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CONTEXTUALIZING TECHNOLOGY IN THE CLASSROOM VIA REMOTE ACCESS: USING SPACE EXPLORATION THEMES AND SCANNING ELECTRON MICROSCOPY AS TOOLS TO PROMOTE ENGAGEMENT IN GEOLOGY/CHEMISTRY EXPERIMENTS

Brandon Rodriguez[1], Veronica Jaramillo[2], Vanessa Wolf[2], Esteban Bautista[2], Jennifer Portillo[2], Alexandra Brouke[2], Ashley Min[2], Andrea Melendez[2], Joseph Amann[3], Abdon Pena-Francesch[4], Jared Ashcroft[2]

[1]EPDC at the NASA Jet Propulsion Laboratory (United States)

[2]Pasadena City College (United States)

[3]Seattle Colleges (United States)

[4]Penn State University (United States)

brandon.rodriguez@jpl.nasa.gov, VIJARAMILLO@pasadena.edu, vwolf@go.pasadena.edu, ebautista.elac@gmail.com, jennifer.portillo.387@my.csun.edu, abrouke@go.pasadena.edu, ashleymin97@yahoo.com, amelendez12@go.pasadena.edu, Joseph.Amann@seattlecolleges.edu, abdon@psu.edu, JMASHCROFT@pasadena.edu

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Abstract

A multidisciplinary science experiment was performed in K-12 classrooms focusing on the interconnection between technology with geology and chemistry. The engagement and passion for science of over eight hundred students across twenty-one classrooms, utilizing a combination of hands-on activities using relationships between Earth and space rock studies, followed by a remote access session wherein students remotely employed the use of a scanning electron microscope (SEM) and energy-dispersive spectroscopy (EDS) to validate their findings was investigated. Participants represent predominantly low-income minority communities, with little exposure to the themes and equipment used, despite being freely available resources. Students indicated greatly increased interest in scientific practices and careers, as well as a better grasp of the content as a result of the lab and remote access coupling format.

Keywords – Remote access, Technology, Engagement, Geology, Chemistry.

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1. Introduction

The availability and creativeness of technology for the classroom has greatly altered pedagogical practices of K-12 educators. Implementation of these practices has taken numerous forms, from use of clickers to capture real-time student response (MacArthur & Jones, 2008) to the popular online interactive lab simulations, such as the University of Colorado's PhET models (Moore, Chamberlain, Parson & Perkins 2014). Communities in academia and in the classroom have partnered to build vast networks of resources, such as nanoHUB's simulation tools, with over 1.4 million users (Madhavan et al., 2013) and the tools employed across the country through the Remotely Accessible Instruments in Nanotechnology (RAIN) community. The RAIN Network represents over sixteen university sites across the United States that provide free, live virtual imaging, wherein faculty of various research institutions can bridge the content of the classroom to the technology used at four-year university research settings. These virtual experiences are done in real time via an online scheduling tool (located at nano4me.org/remote access), which allow for students to remotely control lab equipment, lowering the barrier for communities without physical access to research institutions.

As such, the RAIN network represents a pedagogical opportunity, not simply a resource. As technology becomes more readily available in the classroom, educators must be critical that tablets do not simply replace paper, but that the technology is utilized to further engage students and promote exploration (Sandholtz, Ringstaff & Dwyer, 1997). Additionally, the pedagogical opportunity provided by remote access may help address the income, gender and ethnicity gap inherent to scientific communities. It has been well documented that an achievement gap exists for underrepresented groups in science careers (Else-Quest, Mineo & Higgins, 2013), and that the interest in pursuing these careers, particularly for Latinos and African Americans, falls off dramatically and continuously as students progress through middle and high school (Rodriguez, 2017). While this problem undoubtedly is the result of numerous factors, such as the availability of scientific role models and professional qualifications of teachers (Archer, Osborne, DeWitt, Dillon, Wong & Willis, 2013), it has also been demonstrated that access to technology has been a barrier to success (Shin, 2003). Specific to this study, the access to high-end microscopes has been shown to promote student understanding (Penn & Johnson, 2007), such as the use of a scanning electron microscope (SEM), as well as numerous other instruments that make up the RAIN Network. Naturally the use of such costly equipment will never be practical in a classroom, but the capability to operate these microscopes remotely and in real time has been shown to result in more engaged learning environments (Childers & Jones, 2015). In this work, however, the goal is not just to have students more engaged with technology, but to make the technology essential for the scientific process.

A multidisciplinary experiment applying basic experimental techniques in geology and chemistry was designed in tandem with remote access to an SEM with EDS capabilities to measure the impact of these learning environments in exclusively low-income school systems, across several grade levels. Our primary goal in the design and implementation of the lab were to transform student perception of science and provide connections beyond the classroom. The study included over 800 students, ranging from 4th-12th grade, in classrooms led by twenty-one different teachers. The majority of schools were under Title I designation. Students completed pre- and post-assessment surveys pertaining to their interest in science and socioeconomic factors. The impact of the activity was evaluated by student and teacher perception, as well as by the change in mindsets towards science indicated by the target groups of interest.

2. Experiment and methodology

2.1. Determining the Nature of "Martian Rocks"

In this activity, we used a narrative of space exploration with connection made to the study of physical and chemical properties of geological specimens on Earth with those that might be found on Mars (Figure 1). Students were given a brief content introduction to the upcoming Mars Sample Return (MSR) program being planned by NASA (NASA, 2017). This included a description of future technologies currently in development which are intended to send (return) Martian rock samples to Earth for analysis. The students were presented this background to connect the investigations of the hands-on lab with techniques to be used on Martian rock samples.

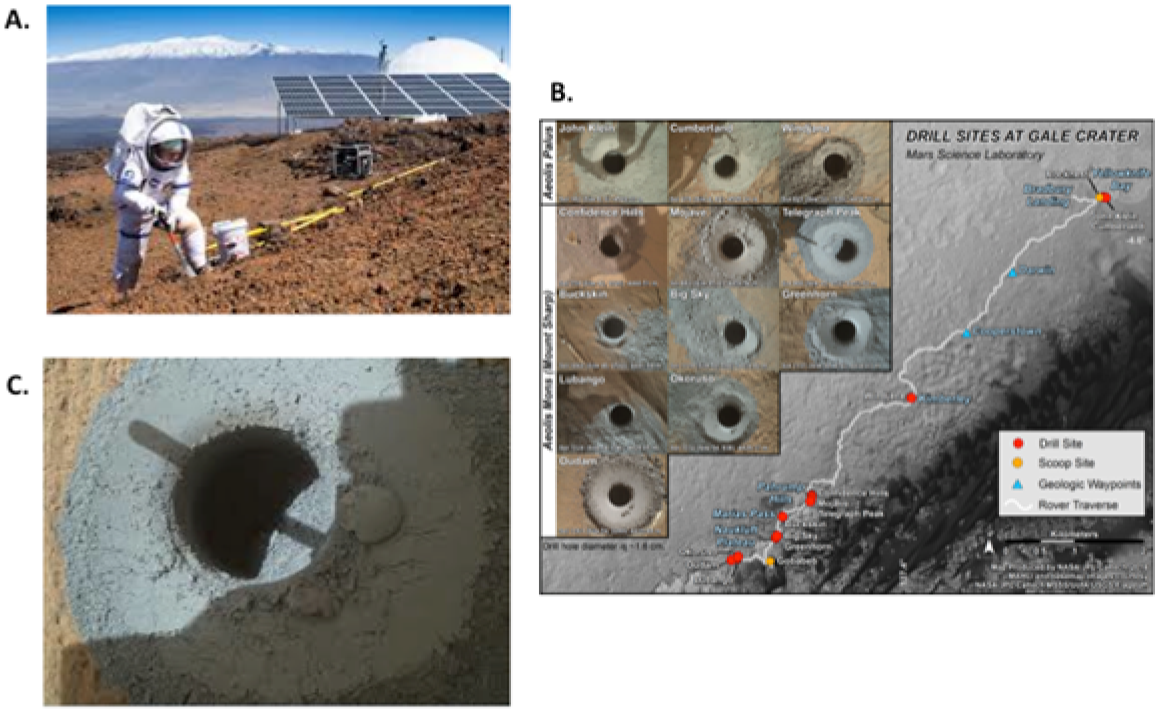


Figure 1. A) Conceptualization of an astronaut collecting minerals B) Mar's Drill Sites C) NASA's Mars rover Curiosity drilled sample hole at Telegraph Peak on Mars

Students were challenged to identify Mars and Earth from a series of pictures (Figure 2), demonstrating some geological similarities of Mars juxtaposed to those geological properties of Death Valley that were previously studied in their Earth Science unit.

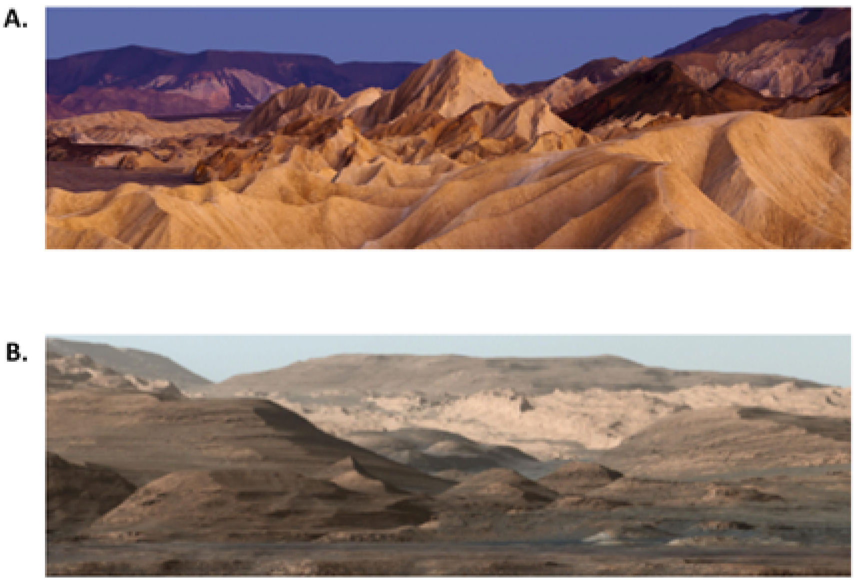


Figure 2. A) Geological formations of Death Valley. B) Geological formations on Mars

Chemical and physical characteristic analysis of an unknown “Martian rock”, a piece of limestone collected from Death Valley, was performed at various stations. Stations included determining physical properties, such as density, Mohs hardness and cleavage, as well as chemical properties like reactivity with acid (to form carbon dioxide, which demonstrates the presence of carbonate), and a flame ionization test (to determine the nature of the cation). Through the use of a reference sheet, student groups made a conclusion as to the nature of the rock.

Scaffolding experimental content was essential due to employing the experiment across a wide range of grade levels. For example, high school students need significantly less guidance on measuring density than do fifth graders, and the discussion around the flame ionization test can be altered from “determining the nature of the cation” to “matching the color of the flame against a series of knowns, presented on an anchor chart”. The investigation of the acid reactivity test may range from the simple observation of the formation of a gas to the writing of a balanced chemical equation.

As a culminating activity, students gathered for a collective fifth station, investigating the unknown sample via SEM with EDS elemental analysis. The same limestone sample had previously been sent to partnering RAIN labs. Dialing into a partnering lab through Teamviewer or Zoom remote access software, students operate a SEM with elemental analysis via the use of a classroom computer. Students are able to remotely control the instrument in its entirety from a classroom computer. In this work, students took turns operating the instrument on a teacher computer projected for the class to see. However, it is important to note that if multiple computers are available, multiple students could operate the instrument simultaneously. During the remote access session, students could simultaneously view the sample as a class on the projector and interact visually and verbally with the RAIN technician at the partner site. This empowered students to direct the investigation by asking the RAIN technician pertinent questions about the unknown. Eventually, EDS analysis gave the chemical composition of the unknown mineral, thus validating or refuting a students’ conclusions on mineral identity (Figure 3).

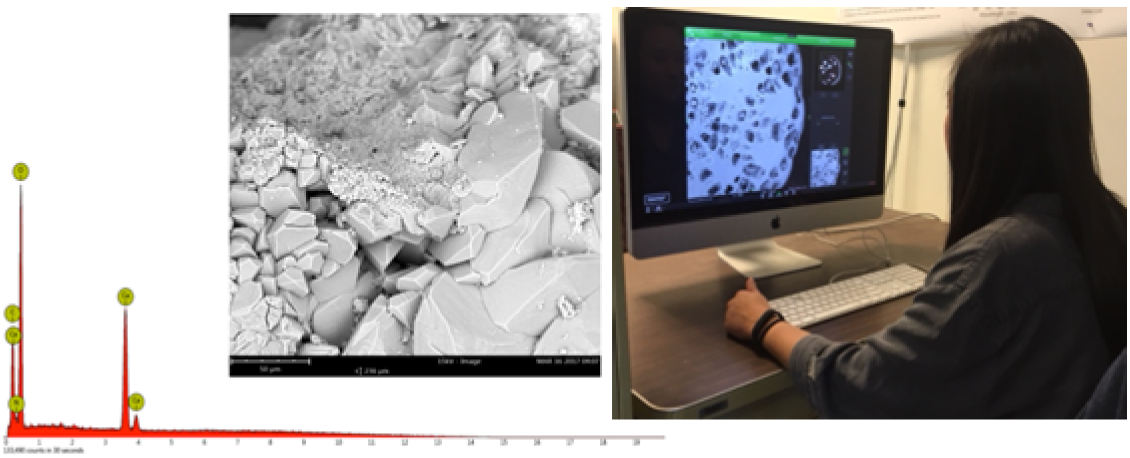


Figure 3. SEM image and EDS elemental analysis of limestone (calcium carbonate) sample

As is immediately evident, the blending of hands-on experiments with remote access is purposeful and essential to the scientific process; not just a flashy culmination of the lab.

2.2. Student Demographics and Pre-Assessment

Prior to the beginning of the activity, 852 students, ranging from grades 4 through 12 (Figure 4) took a pre-assessment. Students represent classes of 21 teachers, with a grade distribution of: three 4th grade classrooms, four 5th grade classrooms, three 6th grade classrooms, four 7th grade classrooms, one 8th grade classroom, three 9th grade classrooms, two 10th grade classrooms, and one mixed 11th-12th grade class. Participating students represented schools from all over the greater Los Angeles area, but were predominantly in Title I schools.

The representation by ethnicity (Figure 4) of student participants (N= 837) was 55% Latino/Hispanic, 21% White, and less than 10% Asian and African American. Participants consisted of roughly 53% female to 47% male students.

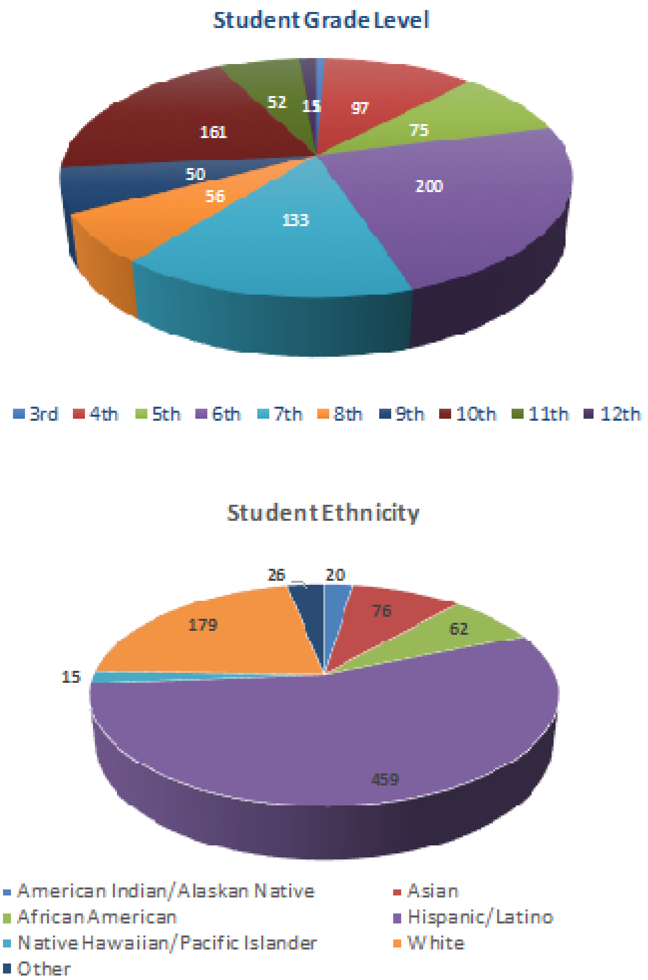
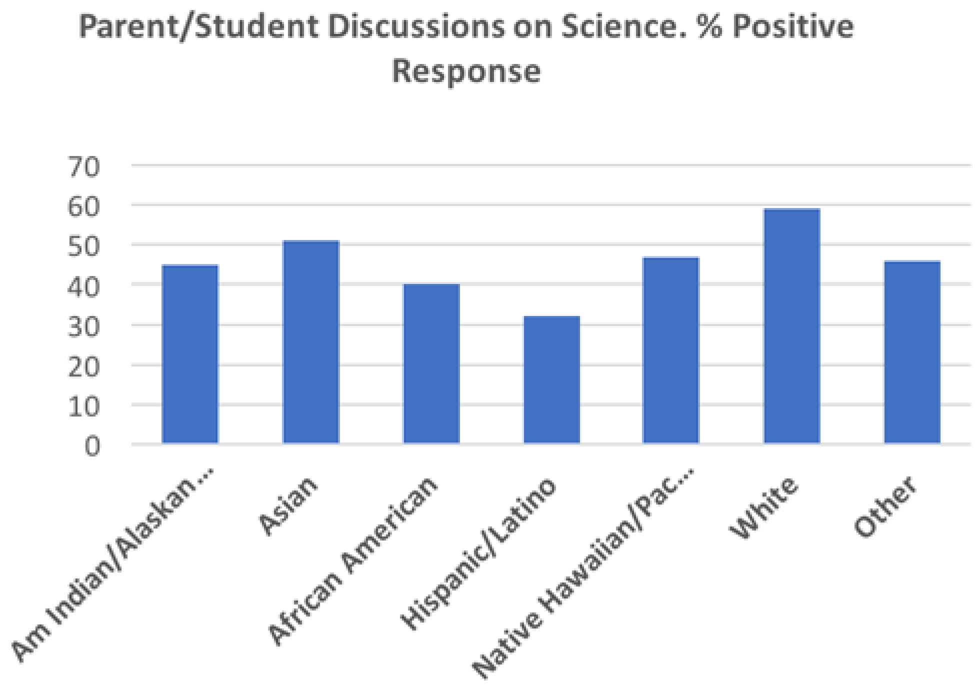


Figure 4. Student participant grade level and ethnicities

The pre-assessment survey queried parent's highest level of education, as well as whether or not parents spoke with them regarding their science coursework. The survey established that there was effectively a split into thirds as to indicating their parents: had a high school education or less, had completed college, or they were unaware as to their parents' education (N=822). Of these students, 41% indicated their parents did not speak about science courses with them, while 59% of the total students reported their parents did discuss science in the home. Further analysis of this data shows that Latino/Hispanic students, followed by African American students saw the lowest parental involvement with science discussion at home (Figure 5), with 32% and 40% indicating in the affirmative, respectively. This is compared to nearly 60% positive response for White students.

A similar breakdown by parental education level (Figure 5) shows a clear correlation between highest education and the probability that parents speak with students regarding science coursework. Parents with less than a high school degree had only 16% of students indicate science discussions at home, compared to 56% of students with parents having a college education or higher. Similarly, of the students who indicated low enjoyment in science (indicating a score of 1 or 2, N= 76), 79% of the students also noted that science coursework was not discussed at home with their parents. No statistically relevant trend was identified by gender.



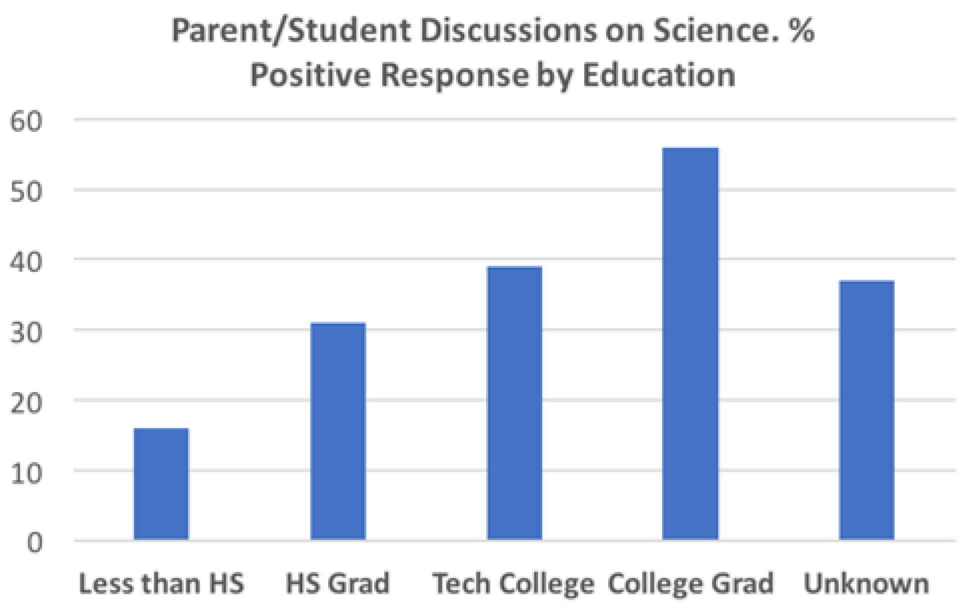


Figure 5. Parent involvement in science discussion in home

Interestingly, across all students, participants ranked a fairly high degree of enjoyment in science, with an average score of 3.9 out of 5. Both female and male students indicated a statistically similar enjoyment, and no observable trend was identified by ethnicity. That is to say, of the 3.9 enjoyment response, the lowest enjoyment average by ethnic group was 3.81 (Latino/Hispanic students) and the highest was 4.12

(Asian American students), but this spread fit within the standard deviation. Once combined with the variables described above, however, such as less educated Latino households, the average enjoyment of science drops significantly (see Figure 6).

Similar to what had been observed in longitudinal studies in other schools (Rodriguez, 2017), enjoyment of science appeared to drop over the range of grade levels surveyed once students moved from middle school to high school, although the low number of certain grade levels polled diminishes the statistical strength of this data.

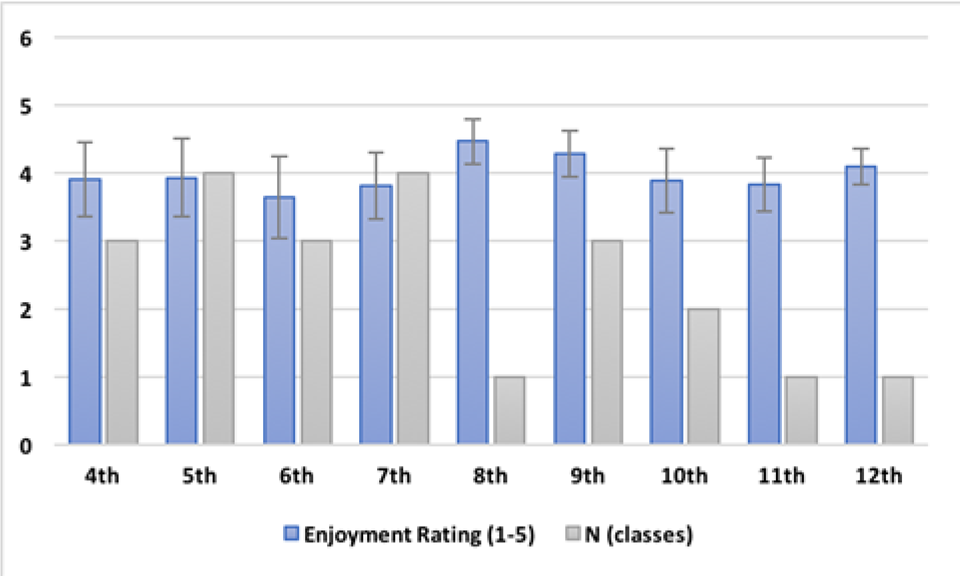


Figure 6. Student enjoyment of science pre-assessment

2.3. Post-assessment data and teacher feedback

In general, students were able to correctly identify the limestone mineral at the completion of the lab via their reference and data sheet. At this point, they completed a post assessment survey.

Students indicated that they enjoyed the use of the SEM imaging (4.27 out of 5) and that the combination lab/remote access format increased their enjoyment of science (4.12 out of 5), with a favorable response that they would like to have incorporation of remote access again in the future (4.3 out of 5). Overall, student perception of science was measured by pre-assessment question 9 versus post-assessment question 5, inquiring as to their enjoyment of science. The lab resulted in an increase of 10% favorability in their enjoyment of science, but this is better measured by quantifying the change of students who originally indicated an unfavorable perception of science. That is to say, while many 4- and 5-rating students will remain the same, we wanted to measure our impact by number of students who indicated an original disinterest in science. By tracking the students who originally rated themselves as 1- or 2- in their enjoyment of science (N=76), we observed an average post-assessment indicator of 4.24. This represents a 2.6-fold increase in enjoyment of science in the originally disinterested students.

Student comments also revealed an overall positive experience gained from the experiment regarding increased enthusiasm for science. While many students were simply excited to see "flame tests" or "use acid", many other students specifically cited the use of the SEM as having a positive impact on their view of scientific experimentation. Students also indicated that their favorite part was "how interactive the experience was" (N=22) or remarked on their excitement for "Being able to identify an unknown" (N= 12). Several other students indicated that the experience "made them want to be a geologist/chemist when (they) grew up" (N=6). A wide degree of favorable comments, ranging from "The coolest thing they have ever done", "I want to share my new knowledge", to "I really enjoyed this, even though I thought I didn't enjoy science" were conveyed.

Similarly, teachers were asked to complete a survey upon completion of the activity. Participating teachers overwhelmingly indicated that they had access to one computer in their classroom (100%) and had the ability to provide students computers for activities (96%) with internet available (100%), thus indicating that RAIN could be used easily in their classroom. When asked if students were engaged in the activity, teachers on average responded highly favorably (4.59 out of 5), indicating that the remote access component contributed to the engagement and student learning (4.44 out of 5). Likewise, teachers indicated they recommend the use of the RAIN network in their own classrooms and for their peers.

When asked what the biggest obstacles were when it came to student success in STEM, teachers rarely indicated limitations of technology in their schools (4%). Akin to our findings from student responses, 19% indicated that student home environment played a role (see Figure 7). However, the largest response indicated was real-life context (22%, N= 15). Thus, the areas we hoped to address with the RAIN/geology tandem lab, namely, transforming student perception of science and providing connections beyond the classroom, appear to be well addressed by both student and teachers' responses.

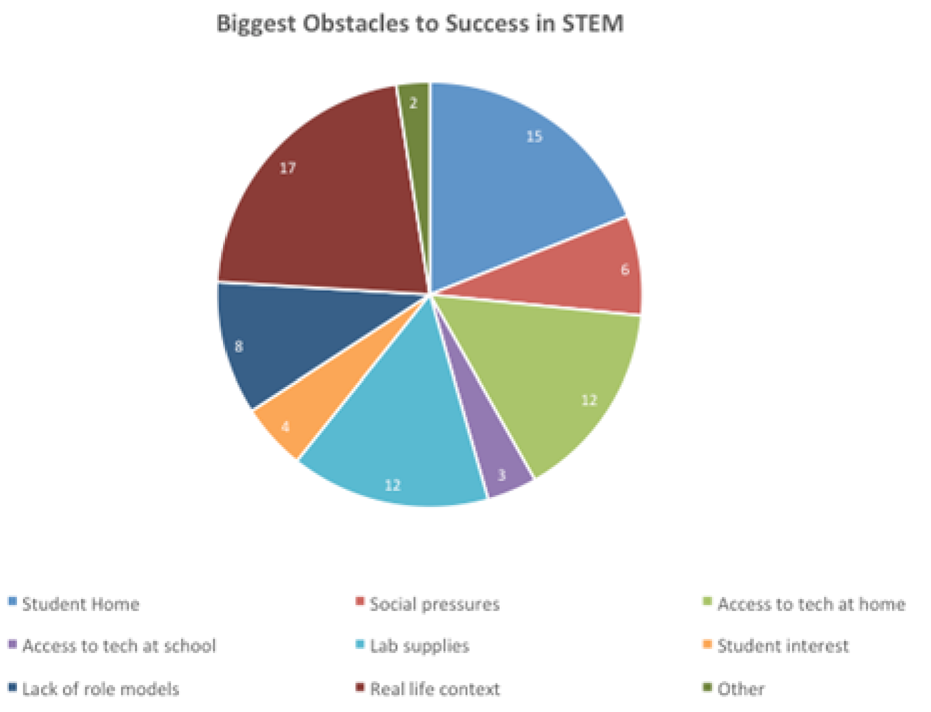


Figure 7. Obstacles for success in STEM in K-12

3. Conclusions

Utilizing free online NASA resources concurrently with freely available RAIN scheduling tools coupled with a hands-on interactive multidisciplinary experiment using geology/chemistry lab skills coupled with remote access SEM/EDS session, a 2.5-fold favorable increase in student perception of science coursework was observed. Moreover, the experiment specifically demonstrates efficacy in targeting students from underrepresented populations, namely low-income minority families without histories of higher education. The ability to 'bring real-life context' to the classroom is identified as the critical obstacle teachers face for these students, and by use of remote access, this context is brought in a meaningful, value-added way. Integrated with a content-narrative experiment, students have context that results in greater student engagement.

A sequence of problem-based learning experiences, implemented throughout an educational year, used simultaneously with remote access through the RAIN Network, can be tailored to Next Generation Science Standards (NGSS). The goal of NGSS is to enrich the science education of K-12 students and ultimately increase student success. NASA and RAIN's free educational resources are opportunities to engage low socioeconomic schools and to entice educators in these settings to implement more problem-based learning experiences in their classrooms. An integrated curriculum with these resources may indeed lead to a long-term increase in passion, equity, and success in students from groups who are currently underrepresented across science disciplines throughout our colleges and universities.

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Declaration of Conflicting Interests

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