. For example, urban and suburban school systems offer 3-4 more math courses on average for high school students. Decreased access to math courses has been correlated with poorer performance on standardized tests, with implications for higher education opportunities[10]. The need for rural students to develop STEM skills is increasingly becoming more important as rural jobs transition away from agrarian, service, mining, and resource based jobs and move toward technical jobs[3]. Students without these skills will stand at a disadvantage compared to students from urban and suburban environments. Informal education has been shown by many to provide unique learning experiences where students can explore and develop or reinforce STEM interests[8, 11-16].

Additionally, there has been little research on how to address the needs of rural communities through informal education. In the past 10 years, the Journal of Research in Rural Education has not published an article dealing solely with informal education[17]. On the other hand, there is a wealth of literature on informal education and museum studies, even focusing on specialized groups such as special needs or urban at-risk students. There is a dearth of literature focusing specifically on rural student needs. This work hopes to bridge the gap between literature on rural needs and informal education by developing a design philosophy catering specifically to rural education.

Project Philosophy

This design philosophy was created as part of *Montana's Big Sky Space Education: The NASA ExplorationSpace at ExplorationWorks*. ExplorationWorks is a science and culture center located in Helena, Montana. Montana is among the nation's most rural states and in 2000 was designated as one of the top 10 states needed critical rural education policy reform by the Rural School and Community Trust[2]. About 75% of the state's schools are located in rural communities[18]. The museum's mission includes reaching not only those students in its immediate vicinity, but also those students statewide who may not have access to a comparable museum experience. ExplorationWorks is categorized by the Association of Science-Technology Centers as very small, since it has 6,000 feet of interior space dedicated to exhibits[9]. ExplorationWorks is one of only three museums dedicated to STEM subjects in Montana, the other two being Museum of the Rockies in Bozeman and spectrUM in Missoula.

To show how the design philosophy was implemented, this work evaluates an exhibit centered on space exploration and space science. Through the use of its exciting missions, unique facilities, inspiring personnel, and vast scientific discoveries, National Aeronautics and Space Administration (NASA) inspires students through its many programs available online, in museums, and in proximity to one of its 10 education centers[19, 20]. NASA centers serve as the epicenter for direct involvement with many of NASA's education programs. However, for the many rural students who do not live in close proximity to one of NASA's centers, the agency's mission can seem remote or irrelevant. NASA has established three learning objectives it hopes to achieve with its education programs, the third of which is to promote STEM literacy and awareness of NASA's mission among the general public through the use of informal education [21]. This work serves to realize this objective.

The exhibits for *Montana's Big Sky Space Education* were developed to fit into the content categories defined by the framework presented in *Framework for Space-Inspired Informal*

Education Exhibits with the intent of highlighting the strengths of NASA's Exploration Systems Mission Directorate[22]. To implement the programs, deliberate choices about design and education philosophy were made. The issues which arose from developing exhibits and thinking about the museum's constituents led the authors to fit their work into the context of the National Research Council's informal education framework for learning in informal environments.

The National Research Council (NRC) in *Learning Science in Informal Environments*[16] builds upon the cognitive models presented by Falk and Dierking in *The Museum Experience*[11] and *Learning From Museums*[12] to describe the processes by which people learn in informal environments. There are three components to the model:

1. Person - the cognitive theory of how people learn, including emotional responses
2. Place - the physical location in which learning occurs and the artifacts by which learners interact
3. Cultural - how concepts relate to a person's interactions with the world and society, making the topic relevant in his or her life[16].

Addressing these categories, and their interaction, is intended to lead to improved educational outcomes. The model identifies six outcomes which are called "strands", forming the goals educators seek when using informal education. The strands are summarized in Table 1, but are fully described in *Learning Science in Informal Environments.*

Although the exhibits were not designed using the NRC's model, the exhibit design philosophy the authors used was mapped to the NRC's model to assess the model's effectiveness for rural informal education. The NRC model frames the most salient issues we found in developing our projects for rural communities. Figure 1 shows how the model is adapted for rural environments. The issues are:

*Conten*t - The content should be interesting, inspiring excitement and curiosity. It should draw upon and reinforce previous knowledge.

Table 1. The six strands that form the desirable outcomes from informal education learning.[16]

Strands of Informal Learning	
Strand 1	Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world
Strand 2	Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
Strand 3	Manipulate test, explore, predict, question, observe, and make sense of the natural and physical world.
Strand 4	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena
Strand 5	Participate in scientific activities and learning practices with others, using scientific language and tools.
Strand 6	Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

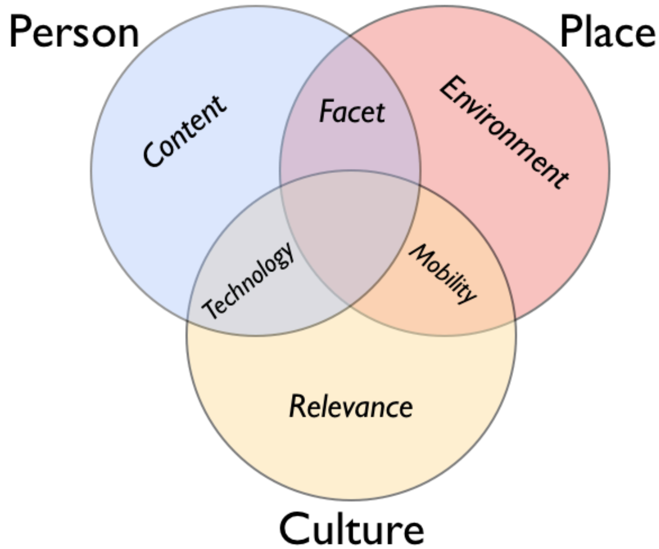

Figure 1. Framework for informal learning from *Learning Science in Informal Environments* [16] adapted to address learning issues for rural environments. Image adapted from [12].

Facet - Include physical, hands on, and virtual elements to the exhibit. This not only provides many avenues for engagement on a personal level, but also allows dissemination to take on many forms, changing the physical context.
Environment - Design the content to fit logically in many educational environments, especially the home, school, and classroom or structured learning scenario. This allows the concepts to be reinforced in many locations, where the physical environment changes the way content is absorbed.
Mobility - Exhibit pieces need to be easily assembled, transported, and fit into small spaces without having many on-site requirements (such as apparatus to hang items from the ceiling, abundance of electrical outlets, internet access, etc). This considers how physical environments are structured, as well as how the exhibit fits into a community's culture for learning.
Relevance - It should draw the information into the user's community, making connections to both daily life and broader society. Evidence of this can be seen in how students engage in the content with their friends, families, and teachers.
Technology - Should promote technologically skilled users, leading to technically skilled workers. It needs to be sensitive to access within the community to the internet, availability of technical hardware such as computers, and user's familiarity with technology.

The Knowledge Station (KS) exhibit was developed for *Montana's Big Sky Space Education* and is analyzed as an example of how these six issues are incorporated into museum exhibit design for rural communities. The KS portal, shown in Figure 2, uses human and robotic space

Figure 2. The Knowledge Station exhibit. A) The exhibit portal with panels behind. B) View of the floor and Knowledge Station screen. C) Screenshot of the software program.

exploration explained at the middle school level to teach students about the complicated issues associated with space exploration. The core of the exhibit is an interactive software program containing content about daily life and exercise aboard the International Space Station (ISS), extravehicular activity and spacesuit design required for Mars exploration, and the use of human-robotic cooperation to study Jupiter's icy moon Europa. Each of these space destinations contains four content modules, one of which includes an interactive element. Users interact with the program using a motion capture camera that detects body movement to manipulate images on the screen, such as moving an astronaut, showing space exercise, or moving a robotic arm. Each section also contains links to additional websites where users can learn more about a topic if they are further interested. The program may be installed on Windows and Macintosh operating systems, without the motion capture capability on Macintosh computers. Additionally, the exhibit uses four informative panels which reinforce and go deeper into some of the KS program content.

*Conten*t - The KS software program includes multiple aspects of space exploration and draws upon fields such as biology, physiology, robotics, engineering, design, and planetary science. Several of these fields are areas in which students will have had some exposure.

Facet - The program has both a physical component (portal and the panels) and virtual component (software program), as seen in Figure 2. The program engages students who learn by listening, watching video, reading text, or physically interacting program through the motion capture.

Environment - The program was implemented in a museum, homes, and in a structured educational setting. The exhibit was open to the museum visitors over summer 2010. Five students were given the program to use in their home for the purposes of this study.

The program was also used to supplement classroom instruction during summer camps given in the museum. This format is also being used for field trip visits to the museum.
Mobility - The exhibit can be distributed in three forms. The first is the full exhibit set up. The KS portal fits into a small moving vehicle and the panels roll up and are lightweight. The second configuration includes the panels with the software program set up on computers, rather than the portal. This alleviates some of the space and logistical issues, while still giving a museum-like experience. Finally, the program can be distributed as the software program only. The exhibit is free standing and requires two electrical outlets. The size of the exhibit allows it to be set up in many locations, such as a school classroom, church basement, or library reading area.
Relevance - The program includes a module specifically devoted to societal motivation for exploration. It also discusses issues students may find relevant to their lives, like exercise and daily life aboard the ISS.
Technology - The program encourages student to use computers. It was also designed to look and feel futuristic to inspire interest in technology. The only functionality that is internet dependent is imbedded links to additional websites.

Research Methods

Does the KS lead to improvement in the six educational strands identified in theNRC model? Data from a qualitative study with both rural and urban Montana students using the KS was used to address this question. The KS was evaluated in two modes, the in-museum set up and the in-home set up. Data for the study was collected both through direct observation and interviewing participants. Both deliberate and convenience sampling techniques were used to find subjects based upon their academic age level, geographic location, and desire to participate in the study. The KS is targeted toward middle school level learners, therefore only students who were in or entering the 5th-9th grades were selected.

To study students using the KS in their home, five students from rural communities were selected. For the purpose of this study, rural was taken to mean any student not living within 15 miles of Helena, Missoula, Billings, Great Falls, or Bozeman, the five largest cities in Montana. Figure 3 shows a map of the approximate geographic distribution of rural study participants. Desired attributes for subjects included diversity of the type of education, ethnicity, and considerations of gender. Students covered a broad range of educational experiences, such as attending K-8th grade schools, being home schooled, or attending middle school. Each of the subjects was Caucasian despite efforts to include minority and Native American students. Finally, the study attempted to equalize the number of male and female students. Three students were female and two were male.

Student participants in the in-museum environment were additionally selected based upon their proximity to Helena, giving them access to ExplorationWorks. Only students living within 15 miles of Helena were selected. In total, 14 students participated in the study, 5 male and 9 female.

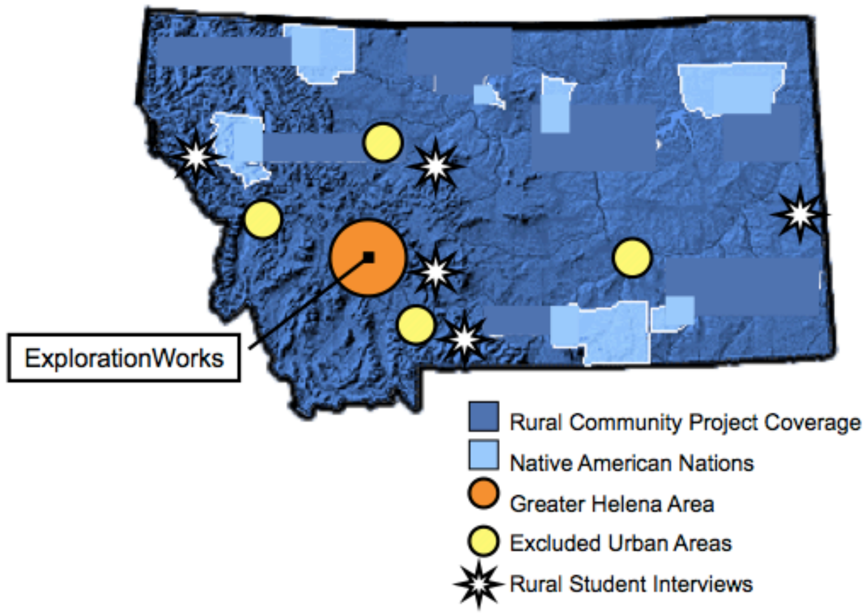

Figure 3. Montana regions of interest. The state of Montana is rural, exceptions denoted by small circles. The stars indicate interviews conducted with students in rural communities and the large circle centered around ExplorationWorks is the region surrounding Helena considered for the in-museum portion of this study. Native American Nations are highlighted since they are regions of interest for the grant under which this effort was funded. Image adapted from [24].

All interviews were semi-structured, but the rural students went through a more in-depth interview protocol. This was done to more fully understand how changing the environment in which the program was implemented would affect the educational experience. This is a salient question since the KS is primarily intended for use in a museum but is being used to reach rural students as well. For rural students, an initial interview was conducted to determine the student's opinion of STEM subjects, learn how and why he or she thinks STEM is important or unimportant, and to understand how he or she normally engages in informal education. It also served as a baseline from which to gauge how much the student learned from exposure to the KS. A secondary interview was conducted between 1.5 - 3 weeks after the KS was installed in the student's home. The objective of the second interview was to determine how the student interacted with the KS, what he or she thought about it, what he or she learned from it, what could be improved and what was successful in the program, and whether or not what he or she thinks about NASA and STEM has changed. This interview was conducted in person for the first 3 subjects, but over the phone for the final two since face-to-face communication did not give substantial additional information. In addition to the student interviews, an interview was conducted with the student's guardian. The purpose of this interview was to determine how the guardian influences their child's learning, what he or she thinks about the Knowledge Station, and what he or she thinks about informal education. Each of the 15 interviews lasted between 15 and 30 minutes, with the average interview time approximately 25 minutes.

Museum participants were tracked as they explored the museum, and then observed while they engaged in using the KS. Students were observed for the interest and engagement level. When the student began using the KS, additional observational data was taken, including any comments the subject made, level of engagement, and confusion or hesitation. After the student was finished, follow up questions, including questions to assess how much information the student absorbed and how he or she felt about the program, were recorded. In some instances, time limited the student's ability to see the rest of the museum and only data collected on interaction with the KS was recorded. Each of these interviews lasted between 15 and 40 minutes with the average time spent on the KS and interview being approximately 20 minutes. Additionally, survey data was taken to understand how all visitors felt the KS fit into their overall museum experience. This information was not included, however, since there were few responses from middle school students and the survey contained minimal information about the KS.

Data Analysis

The interviews were transcribed and coded based on phrases, attitudes, and references that the subject made. Examples of codes include *Performs experiments in science class, Program terminology was difficult, Student participates in Gifted program,* and *Enjoys interactive module*. In total, 156 codes were used. Each code may have been said once by an individual, or referred to several times by multiple subjects.

From these initial codes, the data was binned into larger themes. Some of the codes fit into multiple themes. In total, 10 themes were used: NASA, Space, Classroom, Self Directed Learning (including at home learning), Environment, Access, Extracurricular and Event Based Informal Education, KS, Learning, and Education Attitude. The themes were used to organize the data so specific information relating to the 6 strands could be sifted out and analyzed. For example, when understanding how the KS program influenced *Strand 6 - Identifying with scientific enterprise*, data within the KS, Education Attitude, Space, and NASA themes were considered.

Using multiple interviews contributed to the study's validity. The interview with the guardian was used to triangularize the data, and in a few instances, helped to resolve conflicting information. The guardians also gave additional information about access to opportunities and the home learning environment that could not have been gathered otherwise. Additionally, the interview data were compared to field notes to check whether the coded information accurately reflected the tone of the interview.

The lack of ethnic diversity is a limitation to this study. An unintentional bias came from subject's guardians having an affiliation with their formal education system. This is not wholly surprising since for many rural areas, the largest employer is the school system[2]. Four of the five in-home use students had parents affiliated with the education system and it is not known how many in-museum students had parents involved in education.

Results

The following evidence from the interviews demonstrates the KS's ability to contribute to several of the NRC learning strands.

Strand 1 - Develop interest: The KS's many facets were important to generate interest and engagement. There was great variability in the portions of the program students most enjoyed and interacted with. Students who preferred the interactive portions of the program demonstrated the least prior knowledge of space. However, these modules provided the hook to get the student to participate and become interested. A handful of students enjoyed the text content and websites the most. Typically, those students were among the oldest and demonstrated a deeper understanding of science in the pre-exposure interviews. One facet of the KS exhibit that did not generate the intended interest for the in-museum students were the panels that accompanied the exhibit - only one student read them. Without engaging panels, the exhibit modes using the panels and either the KS portal or normal computers will be less effective than anticipated. These findings confirm that it is necessary to provide a broad range of avenues to explore content to accommodate many different users[12], and that all aspects of the program should be properly designed to maximize interest and learning.

Several students commented on the technology used for the program, such as the sophisticated graphics. Most students felt the program was unique and that it was most akin to video games. In some cases this generated confusion, however, since some students felt that the program should have been more game-like. Additionally, there were several usability issues documented in our previous work[23] which detracted from the interest in the program.

Strands 2 - Understand Scientific Knowledge: The evaluation showed that the KS program changed 80% of the in-home and 57% of the in-museum student's understanding of NASA's mission and issues associated with space exploration. All but one student held common misconceptions about NASA prior to using the program. It was common for students not to know what NASA was or what kinds of activities it does. Many students also seemed to feel that walking on the Moon was a common role of an astronaut or did not know about the ISS. After using the program, however, students were able to either recall specific information from the program or make extrapolations from KS content to their own lives or community. Examples were students who hypothesized about the types of jobs NASA employees performed, discussed spacesuit design and the need for mobility, discussed astronauts exercise on the ISS and why exercise is important for everyone, and why robots are needed for space exploration. The degree to which students retained this information varied, but almost two thirds of the students involved in the study retained and could apply concepts they were unfamiliar with prior to using the KS.

Strand 3 - Engage in Scientific Reasoning: Evidence in this strand was limited since the type of content required to show learning in this area, such as designing exploration missions or identifying ways to improve technologies, was not incorporated into the KS content.

Strand 4 - Reflecting on STEM: Evidence to this outcome was limited, but there was evidence that some students developed a deeper understanding of the nature of engineering and the need for advanced technology. One student was able to discuss how spacesuits being used in new environments (here, exploring mars) generate new requirements, and therefore new designs. The subject was not pressed further to identify other arenas where this may also be true. Another student was able to discuss why technology was so important for space exploration and the limitations of humans in harsh environments. This result was limited to in-home use students where more in-depth analysis of the students' interaction with the program was conducted.

Strand 5 - Engaging in scientific practice: We were not able to identify any outcomes related to this strand due to the short timeframe in which the study operated.

Strand 6 - Identifying with scientific enterprise: Every student asked was able to see ways in which STEM was applicable in their lives prior to using the program. Examples cited were in teaching things to siblings, helping parents on the farm, or understanding doctor's visits. Most students liked learning, and although not true of all students participating in the study, most liked science and many liked math. It was not clear, however, that students felt that space exploration was relevant to their daily lives prior to using the program.

After using the KS program, students were able to identify with the scientific enterprise of space exploration. This is evidenced by students' desire to share information from the program with friends and family. Family members were the primary people students shared their KS experience with. For several students, this meant showing a sibling or guardian how to use the program. Only one in-home use student showed the program to his friend. Two of the in-museum subjects attended the museum as friends and two attended as siblings. Students were also able to see how NASA contributes more broadly to society. Three of the five students interviewed for in-home use felt that the greatest contribution NASA makes to society is playing a role in identifying and solving scientific mysteries. Students felt that NASA does this by using telescopes, rovers or robots, sending astronauts into space, and building space hardware. One student was able to discuss the pro's and con's of NASA's programs given the tenuous nature of the agency's funding. This student believed NASA was important to our society and that it was unfortunate that NASA's programs were going through many changes. Students generally felt that NASA was valuable and could see how space had made an impact in their own lives.

Discussion

The results show that three of the strands were clearly addressed by using the KS, two of which (1 and 6) are strands included in the model to incorporate unique aspects of informal education [16]. This evidence reveals how focusing on the issues of content, facet, environment, relevance, and technology contributed to learning outcomes. The variety of content related to space exploration but stemming from many different fields allowed many students to find interest in the program. Similarly, the multi-faceted ways to engage the program accommodated many users. In both environments studied, the program generated interest and excitement. The program successfully utilized technology, and despite usability issues, students felt that they were participating in a high-technology project. Students demonstrated the program's relevance by sharing the information with those around them and relating it to their own lives.

There was no evidence to support learning in strands 3 and 5, and there was limited evidence to support strand 4. The study was either limited in its duration or design in order to measure these strands. Future studies should focus specifically on addressing these strands to determine whether or not similar rural studies can show evidence of these strands. Additionally, future studies could perform a similar analysis, including students from more diverse backgrounds, even expanding into different age groups.

Mobility as a design issue is not adequately studied in this work. Although the KS was designed with mobility in mind, it has yet to travel to other museums where this can be more fully assessed. One aspect contributing to mobility, the panels, however, were shown to be ineffective in the museum setting. This is a limitation to the exhibit design that should be addressed prior to distributing the exhibit. It is not known, however, whether or not the panels in their current form will be more successful in other environments since they will be one of the primary ways to generate a museum-like feel when placed in common community spaces like a library or classroom.

Conclusion

This project is not the first to incorporate the 6 principles into exhibit design, nor will it be the last. Excellent examples of how projects using the concepts were implemented successfully include NASA's Traveling Trunks and the Challenger Learning Center of Alaska's traveling museum efforts. The contribution of this work is to adapt the educational model presented by the NRC as a best practice for developing projects in rural environments. We also highlight the need for additional research in rural informal education, since research in this field has been focused on formal education. Although it is impossible to generalize these results to all rural communities, since rural communities vary by almost every factor, this broad model addresses some of the systemic issues associated with rural areas, including restricted access to educational opportunities, diversity in access to technology, fewer spaces dedicated to informal education, and the need for increasing STEM skills and interest.

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