Using Innovative Technologies to Increase Middle School Students' Interest in Space Science

Rhonda Christensen
Gerald Knezek
University of North Texas, USA

Troy Cline
Carolyn Ng
NASA Goddard Space Flight Center, USA

Abstract: Innovative technologies can spark middle school interest in STEM careers. This paper is specifically focused on student interest in space science with the intention it will lead to more students choosing careers in this area. NASA's STEM Innovation lab provides development and research of multiple types of innovative technologies aimed at this goal. Findings from research based on these activities offer optimism that engaging, technology-enhanced space science activities at the middle school level can help encourage middle school students to engage in activities that might lead to future scientists and engineers with space science-related areas as their chosen careers. Teacher preparation programs can impact the pipeline for future scientists and engineers by becoming proficient in the use of hands-on, engaging NASA type engagement activities supported by innovative technologies.

Keywords: space science, digital fabrication, augmented reality, virtual reality, robotics

Introduction

The STEM Innovation Lab associated with the NASA Space Science Education Consortium (NSSEC), led by NASA's Goddard Space Flight Center, is developing and implementing innovative technology supported activities to increase learner interest in space science. The University of North Texas is partnering to measure the impact of these activities on middle school students. According to the National Research Council (2009), people often learn science in non-school settings and that is an important component to science education in which policy makers, practitioners and researchers should pay attention. This project includes the goals of enhancing students' knowledge and dispositions toward space science. This paper reports targeted activities using innovative technologies to enhance student understanding of space science with a goal of increasing positive student perceptions toward space science. Innovative technologies included augmented reality (AR), virtual reality (VR), 2D and 3D printing, and robotics. Best practices for using these innovative technologies to focus learning on space science will be addressed, with the goal of suggesting exemplars for how teacher preparation programs could enhance the STEM pipeline of the future.

Literature Review

Interest in Space Science

Space science education is a method to engage students in the missions and activities that occur at NASA and realize career choices are built on positive experiences in which students can engage and explore (Zimmerman, Spillane, Reiff, & Sumners, 2014). A recent survey reported that fewer than half of middle and high school teachers said their students are eager to learn about space-related topics including space exploration and space travel (Will, 2017). NASA is continually launching missions that inform us about our atmosphere and planets. Recently Insight was launched to Mars to study the interior of Mars. Making these missions relevant to middle school students can increase their interest in learning more about space science and some will continue their interest to select related careers. Researchers found that students who attended a space exhibit showed more interest in space as well as an increase in interest in becoming a scientist (Jarvis & Pell, 2005).

Innovative Technologies for Learning

The STEM Innovation Lab at NASA Goddard Space Flight Center is a think tank with an emphasis on space science topics such as missions to Mars, Parker Solar Probe's mission to touch the sun, and the Magnetospheric Multiscale Mission (MMS). It brings together NASA scientists, engineers and educators to explore and develop new ideas related to infusion of educational technology into STEM activities, programs, and approaches. Inside the lab are a variety of interchangeable 'STEM Exploration Stations' fitted with innovative technologies typically found in many of today’s 21st century educational environments. Currently the lab hosts a variety of exploration stations that include: Virtual/Augmented/Mixed Reality, Design Fabrication (paper cutting, 3D printing), Coding and Electronics, Mobile/Cell Phone Sensors, and Digital Learning Environments. By placing these stations in close proximity to each other, the lab encourages users to investigate how the technologies can be effectively blended together for greater impact and integration into NASA related education programs and products. Many of the stations and content-based activities are replicated at a university lab in order to measure the impact of these activities on middle school aged youth. These youth are not only consumers of the content through innovative technologies, but also creators of their own content. The technologies that are incorporated in the activities are described in the following narrative.

While Virtual Reality (VR) is defined as a set of digital tools to provide immersion into a computer-generated environment, it perhaps is better understood within the context of its ability to provide the user with a sense of presence (Steuer, 1992). VR allows the creating of authentic learning opportunities within an immersive, simulated environment by creating more concrete experiences where often there are abstract concepts. There are a wide range of virtual reality experiences from the VR goggles with a smartphone inserted to view 360 video to more immersive environments such as the Vive. One of the Vive activities students can experience is “Cycling Pathways to Mars” presented by astronaut Buzz Aldrin as he showed his plan for inhabiting Mars. The VR activities using simple and inexpensive goggles (similar to the basic Google Cardboard-type headset) leverage smartphones to deliver experiential content through apps. Simply utilizing free 360 videos on YouTube, students have an opportunity to experience an immersive and realistic environment. These devices allow students to experience things beyond their immediate reality and sate their curiosity about subjects normally outside of their reach – such as the sun or exo-planets outside our solar system. In addition, students can create their own VR videos using a specialized 360 camera. This camera has lenses on both sides, allowing the user to capture a 360 field of view while taking pictures or videos.

Augmented Reality (AR) is defined as a technology that incorporates a “layering of information over a view or representation of the normal world, offering users the ability to access place-based information in ways that are compellingly intuitive” (Johnson, Adams, & Cummins, 2012, p. 5). AR can be considered a positive advantage for education because it offers opportunities to expand what is possible in a real-world environment. AR has gained popularity because of the geo-location abilities of smart phones. AR is an immersive augmented environment considered to be highly engaging and motivational. NASA has created several AR apps that are free to download and use. One app that students really enjoy exploring is Spacecraft 3D because it allows them to learn about and interact with several different spacecraft that explore the solar system. Using a downloaded “trigger”, students can open the app, point their smartphone or tablet at the trigger and begin to explore these spacecraft and can even hold one in the palm of their hands. After participating in AR activities, students are able to develop their own AR environment using Taleblazer, a freely available AR development platform. When students complete their AR games, they learn through trial and error about how to make sure their virtual markers are where they thought they were placing them in the real world. Students play each others’ AR games and provide feedback for improving their game.

Digital fabrication involves automated conversion of a digital design into a physical object through a computer-controlled fabrication system (Standish, Christensen, Knezek, Kjellstrom, & Bredder, 2016). Technologies like 3D printing are not only exciting and engaging, but provide new pathways to connect engineering, science, and technology for learners. These concrete experiences provide a meaningful context for understanding abstract concepts. Using a freely available CAD program called Tinkercad, students can design and print objects such as rockets or parts of a rocket to construct for launching.

The use of robots in education is effective for increasing students’ problem solving and computational thinking skills (Eguchi, 2016). Programming robots is a tangible way to see instant feedback from the user’s coding (Bers, 2008). Programming robots is an engaging and hands-on activity to support problem solving as well as logical reasoning (Eguchi, 2016). An important aspect of the robotics activities includes the teamwork aspect of building the robots. When students put the robots together and program them to run, they pay attention to the types of wheels needed for different surfaces, types of instruments that are attached to the rover and how to get the rover to its destination in one piece. The use of spacecraft, orbiters, rovers, and other robotic technology has enabled discoveries in environments that otherwise would be dangerous to humans since robots can be remotely controlled. Youth are introduced to the way NASA uses robotic arms, rovers and spacecraft for space exploration.

Drones (unmanned aerial vehicles, remotely piloted aircraft) are becoming more popular in schools as teachers recognize the valuable skills that can be enhanced through the use of programming and piloting drones. Drone technologies are used in many STEM areas and it is important to introduce and teach students to use them in order to stimulate interest as well as develop a workforce for the growing drone industry. Future careers could include drone pilots, technicians, designers and manufacturers.

These technologies are embedded in curriculum activities related to space science. While students may work on one activity at a time, there are cross-cutting concepts that form a cohesive understanding of the ideas of space science. For example, the Spacecraft 3D augmented reality activity focuses on different types of spacecraft and their unique contributions of data to inform scientists. There are rovers and satellites that can be explored and these activities are tied to the programming of rovers in the robotics activity and the programming of drones in that activity.

Methods

Participants

Over the past three years multiple types of activities have been conducted and range in time allocation from one 45 - minute session to a four hour camp to a one week camp. These different types of sessions allow the researchers to determine the impact of these activities with differing dosages of implementation. The participants are typically middle school-aged youth who participate in these informal learning activities. The youth groups range in demographics that include gender and ethnicity, as well as rural, suburban and urban locales. Pre and posttest data are typically gathered for each activity.

Content Focus

Over the past three years there have been different targeted content areas including: a) the solar eclipse in 2017, b) the anniversary of the manned landing on the moon, c) the launch of the Parker Solar Probe mission in 2018, and d) the launching of a variety of spacecraft to Mars. The eclipse of 2017 bisected the United States and allowed for many people in the U.S. to view it. In 2018 there was a 50th anniversary of "Moonrise" in which the first manned mission orbited the moon. The 50th anniversary of the first landing on the moon is 2019. The Parker Solar Probe launched in 2018 for the purpose of providing new data on solar activity in order to forecast major space-weather events that impact life on earth. Mars is the focus of many different types of spacecraft with a variety of explorations. Particular attention was given to ensure activities related to students in their daily lives. For example, the solar probe is intended to provide data related to space weather, specifically solar storms, which can severely impact power and communications on earth.

Instrumentation

Content and interest as well as attitudinal survey instruments were included as measures of impact of activities related to space science using innovative technologies. Content items have changed from year to year depending on the particular focus for the year. Measures for dispositions included a semantic differential on overall perceptions of space science (see Appendix) and a Likert-type survey with specific items related to interest in space science (see Appendix). In addition content items related to topics such as the eclipse or the Parker Solar Probe mission were also included in the battery of instruments. Pre-post assessments of each of the activities were conducted to measure change in knowledge, interest and dispositions. Demographics such as gender, grade level and ethnicity were part of the data collection. Paired *t*-tests were conducted to determine the pre-post changes in content, interest and dispositions.

Findings and Discussion

In general, students who participated in each of the activities using innovative technologies to learn about space science concepts gained in their content knowledge and interest in space science. Multiple formats of implementation of activities have emerged to fit different needs of groups. The three formats discussed in this paper are described below followed by findings for each of the three groups.

Format 1 included 45-minute school visitation guided activities with AR/VR and robotics. Even 45-minute AR and VR inquiry-based activities (during a school site visit engaging students in round-robin groups of 15 minutes per station) were successful in instilling content knowledge and interest in space science. The activities took place in an elective technology course with 7th and 8th grade students in a middle school in a rural district. While both dispositions toward (overall perceptions of) space science and specific interests in space science went up from pre to post, only interest was significantly ($p < .05$) more positive at posttest than pretest. These findings are depicted in Figures 1 and 2.

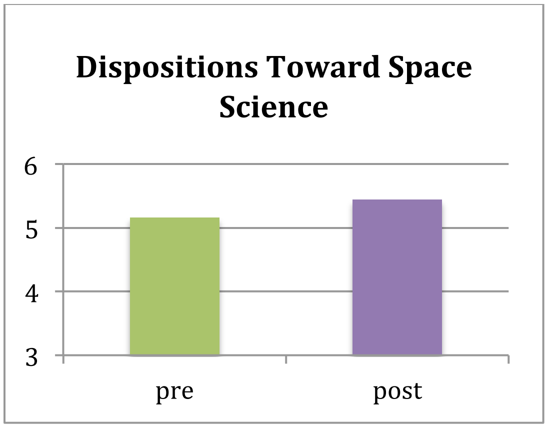

Figure 1. Pre-post space science dispositions

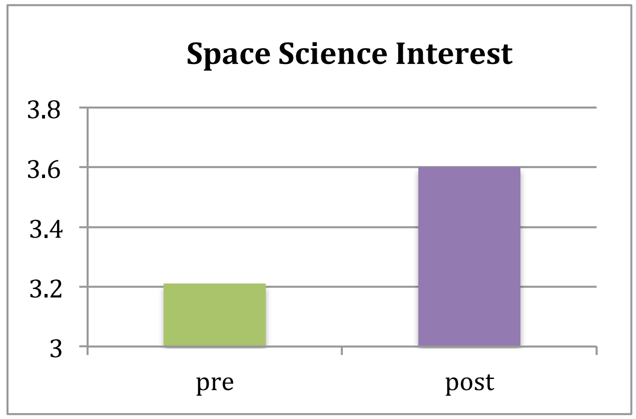

Figure 2. Pre-post space science interest (5 point scale)

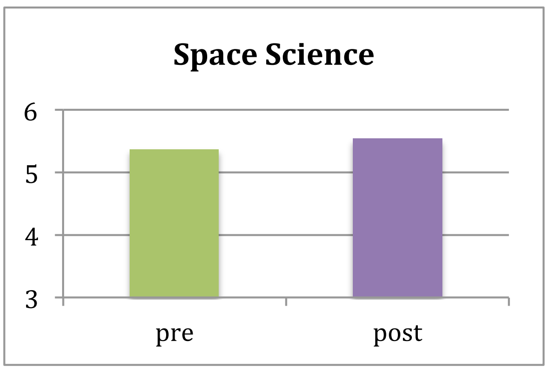

Figure 3. Pre-post dispositions toward space science as measured by the semantic differential.

Format 2 was a week-long camp using AR, VR and 3D printing focused on space science. While the focus of the whole camp was space science, one day was devoted to the innovative technologies and content discussed in this paper. Evaluation of impact from the week-long space science summer camp showed that learners arrived with high interest and generally maintained interest in space science. Although the students had positive dispositions (5+ on a 7-point scale) when they arrived to the camp, their dispositions became more positive (see Figure 3).

Format 3 participants experienced a half-day weekend camp in the STEM Innovation facility at the university as sixth graders. The sixth graders were able to try out each of the innovative technology activities focused on space science topics. These students were invited to return as seventh graders for a follow up camp one year later. For the 2nd visit, the students were allowed to select from one of the innovative technology areas and create their own products such as AR, VR, building and programming robots or 3D designing and printing. Thus these students had a half-day weekend space science camp in spring 2017 as consumers of the content using innovative technologies with returning in spring 2018 as creators of their own content using innovative technologies. These participants also experienced the solar eclipse in August 2017 with their entire class with viewing glasses, as real-time observers. As shown in Figure 4, for this group: a) content knowledge increased pre to post and still maintained a high level after one year, b) Interest increased from pre to post but declined somewhat by the end of the year, and c) Semantic perceptions / dispositions toward space science and a solar eclipse began high when the students had been selected based on their written essays as one of 20 participants for the Saturday camp, then declined slightly pre to post the day of the camp, then rose significantly ($p < .05$) by the time of the third measurement, at the end of one year.

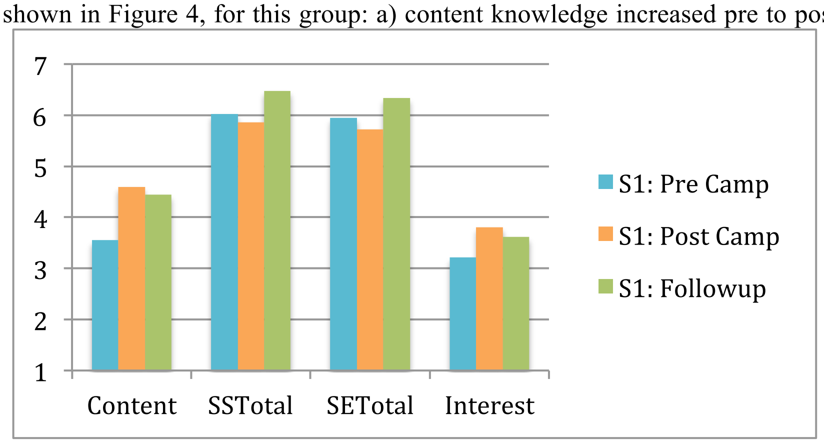

Figure 4. Changes in content knowledge, semantic perceptions of space science (SS) and a solar eclipse (SE), and interest in space science over three time periods spanning one year.

Researchers concluded that 45-minute AR and VR inquiry-based activities following selected content-related video segments were successful in instilling content knowledge and interest in space science. A week-long space science summer camp with participants who arrived with high interest maintained their space science interest while dispositions became more positive. However, a half-day weekend camp with follow-up discussion of content was more effective in instilling long-term lasting dispositions, and it appears that a second year of the camp with a self-selected area of activities concentration not only further enhanced dispositions toward space science but also fueled even higher interest. The magnitude of the difference in interest in space science between the pretest of the school visitation space science activities, and the a subset of this class who went through two weekend space science camps over two consecutive years (post test = last bar in Fig. 5), was Cohen's d effect size = .94 (p = .005), which is a very large increase according to established guidelines. Similarly, the magnitude of the increase in long term attitudes (positive dispositions) toward space science, for these same measurement points was ES = 1.07 (p = .002) (very large). Differences in space science dispositions are graphically displayed in Figure 6.

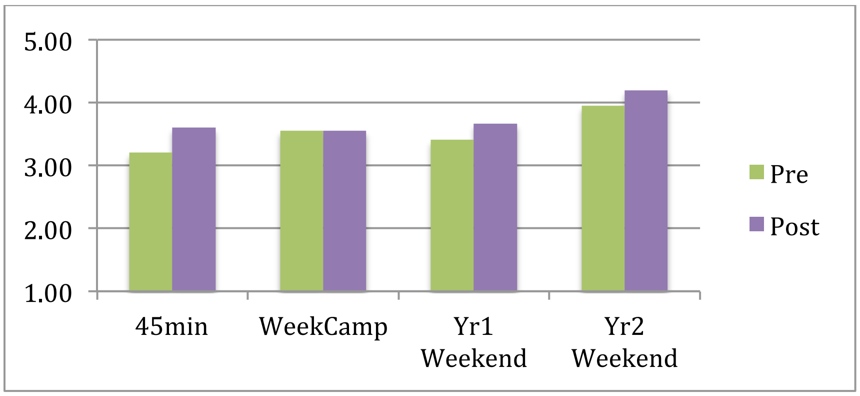

Figure 5. Pre-post interest in space science for school visit, weekend & summer camp participants.

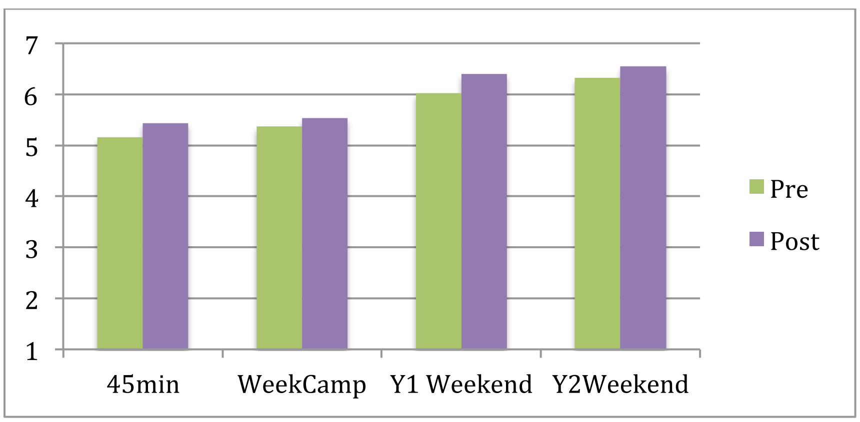

Figure 6. Pre-post long term attitudes (dispositions) toward space science for school visit, weekend & summer camp participants.

Conclusions

These findings indicate that for middle school-aged youth, a combination of initial stated desire to learn more about space science, coupled with renewed engagement in space science activities over one year, can result in an increase in space science interest and dispositions. Findings offer optimism that engaging, technology-enhanced space science activities at the middle school level can help encourage middle school students to engage in activities that might lead to future scientists and engineers with space science-related areas as their chosen careers. Teachers and school systems, and by implication teacher preparation programs and teacher preparation candidates, can impact the pipeline for future scientists and engineers by becoming proficient in the use of hands-on, engaging NASA type engagement activities incorporating innovative technologies and making them relevant to student's lives.

References

Bers, M. U. (2008). Using robotic manipulatives to develop technological fluency in early childhood. In O.N. Saracho & B. Spodek (Eds.), *Contemporary Perspectives on Science and Technology in Early Childhood Education* (pp. 105-125). Charlotte, NC: Information Age Publishing, Inc.

Eguchi, A. (2016). Computational thinking with educational robotics. In G. Chamblee & L. Langub (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 79-84). Savannah, GA, United States: Association for the Advancement of Computing in Education (AACE). Retrieved March 5, 2018 from https://www.learntechlib.org/p/172306/.

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during and after a visit to the UK National Spaced Centre. *Journal of Research in Science Teaching, 42*(1), 53-83.

Johnson, L., Adams, S., & Cummins, M. (2012). *NMC Horizon Report: 2012 K–12 Edition*. Austin, TX: New Media Consortium.

National Research Council (NRC). (2009). *Learning Science in Informal Environments: People, Places and Pursuits. Committee on Learning Science in Informal Environments*. P. Bell, B. Lewenstein, A.W. House, & M.A. Feder (Eds). Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Standish, N., Christensen, R., Knezek, G., Kjellstrom, W., & Bredder, E. (2016). The effects of an engineering design module on student learning in a middle school science classroom. *International Journal of Learning, Teaching and Educational Research, 15*(6), 156-174.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of communication*, 42(4), 73-93.

Will, M. (2017). Most students are not naturally interested in STEM, teachers say. *Edweek*. Available: http://blogs.edweek.org/teaching_now/2017/06/how_can_teachers_get_students_interested_in_science_and_math.html.

Zimmerman, L., Spillane, S., Reiff, P., & Sumners, C. (2014). Comparison of student learning about space in immersive and computer environments. *Journal and Review of Astronomy Education and Outreach, (1),* A5-A20.

Acknowledgement

This research and development was supported in part by the U.S. National Aeronautics and Space Administration (NASA) Grant # NNX16AL63A.

Appendix.

Semantic perceptions of space science

Instructions: Choose one circle between *each* adjective pair to indicate how you feel about the object.

To me, space science is									
1.	Fascinating	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	Ordinary
2.	Appealing	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	Unappealing
3.	Exciting	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	Unexciting
4.	Means nothing	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	Means a lot
5.	Boring	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	Interesting

Interest in space science topics (Likert-type items)

Rate each statement on a scale of 1-5, 1=Strongly disagree, 5=Strongly agree

	1	2	3	4	5
I want to learn more about the moon.	○	○	○	○	○
I want to learn more about Mars.	○	○	○	○	○
I want to learn more about the sun.	○	○	○	○	○
I know where to find more information about launch of the probe to study the sun.	○	○	○	○	○
NASA's Parker Solar Probe mission to the sun will revolutionize our understanding of the sun.	○	○	○	○	○
Weather (space weather) that occurs in space can impact my life.	○	○	○	○	○