Space Science Activities to Enhance Middle School Students' Interest in STEM: Follow-up Assessment of Disposition Retention

Gerald Knezek
gknezek@gmail.com

Rhonda Christensen
Rhonda.christensen@gmail.com

University of North Texas
USA

Abstract: Sixth grade students participating in a four-hour hands-on technology enriched space science camp acquired more positive dispositions toward space science (ES = .46, $p < .05$), as measured by pre-camp (time 1) and post camp (time 2) assessments. Topics related to the Parker Solar Probe mission, the Apollo 11 moon mission and Mars spacecraft were taught through innovative technology experiences such as augmented reality, virtual reality, 3D printing, robotics and drones. Follow up (time 3) assessments were the focus of the current study, with findings indicating that dispositions toward space science regressed somewhat three months after the camp (ES = .18, NS) but remained significantly ($p < .05$) more positive (ES = .74, $p = .002$) than their comparison group classmates had been at the time of the pretest. Findings imply that being selected based on writing an essay for an opportunity to participate in the technology-enriched space science activities may itself have had a positive impact on dispositions toward space science. Camp activities also appear to have infused a degree of resilience that caused participant dispositions not to decline back to their pretest levels, as the school year progressed. However, dispositions for participants did decline at time 3, after rising from time 1 = pretest to time 2 = post test. Findings highlight the importance of follow-up reinforcement activities after an engaging event such as a space science camp, if educators wish to keep dispositions toward STEM topics such as space science highly positive.

Keywords: space science, STEM disposition retention, digital fabrication, augmented reality, virtual reality, robotics, drones

Introduction

The NASA Space Science Education Consortium (NSSEC), led by NASA's Goddard Space Flight Center, focused educational resources for the 2018-2019 academic year on activities supporting learner interest in space science with particular interests in the Parker Solar Probe mission to *Touch the Sun*, the 50th anniversary of the Apollo manned walk on the moon and Mars exploration with spacecraft such as Insight. According to the National Research Council (2009), people often learn science in non-school settings and that is an important aspect of science education to which policy makers, practitioners and researchers should pay attention. This project includes the use of innovative technologies in informal learning environments to enhance students' knowledge and dispositions toward space science. This paper reports on 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, robotics and drones. Christensen et al. (2019) previously reported on measured impacts of the same middle school space science camp, pre (time 1) to post (time 2). The current study is an extension of prior work and focuses on retention of dispositions three months later, at time 3, in the context of comparison group mean values at the time of the pretest, gathered from the remainder of the class (n = 174) of sixth grade students, from which 24 students who wrote essays expressing their interest in participating, were selected to take part in a four-hour space science camp.

Literature Review

Interest in Space Science

While there have been no recent manned space missions to the moon, NASA is continually launching missions that inform us about our atmosphere and the planets. NASA recognizes the need to prepare and interest students for future STEM careers who will continue the work NASA has been doing over the past decades. 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). 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). Researchers who measured attitudes toward science and space for 300 students who attended a space exhibit, found students who attended showed more interest in space as well as an increase in interest in becoming a scientist (Jarvis & Pell, 2005).

Innovative Technologies for Learning

Innovative technologies have been shown to be effective tools for learning whenever educators do not start by focusing on the technology but rather by determining what kind of learning experience needs to be acquired by the learner, and then consider ways in which technology can be used to enhance the process (Lai, 2018; Scardamalia, 2001). Scardamalia (2001) suggested that we should encourage students to use digital technologies to pursue deep understanding of concepts, rather than simply acquiring technological skills for their own sake. Wellington (2004) encouraged the use of technologies to pursue authentic learning, which adds value to the learning experience, rather than just saving time and labor. Lai (2018) proposed that a unique contribution of new digital technologies for learning is their affordances in supporting the development of innovative and creative skills. As access to innovative technologies is becoming more commonplace in the 21st century, greater opportunities are arising for putting the recommendations of researchers and other scholars into practice.

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). By creating authentic learning opportunities within an immersive, simulated environment, "VR can overcome shortcomings in STEM education including a reliance on theory and lack of concrete experiences" (Adams Becker, Freeman, Hall, Cummins, & Yuhnke, 2016, p. 42). While many research studies find virtual reality to be beneficial for learning in K-12 environments (Ferdig, Gandolfi, & Immel, 2018), there needs to be more models of how VR can be successfully implemented into PreK-12 settings (O'Shea & Elliott, 2016; Radu, McCarthy, & Kao, 2016). However, more research should be focused on accessibility and usability to successful implementation (Riva & Wiederhold, 2015).

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 is a way to bring together the real and the virtual world, which allows for interactivity in real time (Azuma, 1997). Brill and Park (2008) see AR as a positive advantage for education because it offers opportunities to expand what is possible in a real-world environment. Mobile delivery of AR has gained popularity because of the geolocation abilities of smart phones as well as the ubiquity of cellular devices across socio-economic status, gender, race, ethnicity, and age (Gandolfi, Ferdig, & Immel, 2018). Researchers have found an immersive augmented environment to be highly engaging and motivational for middle and high school students (Dunleavy, Dede, & Mitchell, 2009).

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 bring engineering, science, and technology to learners. These concrete experiences provide a meaningful context for understanding abstract science and math concepts (Martinez & Stager, 2013). Digital fabrication is being used to promote higher order thinking and problem solving skills in middle school students by allowing students to conceptualize an idea and then realize the idea in a physical form (Bull & Groves, 2009).

The use of robots in education is effective for increasing students' problem solving and computational thinking skills (Eguchi, 2016). Robotics has been shown to enhance students' creativity, persistence, social interactions, and teamwork skills (Altin & Pedaste, 2013; Eguchi, 2014; Kandlhofer & Steinbauer, 2015). Programming robots is a tangible way to see instant feedback from the user's coding (Bers, 2008) and is an engaging and hands-on activity that supports problem solving as well as logical reasoning (Eguchi, 2016).

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. Teachers have found students are more motivated and even have better attendance since the introduction of drones in the curriculum (Schaffhauser, 2018). 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. In addition, teachers have found the use of drones can help enhance orientation skills and motor skills (Cenejac, 2017). Future careers could include drone pilots, technicians, designers and manufacturers.

For the study presented in this paper, these technologies were embedded in curriculum activities related to space science. While students participated in one activity at a time, there were cross-cutting concepts that formed a cohesive understanding of the ideas of space science. For example, the Spacecraft 3D augmented reality activity focused on different types of spacecraft and their unique contributions of data to inform scientists. Included in space science exploration are rovers and satellites. The camp activities were tied to the programming of rovers in the robotics activity and the programming of drones in that activity.

Research Questions

The research questions guiding this study were:

1. To what extent do students who attended a four-hour space science camp retain gains in their dispositions related to space science, three months after the event?
2. To what extent do students selected to attend the space science camp differ in their pre (time 1), post (time 2) and follow-up (time 3) space science dispositions from their comparison group classmates (remainder of 6^{th} grade class) at the time of the pretest?
3. To what extent are there gender differences in acquisition and retention of positive space science dispositions?

Methods

Participants

In 2019, twenty-four sixth grade students from a rural school district attended a four-hour long Saturday Space Science Camp at a nearby university that focused on space science activities. Students wrote an essay indicating their interest in attending the camp and school district personnel selected the students to attend the camp. Pre-test data were collected from the students two weeks prior to the camp (time 1) and posttest data were gathered following the four-hour camp (time 2). Follow-up (time 3) data were gathered from the camp participants approximately 3 months later. The 2019 participants included 10 males and 14 females forming the treatment group for this study. In addition, pretest data were collected at the same time as for the treatment group, from the remaining 174 students in the same grade level who did not attend the camp. These students are referred to in this paper as the comparison group.

Content Focus

While the overall focus was space science, three themes were highlighted because of the current focus at NASA. The three themes within which activities were created included the probe launch to study the sun, the 50^{th} anniversary of the Apollo first man on the moon and the spacecraft that have been or will be launched to study Mars.

Touch the Sun is a theme focused on the Parker Solar Probe mission that launched in August of 2018 for the purpose of providing new data on solar activity in order to forecast major space-weather events that impact life on earth (NASA, 2018). The probe will provide data related to space weather, specifically solar storms, which can severely impact power distribution and communications on earth.

The year 2019 marks the 50^{th} anniversary of the Apollo 11's mission that put the first man on the moon. The first steps by humans on another planetary body were taken by Neil Armstrong and Buzz Aldrin on July 20, 1969. The first astronauts were true explorers who risked their lives to advance space science. The astronauts brought back samples of moon rocks and soil, a first for mankind.

There have been many spacecraft sent to Mars, each with a specific purpose. The overall goal is to determine if life is possible on the surface of Mars. There is indication that there was once water on Mars and current spacecraft such as Insight, are exploring beneath the surface of Mars.

Activities

Space science camp activities began with an introduction presented to the entire group. This provided a focus for the day as well as some short introductory videos on missions to the moon, Mars, and the sun. NASA personnel in attendance also spoke briefly about their duties at NASA during the introductions and then answered open-ended questions about space science topics at the end of the day. Spinoffs of NASA projects were also featured during the introduction in order to show how NASA research and products impact our daily lives.

After the introduction, the 24 students rotated through each of the activities focused on the content described above using various types of innovative technologies. Students were able to experience augmented and virtual reality including goggles and VIVE, 2D and 3D designing and printing, and programming robots and drones. While the groups varied in their content focus (sun, moon or Mars), each of the activities had the same goal – learning about space science using hands-on, engaging technologies. Each of the innovative technology activities are described in more detail in the sections that follow.

Augmented Reality (AR) Activities

In these activities, students were introduced to the concept of augmented reality and then given iPads with augmented reality applications installed to explore. The applications that were introduced included Spacecraft 3D and NASA 3DV. The application functioned by locating a physical "marker" (in this case an image like the NASA logo) and centering that image on the iPad screen. Once the camera recognized the marker, a projected image was displayed in 3D and included spacecraft such as the Curiosity Rover and Insight. Students were then given opportunities to explore different aspects of the rovers, probes, and other space equipment by selecting certain animations in the application. The augmented reality applications allowed the students to examine the working parts of various spacecraft in greater detail. Furthermore, information in the applications gave the students a greater understanding of how and why NASA used the space equipment.

Virtual Reality (VR) Activities

The VR activities used basic VR headset configurations that leveraged smartphones to deliver experiential content through apps. Simply utilizing free 360-degree "google cardboard" videos on YouTube, students were given an opportunity to experience all angles of an immersive and realistic environment. These simple devices allowed students to experience other things beyond their immediate reality. Some applications used in the activities were *Titans of Space* and *Apollo 15*. *Titans of Space* is an immersive "walkthrough" of the solar system, while *Apollo 15* is a more interactive experience for the students. *Titans of Space* provided many "to-scale" representations of the planets and stars, correctly modeling the proportions of the Earth to the Sun and the Sun to Sirius, a star ten times bigger than the Sun. The apps also correctly modeled the anomalies of our solar system, such as the planet Venus turning backwards. *Apollo 15*, on the other hand, created the experience of Apollo 15 launching and landing on the moon, and allowed the students to perform many of the actions the astronauts would have done in a virtual reality setting. Students could see the rover up close and control its movements on the moon's surface.

In addition to the VR headset experience, every student was introduced to the VIVE system, a virtual reality hardware and software system to provide interactivity in a virtual environment. Each student had an opportunity to interact with components built in a model that replicated the NASA Goddard Spaceflight Center Virtual Reality Lab. Students interacted with the VR Lab wearing a VIVE VR Head Mounted Display (HMD) inside a green cube "room" designed for mixed reality. Each student took turns for the VR experience while others watched the participant interact in VR that was transmitted on a display monitor in the room. The hand-held VIVE controllers were used to navigate, teleport and grab objects in the virtual environment. Inside the NASA VR Lab, students interacted with four different virtual environments: 1) The VR Lab with models of planets in the solar system floating under a ceiling, 2) Earth in space simulated with the magnetic fields displayed between the sun and the earth, 3) a closer look at the surface of the sun, and 4) the clean room with a model of the Magnetospheric Multiscale Mission (MMS) satellite. For many this was their first experience in a virtual environment, but they were quick to get accustomed and did not hesitate to explore and interact in the virtual environment. Many left the VR Lab wishing they could have this app to continue the experience at home.

3D Digital Fabrication Activities

Camp participants were first introduced to 3D printing through demonstrations of a 3D printed lunar rover and an interplanetary rocket, as well as a video clip from the International Space Station (ISS) in which the astronauts demonstrated 3D printing in space (https://www.youtube.com/watch?v=HouJPqYG5E4&frags=pl%2Cwn). Then the students reviewed the concepts of 3D printing by closely studying a working 3D printer that was printing a drone later used as a prize for winning the drone-flying competition. The students spent the majority of the time designing their own 3D models, and learning how to use TinkerCAD, an online 3D designing tool that they used to design. While some decorated models of the sun given to them as a template, others chose to build their own models. Some of the final products included a hammer, a castle, a skeleton, and an alien, etc. Due to time constraint, the 3D models designed by the students were printed after the camp and distributed to them afterward. Since one of the themes of the day was *Touch the Sun*, the students were instructed to take criteria into consideration, such as how can 3D printing help space exploration, and what are the problems 3D printing might encounter in space. In the end, the students not only understood the mechanism of 3D printing, but also the purpose and applications of 3D printing in space exploration.

Robotics

Camp participants in the robotics group learned about the space science topics through the programming of robots. The use of spacecraft, orbiters, rovers, and other robotic technology has enabled discoveries in environments that otherwise would be dangerous to humans since they can be remotely controlled. The participants were introduced to the way NASA uses robotic arms, rovers and spacecraft for space exploration. Students viewed Spacecraft 3D, an augmented reality application, to see a 3D image of how robots work.

The goal of this activity was to make a connection between the importance of robotics and NASA's missions. The use of robots has facilitated NASA's endeavor in exploring the extraterrestrial. Robots follow a set of instructions/algorithms to accomplish their tasks that are defined in computer programs written by computer scientists at NASA. An emphasis was made that computer programmers are not the only ones who work on robotics but there are may others including electrical and mechanical engineers who make a significant contribution to robotics. The camp participants were amazed at the many opportunities there are available in NASA's robotics. Students quickly understood the programming platform due to their prior exposure to programming with MIT's Scratch programming platform.

The robotics activities focused on programming the robot to complete a set of tasks. There was a set of challenges that the students had to consider and find solutions in order to accomplish each task. The programming platform, Mblockly was very similar to Scratch. In the coding, participants could adjust the magnitude of the speed of the robot and the duration in which the robot should maintain that speed. Given these parameters allowed the participants to determine the distance that the robot could travel. In addition, the robot had an arm that could be controlled through the coding program. The camp participants had to think about how fast and how far they wanted the robot to travel. When attempting to pick up an object they had to consider the distance between the robot and the object and at which angle to they wanted to lower or raise the robot's arm in order to pick up the object. Both the robotics and drone activities involved programming with instructions.

Drones

Participants were able to experiment with flying drones and learned about NASA's drone programs allowing them to make the connection between what NASA does with drones and how drones are used in their commercial and private lives. Students were shown a video (www.youtube.com/watch?v=oOMQOqKRWjU&feature=youtu.be) that showed what NASA is currently designing in terms of drones, what NASA anticipates to use these drones for in the future, and why NASA believes drones are the next generation of space exploration. For the challenge, students were asked to fly the drone from the takeoff point to the landing target as quickly as possible. After a few practice runs to allow the students to get familiar with the controller and how the drone flew, times were recorded for each student. A leader board was kept to see which student could fly the drone into the target area the fastest. At the end of the day the student with the fastest time was awarded a 3D printed drone to take home. As the activity progressed, the students gained confidence in flying the drones, which was evident in the decrease in flight times. The participants were engaged in the drone flying challenge. They experienced the trial and error of lifting the drone too quickly or high but they quickly adapted their skills. The first-hand experience also got the students really excited about the drones and many stated that they wanted to fly more drones and would ask for one as a birthday or Christmas present.

Instrumentation

Each participant completed a Space Science Survey instrument consisting of demographic items plus: a) a five-adjective, seven-point Semantic Differential scale (example: Boring _ _ _ _ _ _ _ Interesting) (5 items, alpha = .74) with the target of "To me, space science is"; b) a ten-item, five-rating point Likert scale (SD to SA) representing three constructs was included. The constructs included an interest in space science (5 items, alpha = .83), belief in the impacts of space science (2 items, alpha = .72) and belief that technology innovation improves learning (3 items, alpha = .91). In addition, an eight item, multiple choice, content knowledge related to the Parker Solar Probe, the

Apollo 11 first manned moon landing and Mars spacecraft such as Insight was assessed. The scores include the total number of content items correct. Demographics such as gender, grade level and ethnicity were also part of the data collection. Only dispositions toward space science are addressed in this paper.

Results

T-tests were conducted to determine the changes in students' dispositions regarding space science, from prior to the camp to following the four-hour camp activities. Regarding the pre to post (time 1 to time 2) analysis, the stronger test of paired-t was used. For the follow-up survey, unpaired t was used to compare the follow up data (time 3) to the pretest level. As shown in Table 1, the semantic differential measuring dispositions toward space science increased significantly ($p < .05$) from pre to post. The magnitudes of the change pre to post (effect size) was Cohen's d = .46 for positive change in dispositions toward space science. This falls in the range of small to moderate according to guidelines by Cohen (1988). Gains in Space Science Dispositions (ES = .46) surpass the ES = .3 criteria for the point at which an intervention is normally considered educationally meaningful (Bialo & Sivin-Kachala, 1996).

Table 1.
Paired Sample t-tests

	Mean	N	Std. Dev.	Sig. (2-tailed)	Effect Size
Space Science Disp. Comparison Group Pretest	5.42	174	1.55		
Space Science Disp. T1 = Pre	6.41	24	.59		
Space Science Disp. T2 = Post	6.67	24	.55	.035	.46
Space Science Disp. T3 vs. T1	6.52	22	.63	.540 (NS)	.18
Space Science Disp. T3 vs. Comparison Group Pre	6.52	22	.63	.002	.74

Also shown in Table 1 is that at the follow-up (time 3) assessment, dispositions toward space science had regressed somewhat 3 months after the camp (ES = .18, NS) but remained significantly ($p < .05$) more positive (ES = .74, $p = .002$) than comparison group values at the pretest, for all other 6th graders in this school as a whole. If this comparison group mean average (5.42 on a scale of 1 to 7) is used as the basis for comparison to the treatment group throughout times 1, 2, and 3, then the effect size of requesting and being selected for the space science camp is estimated to be Cohen's d = (6.41-5.42) / Estimated Pooled Std. of (.59, 1.55) = .67 (Lenhard & Lenhard, 2016). This represents a moderate effect according to guidelines by Cohen (1988). At the time of the post test the effect had grown to Cohen's d = (6.67-5.42) / Estimated Pooled Std. of (.55, 1.55) = .85 (large), and then regressed to Cohen's d = (6.52 – 5.42) / Estimated Pooled Std. of (.63, 1.55) = .74 (moderately large). This effect size of Cohen's d = .74 represents the combined effect of being selected based on one's essay for participation in the space science camp, participation in the activities, and retention of positive space science dispositions into the follow-up time frame (time 3), 3 months after the event.

Christensen et al. (2019) reported differential effects by gender in the previous analysis that compared pretest (time 1) to post test (time 2) contrasts for males vs. females. As shown in Table 2 and graphically displayed in Figure 1, females overall in the 6th grade class from which space camp participants were drawn, possessed significantly ($p < .05$) more positive dispositions toward space science than their male counterparts, at the time when pretest measures were gathered, prior to the beginning of space science camp activities. A regression analysis (not shown) predicting average space science dispositions based on time 1 (pretest), time 2 (post test), and time 3 (follow-up assessment) determined that 66% (RSQ = .658) of group mean dispositions toward space science could be predicted based on time period ($p = .015$). However, 79% (RSQ = .785) could be predicted for males, while just 58% (RSQ = .583) could be predicted for females. As shown in Figure 1, it appears that for males the dispositions toward space science rose consistently and remained high (were retained) during the follow-up assessment 3 months later, while for females the dispositions were initially more positive than for males, rose somewhat during camp activities and then declined to the approximate level of pre-activity space science dispositions, by the time of the follow-up assessment 3 months later. This indicates that the primarily source of the time 2 (post test) to time 3 (follow-up) decline in space science dispositions reported in Table 1, was female space science camp participants. However, this trend must also be considered in the context of female dispositions being initially higher than males.

Table 2.
Space Science Dispositions by Gender

Measure	Gender	Mean	N	Std. Dev.	Sig. (2-tailed)	Effect Size
Space Science Disp. Comparison	Male	5.15	82	1.74		
Space Science Disp. Comparison	Female	5.68	88	1.33	.028	.34
Space Science Disp. Camp Pre (T1)	Male	6.32	10	.70		
Space Science Disp. Camp T1-Post	Male	6.66	10	.39	.20	.60
Space Science Disp. Camp T1-T3	Male	6.69	9	.53	.22	.60
Space Science Disp. Camp Pre (T1)	Female	6.47	14	.52		
Space Science Disp. Camp T1-Post	Female	6.67	14	.66	.34	.37
Space Science Disp. Camp T1-T3	Female	6.48	12	.65	.97	.02

Note 1. For comparison group 4 students with gender not identified (n=170).
Note 2. At T3 n= 9 males and n = 12 due to student absences for T3 administration.

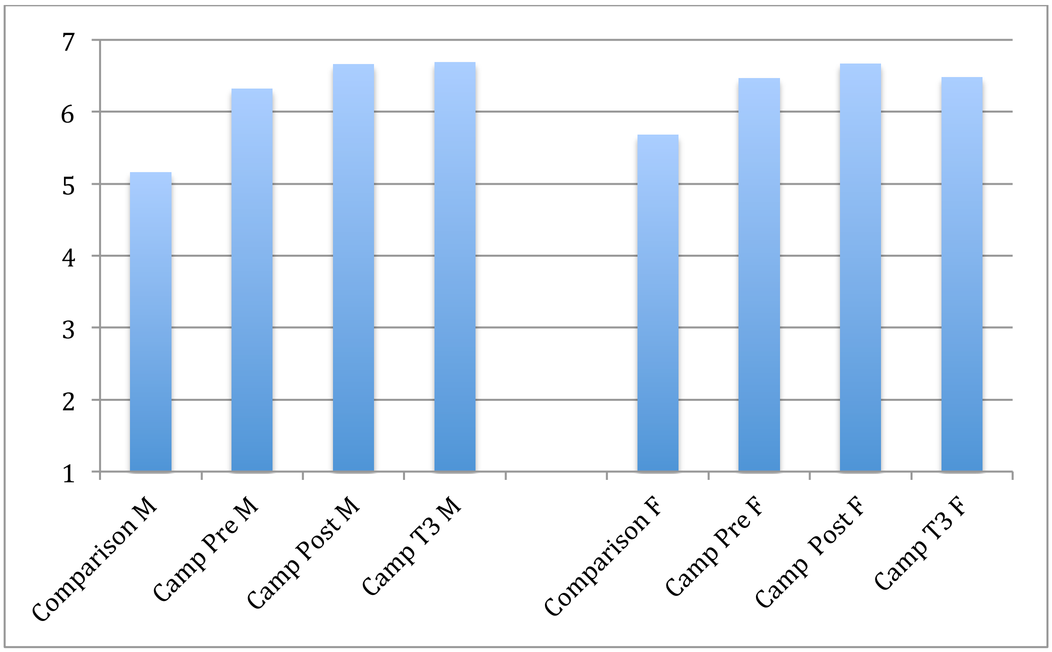

Figure 1. Trends in space science dispositions by gender for comparison group pretest versus treatment group, pre, post and follow-up assessments.

Viewing these findings collectively allows one to answer the three research questions posed in this this study:

1. *To what extent do students who attended a four-hour space science camp retain gains in their dispositions related to space science, 3 months after the event?* The answer to RQ1 is that student dispositions became significantly (p = .035, ES = .46) more positive from pre to post, and then regressed somewhat after 3 months, to the point where dispositions were no longer significantly (p < .05) higher than at the time of the pretest. The lasting effect was positive but small (ES = .18) with some indications that male participants tended to retain their positive dispositions while females tended to regress or decline.
2. *To what extent do students selected to attend the space science camp differ in their pre (time 1), post (time 2) and follow-up (time 3) space science dispositions from their class as a whole at the time of the pretest?* The answer to RQ2 is that students who were selected and attended the space science camp were significantly (p < .05) more positive in their dispositions toward space science than their classmates who did not attend camp as a comparison group, at all three time periods. For time 1 (pretest) the effect size was Cohen's d = .67 (moderate), while for time 2 (post test) the effect rose to Cohen's d = .85 (large), and at time 3 (follow-up) the magnitude of the effect declined somewhat to Cohen's d = .74 (moderate to large).

3. *To what extent are there gender differences in acquisition and retention of positive space science dispositions?* The answer to RQ3 is that females were significantly ($p < .05$, ES = .34) more positive in their dispositions toward space science than males for the comparison group of all 6th grade students at the participating school who were not space camp attendees, at the time of the pretest, but there were no significant ($p < .05$) nor any noticeable differences (see Fig. 1) by gender at the time of the pretest or post test for the 24 camp participants. At the time of the 3 month follow-up, no significant ($p < .05$) differences were found by gender for the treatment group, but an estimated effect size due to gender of Cohen's d = .35, combined with noticeable differences in retention-of-dispositions trends (see Fig. 1), led the researchers to conclude that the inability to confirm significant differences at time 3 for the space camp participants was probably due to the small sample size for each gender. Regression analyses of group means on space science dispositions predicted across times 1, 2, 3 confirmed that the fit was much better for males than females, leading to the conclusion that gender differences do exist in the acquisition and retention of space science dispositions for the participants in this study.

Discussion and Conclusions

In the current study, space science disposition gains that occurred during a four-hour focused camp were anticipated to remain over time, as in similar previous studies (Christensen et al., 2018; Knezek & Christensen, 2018). Additional data gathered from the participants in this study three months after the camp determined that dispositions regressed somewhat from the post test (time 2) high but remained higher than for the same group at the time of the pretest, and extensively higher than comparison group pretest dispositions of their classmates who did not attend the space science camp. Analysis of disaggregated data by gender indicates that females tended to have higher dispositions toward space science, at the time of the pretest in the comparison group and in the treatment group before activities began, but females remained less altered over times 1, 2, and 3, than the males, whose dispositions rose across times 1, 2, and 3 to the point where they surpassed the initially-higher space science dispositions of females. In a previous study involving a solar eclipse (Christensen et al., 2018), teachers reinforced the positive dispositions by bringing the topic up in class from time to time after the camp and before the students viewed the eclipse – and the persistence in that situation tended to be stronger. In the absence of a direct connection to the school curriculum and/or current events, it may be that follow-up Zoom sessions with some of the space camp instructors or NASA subject matter experts who took part in the 2019 space science camp, or some form of ongoing social media interactions, could serve this sustained reinforcement purpose. Additional research is warranted in this area.

Additional research is also warranted addressing a limitation of the current study, where the research design made it not possible to determine whether the students were already more positive in their space science dispositions than their comparison group peers before they wrote their essays, and this caused them to write an essay and be selected, or if the process of being selected raised their dispositions toward space science compared to their peers, even before the camp began. In either case, the overall strong impact of: a) writing an essay to express interest in being selected for participation in a space science camp, plus b) participating in camp activities is empirically indicated to be initially large (Cohen, 1988) and sustainably moderate to large. These empirical findings align with the direct observation of the students' school principal, who attended the Saturday space science camp and observed that these kinds of activities provide an opportunity for middle school students to become excited about STEM areas and to learn new things they may not get in class.

References

Adams Becker, S., Freeman, A., Giesinger Hall, C., Cummins, M., & Yuhnke, B. (2016). *NMC/CoSN Horizon Report: 2016 K-12 Edition*. Austin, Texas: The New Media Consortium.

Altin, H., & Pedaste, M. (2013). Learning approaches to applying robotics in science education. *Journal of Baltic Science Education, 12*(3), 365–378.

Azuma, R.T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments, 6*(4), 355-385.

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.

Bialo, E., & Sivin-Kachala, J. (1996). The effectiveness of technology in schools: A summary of recent research. *School Library Media Quarterly, 25*(1), 51–57.

Brill, J.M., & Park, Y. (2008). Facilitating engaged learning in the interaction age: Taking a pedagogically-disciplined approach to innovation with emergent technologies. *International Journal of Teaching & Learning in Higher Education 20*(1), 70-78.

Bull, G., & Groves, J. (2009). The democratization of production. *Learning & Leading with Technology*, *37*(3), 36-37.

Cenejac, J. (2017). Five ways to use drones in the classroom: Cherishing students' passion for technology. *Educational Technology, eLearningIndustry*. Retrieved from https://elearningindustry.com/drones-in-the-classroom-5-ways-cherishing-students-passion-technology.

Christensen, R., Knezek, G., den Lepcha, S., Dong, D., Liu, S., Wang, K., Wu, A. & Yotchoum Nzia, H.A. (2018). Outcomes from technology enhanced informal learning activities to increase middle school students' interest in STEM. In T. Bastiaens, J. Van Braak, M. Brown, L. Cantoni, M. Castro, R. Christensen, G. Davidson-Shivers, K. DePryck, M. Ebner, M. Fominykh, C. Fulford, S. Hatzipanagos, G. Knezek, K. Kreijns, G. Marks, E. Sointu, E. Korsgaard Sorensen, J. Viteli, J. Voogt, P. Weber, E. Weippl & O. Zawacki-Richter (Eds.), *Proceedings of EdMedia: World Conference on Educational Media and Technology* (pp. 1368-1377). Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE). Retrieved April 1, 2019 from https://www.learntechlib.org/primary/p/184353/.

Christensen, R., Knezek, G., Hobbs, F., Kelley, J., den Lepcha, S., Dong, D., Liu, S., Wang, K., Wu, A. & Yotchoum Nzia, H.A., and Kelley, D. (2019). Creating technology enriched activities to enhance middle school students' interest in STEM. Paper presented to *EdMedia: World Conference on Educational Media and Technology*. Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE).

Cohen, J., 1988. *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education Technology, 18*(1), 7–22. DOI 10.1007/s10956-008-9119-1.

Eguchi, A. (2014, July). *Robotics as a learning tool for educational transformation*. Paper presented at the 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education, Padova, Italy. http://doi.org/10.4018/978-1-4666-8363-1.ch002

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/.

Ferdig, R.E., Gandolfi, E., & Immel, Z. (2018). Educational opportunities for virtual reality. In J. Voogt, G. Knezek, R. Christensen & K-W Lai *(Eds.). Handbook of Information Technology in Primary and Secondary Education*, in the series *Springer International Handbooks of Education*. Springer International Publishing, Cham, Switzerland.

Gandolfi, E., Ferdig, R.E., & Immel, Z. (2018). Educational opportunities for augmented reality. In J. Voogt, G. Knezek, R. Christensen & K-W Lai *(Eds.). Handbook of Information Technology in Primary and Secondary Education*, in the series *Springer International Handbooks of Education*. Springer International Publishing, Cham, Switzerland.

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.

Kandlhofer, M., & Steinbauer, G. (2015). Evaluating the impact of educational robotics on pupils' technical- and social-skills and science related attitudes. *Robotics and Autonomous Systems*, *75*, 679–685. http://doi.org/10.1016/j.robot.2015.09.007

Knezek, G. & Christensen, R. (2018). Capitalizing on informal learning opportunities to enhance formal learning in classroom environments. In E. Langran & J. Borup (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 1920-1926). Washington, D.C., United States: Association for the Advancement of Computing in Education (AACE). Retrieved April 1, 2019 from https://www.learntechlib.org/primary/p/182791/.

Lai, K. W. (2018). The learner and the learning process: Research and practice in technology-enhanced learning. In J. Voogt, G. Knezek, R. Christensen, & K. W. Lai (Eds.), Second handbook of information technology in primary and secondary education (pp. 127-142). Amsterdam: Springer.

Lenhard, W. & Lenhard, A. (2016). Calculation of Effect Sizes. Retrieved from: https://www.psychometrica.de/effect_size.html. Dettelbach (Germany): Psychometrica. DOI: 10.13140/RG.2.1.3478.4245

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

NASA. (2018). Parker Solar Probe. Available from http://parkersolarprobe.jhuapl.edu

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

O'Shea, P. M., & Elliott, J. B. (2016). Augmented reality in education: An exploration and analysis of currently available educational apps. In C. Allison et al. (Eds.), i*LRN 2016, CCIS 621* (pp. 147–159). New York, NY: Springer.

Radu, I., McCarthy, B., & Kao, Y. (2016). Discovering educational augmented reality math applications by prototyping with elementary-school teachers. *IEEE Virtual Reality (VR) 2016*; DOI:10.1109/VR.2016.7504758.

Riva, G., & Wiederhold B. K. (2015). The new dawn of virtual reality in health care: Medical simulation and experiential interface. *Studies in Health Technology and Informatics, 219*, 3-6.

Schaffhauser, D. (2018). Drones take off in education. *THE Journal*, July, 2018. Retrieved from https://thejournal.com/articles/2018/07/25/drones-take-off-in-education.aspx.

Scardamalia, M. (2001). Big change questions. Will educational institutions, within their present structures, be able to adapt sufficiently to meet the needs of the information age? *Journal of Educational Change, 2*(2), 171-176.

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.

Wellington, J. (2004). Has ICT come of age? Recurring debates on the role of ICT in education,1982-2004. *Research in Science and Technological Education, 23*(1), 25-39.

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. The authors also wish to acknowledge the contributions of the following individuals to the activities of the space science camp and content of this paper: UNT personnel and volunteers Destiny Dong, Frederick Hobbs, Daniel Kelley, Jenna Kelley, Samson Den Lepcha, Samuel Liu, Karen Wang, and Huram-Abi Yotchoum Nzia; and NASA personnel Kyle Boyer, Troy Cline, and Edward Gonzales.