Bringing Space Science Down to Earth for Preservice Elementary Teachers

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Abstract

This article reports on a collaborative enterprise between Oklahoma State University's (OSU) NASA Education Projects and OSU's College of Education preservice elementary teachers (PSTs) to engage approximately 400 middle school students for a 20-minute live downlink with Commander Kevin Ford from the International Space Station (ISS). NASA supports this opportunity through a competitive proposal process (National Aeronautics and Space Administration, 2014). The project's theme, Pioneers in Space: STEM Careers on the Space Frontier, engaged both PSTs and middle school students in discussing the benefits of space research, while drawing on themes relevant to students' regional history. PSTs prepared Pioneers in Space instructional units and led classroom activities linking 6th grade state science standards. The desired outcome was to promote a greater understanding of how space exploration benefits society and contributes to STEM innovations. This paper reports on how curriculum design and leadership experiences in space education and outreach impacted the PST participants.

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Introduction

Forty years after the moon landing, live International Space Station (ISS) Downlink experiences continue to help sustain public support and awareness about the benefits of space services (Entradas & Miller, 2010; Som, 2010). To date, millions of students have watched crewmembers demonstrate space concepts and participated in live question and answer sessions. NASA-sponsored downlink experiences provide key lessons related to life in space and how scientists from different countries work together on the ISS. These downlinks are intended "to encourage K-12 students to study and pursue careers in science, technology, engineering, and math (STEM)" (NASA, 2014, p. 1). MacLeish and Thomson (2010) outlined the potential ways space education events like these contribute to STEM education reform and for the development of a global space science workforce. While NASA Downlink opportunities connect formal and informal education about Earth and space science (Hofstein & Rosenfeld, 1996), reflective evaluation by science education programmers identifies the need to better utilize existing educational resources and to develop more strategies for connecting teacher networks (Edgett & Christensen, 1996; Kisiel, 2013; Stocklmayer, Rennie, & Gilbert, 2010).

Despite the importance of science subject knowledge to teaching, research literature points to elementary teachers' lack of science content knowledge (e.g., Czerniak & Haney, 1998; Diamond, Maerten-Rivera, Rohrer, & Lee, 2014; Duschl, 1983; Fulp, 2002; Hone, 1970; Westerback, 1982). In the area of space science, the concern is more grave as space science does not hold a prominent place in the modern school's science curriculum. Few teachers take space science courses in their preparation programs nor were they exposed to rigorous space science studies during their formative years. For instance, the typical K-12 science curriculum limits space science a study of planets in the Earth's solar system and phases of the moon. In this study, researchers purposefully introduced preservice teachers (PSTs') to authentic teaching and learning space science experiences hypothesizing that these experiences would increase PSTs' current knowledge of space science content and confidence in teaching space science lessons.

Background

This research is informed by Kolb's (1984) view of experiential learning wherein knowledge results from a transaction between the learning and the environment. Learners enter an experience with certain beliefs and understandings of the world honed through reflective engagement with concrete experiences. Experiential learning experiences can encourage the development of young science teachers to learn from other teachers, both in team building and in field-testing curriculum to engage learners (MacLeish et al., 2005; MacLeish et al., 2007). This article contributes to research in experiential PSTs' space science education by exploring how such experiential learning might affect their science teaching self-efficacy, perceptions of space science and scientists, and awareness of STEM careers. The following sections present literature on four areas that help to frame the study within current literature on the following areas of elementary teachers': (a) space science preparation, (b) science teaching self-efficacy, (c) perception of science and scientists, and (d) STEM career awareness.

Space Science Preparation

The lack of teachers who are prepared to teach Earth and space science challenges the implementation of space education in elementary classrooms (Wysession, 2013). As a group, elementary teachers have few experiences with space science experiences in their own K-12 and post-secondary science education. Typically, elementary space science content is limited to learning about the planets and the solar system. Fortunately, renewed emphasis on Earth and space science in the newly released Next Generation Science Standards ([NGSS], NGSS Lead States, 2013) suggests new pathways and topics for learning about space systems. For example, learning progressions (across grades1-5) guide students from an observational understanding of the sky to a more sophisticated use of data and scientific modeling.

Indeed, there is an emerging need to engage elementary teachers in improving Earth and space education and to provide professional development for preservice elementary science teachers. Research suggests that engagement with space education content can improve teachers' knowledge base and introduce them to a broad range of curricular materials available through NASA's education programs (MacLeish et al., 2008). Placing science learning in the context of space explorations helps to create exciting science classroom content, encourage space career awareness, and incorporate global perspectives about an interconnected world.

Science Teaching Self-Efficacy

Borko and Putnam (1995) reasoned that teachers "must acquire richer knowledge of subject matter, pedagogy, and subject-specific pedagogy; and they must come to hold new beliefs in these domains" (p. 60). Enochs, Scharmann, and Riggs (1995) indicated that teachers with low science teaching efficacy are more likely to avoid teaching science than those teachers with higher levels of science teaching efficacy. Personal teaching self-efficacy is understood as the belief in one's own ability to effectively present the knowledge, perform the processes, and guide students toward understanding (Bandura, 1977; Khourey-Bowers & Simonis, 2004).

Teaching self-efficacy is context specific (Bandura, 1982; Pajeres, 1996). Teaching self-efficacy scales need to focus on both teaching and learning outcomes—thus the development of subject specific instruments such as the Science Teaching Efficacy Belief Instrument (Riggs & Enochs, 1990). Research suggests efficacy beliefs are influenced by teacher attitudes and anxieties about science (Westerback, 1982; Westerback & Primavera, 1988). Woolfolk and Hoy (1990), however, provided evidence that preservice teachers might demonstrate improved science teaching self-efficacy beliefs during their early career formation.

Perception of Science and Scientists

Historically, elementary teachers hold stereotypical images of scientists that relate to negative images of science. It is important for teachers to have accurate perceptions of science and scientists because they can inadvertently relay their perceptions and attitudes of science and scientists to their students (Milford & Tippett, 2013). Further, children may not pursue a science career due to the negative images associated with scientists (Fung, 2002; Kahle, 1988). The research literature suggests that preservice elementary teachers enter their science methods course with a stereotypical understanding of science and scientists (Abd-El-Khalick & Akerson, 2004; Moseley & Norris, 1999; Rubin, Bar & Cohen, 2003). Thus, developing a better understanding of preservice teachers' views toward science and scientists is important to further understanding how teachers' negative views toward science and scientists influence their instruction of science in the classroom (Kahle, 1988; Rosenthal, 1993).

STEM Career Awareness

MacLeish and Thomson (2010) outlined the potential benefits of space education for STEM education reform and for the development of a global space science workforce. Recent reports from educational research and outreach programs suggested that more efforts are required to increase public understanding about STEM careers (Harris Interactive, 2012) and promote the importance of early exposure to STEM careers (e.g., Morton, Kryk, Awender, & Diubaldo, 1997; Tai, Qi Liu, Maltese, & Fan, 2006). Research findings indicated that children often have limited notions about career choices beyond professional athlete, police officer, and teacher (e.g., Bobo, Hildreth, & Durodoye, 1998; McMahon, Carroll, & Gillies, 2001; Thomas, 2013). Additionally, Howard and Walsh's (2010) research on career awareness confirmed a range of self-reflection and understanding about career choices and attainment—from fantasy and magical thinking to higher order reasoning, which considers personal interests, abilities, and job requirements.

Schools and teachers can play an important role in increasing student awareness, interest, and self-efficacy about careers (McMahon, Gillies, & Carroll, 2000). Some research explores age-appropriate career education (McMahon & Watson, 2008), but very little is known about teachers' career awareness or their efforts to raise students' STEM career awareness (Hulings, Thomas, & Orona, 2013). In fact, students may not be exposed to STEM careers in K-12 classes. As Causer (2010) found, 64% of students indicated that their teachers are NOT doing an adequate job of effectively talking to them about engineering careers. Moreover, 42% of students reported that teachers are inadequately teaching students how science is used in careers.

Purpose and Research Questions

This project, *Pioneers in Space*, intended to engage both PSTs and middle school students in discussing the benefits of space research, while drawing on themes relevant to students' regional history. We hoped to promote a greater understanding of how space exploration benefits society and contributes to STEM innovations. The purpose of this research was to examine how participation in the *Pioneers in Space* project impacted the PSTs. As such, this study asks: How does an experiential NASA learning experience impact PSTs' ideas about the teaching and learning of space science?

Methods

Participants

Participants were senior undergraduate elementary education majors enrolled in an elementary science methods class during the semester prior to their student teaching. These students sought generalist certification for grades 1-8. Nearly all students enrolled in the class (31 out of 32, or 97%) participated in the study. Of the 31 participants, most self-identified as female (two as male). While 29 participants self-identified as white, one self-identified as Hispanic/Latino and one as American Indian.

Context of the Study

Researchers first earned NASA's support for a proposal, *Pioneers in Space: STEM Careers on the Space Frontier*. This collaborative project, (organized by researchers, local middle school teachers and school leaders), engaged PSTs as leaders in preparing middle school students for a NASA ISS downlink. Downlink preparation organized multiple opportunities for developing middle school science lessons (led by PSTs and middle school teachers). Within their elementary science methods course, the PSTs (n=31) began by reviewing online NASA education resources. These lessons demonstrated the difference between mass and weight (on earth and in micro-gravity) by comparing classroom results with video clips previously filmed by astronauts performing similar activities onboard the ISS. In particular, these lessons focused on Newton's Second Law of Motion (F=ma). The goal of these lessons was to guide middle school students' preparation of informed questions for Commander Ford at the time of the live ISS downlink; these questions guided the format of the 20-minute downlink.

Methods class preparation. In groups, PSTs prepared lessons that would link STEM career opportunities with life on board the ISS. During this process, it became apparent to the instructor and the PSTs that their lack of space science content knowledge hindered the lesson development process. Given the impending timeline of the ISS downlink, the course instructor sought expertise from NASA Education Specialists to select preexisting NASA lessons. Eventually, the instructor selected lessons titled *Mass vs. Weight: A Heavy Duty Concept* from the Stennis Space Center (National Aeronautics and Space Administration, 2010) about the behavior of mass and weight on Earth and in microgravity environments. During the science methods class, the course instructor modeled the Mass vs. Weight lessons. Wearing their *student hats*, the PSTs practiced the lesson experiments in the methods classroom, which included predicting, recording, analyzing, and interpreting collected data about the behavior of masses. Then, PSTs predicted how they thought the same masses would behave in a microgravity environment. Next, PSTs watched a video of astronauts performing the same mass vs. weight activities on the ISS and compared their predictions to actual microgravity behavior. Finally, wearing their *teacher hats*, the PSTs worked in small groups to practice teaching the lessons to each other prior to their authentic field experience in the middle school setting.

Collaboration with middle school teachers. Three science teachers at the middle school led participant sixth graders through a web quest on the NASA Website: *International Space Station: Painting the World Green* (*http://www.nasa.gov/externalflash/issgreen/index.html*). This website provided students an opportunity to learn (a) about contemporary life onboard the ISS and (b) how astronauts must maximize energy usage and use innovative technologies to support life on board the ISS. Then, middle school teachers led students through the first lesson from the Mass vs. Weight series: *Careers in Space*. This introduction helped prepare sixth graders for the PSTs' lessons in the following week.

Middle school lessons. Before PSTs taught at the middle school, the science methods course instructor assigned them to one of 6 groups (with 5-6 PSTs in each group) to cover the three 6^{th} grade science sections each hour. Half of the PST groups taught the morning class sessions and the other PST groups taught the afternoon sessions (wherein PSTs had the opportunity to repeat teaching the same lessons at least three times). While teaching the lessons, each PST worked with a table group of students within the classroom. One PST would serve as the facilitator to help pace the lessons and to present the ISS video microgravity demonstrations.

ISS downlink experience. The NASA downlink experience was a full-scale community event held on the university campus approximately one-week after the PSTs completed their teaching at the middle school. The middle school students were transported to the event by bus. The PSTs greeted each bus of students as they arrived on the university campus and escorted them into the viewing room. Other attendees included interested school, community, university faculty/students, and NASA officials. Illustrative of the collaborative nature of the event, the middle school librarian served as master of ceremonies and entertained the students while NASA personal prepared for contact with Mission Control and the ISS.

During the first 30 minutes prior to the downlink program, a NASA Education Specialist made a presentation about space survival. He demonstrated different types of food that astronauts eat in space and how they attend to personal biological functions (a topic of interest for sixth graders). Further, he invited three middle school teachers and three middle school students on the stage to try on different pieces of a space suit and explained important survival features of the suit components.

At the onset of the actual downlink, a hush fell over the crowd when they first heard Mission Control direct Commander Ford on the ISS and Stillwater Middle School students to prepare for downlink. When Commander Ford appeared on the big screen, the crowd erupted in cheers and applause. Importantly, 20 middle school students (selected by their classroom teachers) and one PST (nominated by her peers) brought prepared questions they would ask Commander Ford. These participant questions both organized the 30-minute downlink and helped Commander Ford establish a personal connection with the audience at large.

Off-site individuals and classrooms could access the live event via a live video feed streamed on the Internet. Ultimately, the live event had over 6,500 Internet hits; however, the total number of individuals reached is difficult to ascertain as a single hit could include classrooms of students. Additionally, the event is archived at http://bit.ly/1wxCE2b for future viewing.

Design

This case study followed the *participant-as observer* model (Spradley, 1980) wherein the lead researcher was also the instructor for the elementary science methods course. The case study approach allowed researchers to "explain causal links in real-life interventions that are too complex for the survey or experimental strategies" (Yin, 1995, p. 25). Researchers followed mixed methods (Creswell, 2003) procedures wherein both quantitative and qualitative data were collected simultaneously.

Measures and Analysis

Multiple measures assessed the impact of the experience on the preservice teachers' self-efficacy and beliefs toward space science teaching, their perceptions of space scientists, and their overall perceptions of the experience. Researchers entered data for the Space Science Teacher Efficacy Beliefs Instrument (S-STEBI) and the Draw-A-Space-Scientist Test (DASST) into IBM SPSS Statistics v21 for statistical analysis. Due to the small sample size and heteroskadiscity of data, researchers utilized the nonparametric Wilcoxon Matched Pairs Sign Ranks test (Siegel, 1956). Description of quantitative measures, qualitative prompts, and analysis methods follow here below.

Science Teacher Efficacy Beliefs Instrument-Space. Researchers developed the Space–Science Teacher Efficacy Beliefs Instrument (STEBI-Space) by adapting the Science Teacher Efficacy Beliefs Instrument (Enochs & Riggs, 1990), a 23-item questionnaire specifically developed to assess PST's efficacy of *space* science teaching. The original STEBI consists of two subscales: (a) Personal Science Teaching Efficacy (PSTE) and (b) Student Teaching Outcomes Expectancy (STOE). Researchers modified the STEBI by revising the 13 PSTE subscale items to specifically reference space science rather than science in general. For instance, the Personal Space Science Teaching Efficacy Beliefs (PSSTE) subscale included statements such as:

- I look for better ways to teach *space* science concepts.

- I understand *space* science concepts well enough to be effective in teaching s*pace* science.

Researchers' creation of the STEBI-Space followed Rubeck and Enochs' (1991) development of the STEBI-CHEM. These researchers modified the STEBI in order to measure teachers' self-efficacy and science teaching outcome expectancy in teaching chemistry. Reliability and factor analysis studies conducted by Rubeck and Enochs indicated that the PSTE and STOE constructs of the STEBI-CHEM remained intact. In this study of the STEBI-Space, researchers were not able to construct validity through factor analysis due to the small sample size. Instead, researchers established face validity by consulting three different faculty with expertise in space science education and teacher efficacy.

Administration of pre/post surveys measured changes in teachers' beliefs toward space science teaching and learning over the science methods course. The instrument includes 23 items wherein participants responded using a five-point Likert type scale ranging from Strongly Disagree to Strongly Agree. Scoring was accomplished by assigning a higher score to the positively phrased responses (5 = strongly agree, 4 = agree) and a lower score to the negatively phrased responses (2 = disagree, 1 = strongly disagree). (*Note: Twelve items were reverse-coded because they were negatively worded items.*) The range of scores possible on the PSSTE is 13-65. The range of scores possible on the STOE is 10-50.

Draw-A-Space-Scientist Test. According to Finson and Pedersen (2011), instruments like Draw-A-Scientist allow participants to transform their mental concepts about scientists into visual data by recording information into a form that researchers can analyze. In this study, researchers looked to the long established model of the Draw-A-Scientist Test ([DAST], Chambers (1983), to assess PSTs' conceptions of a *space scientist*'s work and followed the modified Draw-A-Scientist Test (mDAST, Farland-Smith, 2012; Farland, 2003) format and scoring procedures. The mDAST format asks participants to draw three images rather than the one single image common to the DAST. Researchers hypothesized this three-illustration-expectation would illuminate greater depth and breadth of participants' understanding of *space scientists.*

Researchers followed Farland-Smith's (2012) recommended mDAST data collection (wherein PSTs drew and described three images of a space scientist). mDAST scoring procedures guided researchers review of the following space scientist features: *appearance* (what space scientists look similar to), *location* (where space scientists work), and *activity* (what space scientists do). Finally, researchers averaged participants' scores for each of these features across all three images to determine significant pre-to-post differences according to these factors.

Researchers followed Miles and Huberman's (1994) multiple procedures to verify our data. Recognizing the likely bias as preservice teacher educators (*objectivity*), researchers held frequent meetings to insure high inter-rater consistency among the researchers and graduate research assistant over time (*dependability*). Researchers continued data analysis and discussions to refine the coding, define the themes, inter-relate the mixed-methods results (*authenticity*), and establish recommendations and likely implications (*applicability*).

End of project reflections. Following the ISS downlink, the PSTs responded to researcher-developed, open-ended questions aimed to gain a deeper understanding how the downlink experience impacted the PSTs' awareness of teaching space science. Specifically, the PSTs responded to the following prompts:

- What did you learn about yourself as a teacher of space science concepts through your experiences with the NASA Downlink?
- How did your preparation to teach lessons at the middle school influence your thoughts on the teaching of space science concepts?
- How did teaching the NASA space science lessons influence your thoughts on the teaching of space science concepts?
- How did the NASA Downlink experience with Commander Kevin Ford on board the International Space Station influence your thoughts on the teaching of space science concepts?

These narrative data were analyzed by constant, comparative analysis, and results were organized into themes as guided by this analysis (Merriam, 1988).

Results

This section organizes the findings of the study by measures: (a) Science Teaching Efficacy Beliefs Instrument-Space, (b) Draw-A-Space-Scientist Test, and (c) End of Project Reflections.

Science Teaching Efficacy Beliefs Instrument-Space (STEBI-Space)

A Wilcoxon Matched Pairs Signed ranks Test (Siegel, 1957) pointed to significant gains in participants' space science teaching efficacy and beliefs. Table 1 indicates that PSTs made significant gains on the PSSTE scale ($Z = -4.786$, $p < .001$). Of particular interest, the minimum score on teachers' PSSTE increased by 17 points. Changes in PSTs' STOE score were also statistically significant ($Z = -2.476$, $p = .013$).

Table 1

Changes in preservice teachers' (n=30) scores on the Science Teaching Efficacy Beliefs Instrument-Space (STEBI-Space)

Subscale	Pretest			Post-test				
	Min.	Max.	*Mdn*	Min.	Max.	*Mdn*	*Z*	*p**
PSSTE[1]	22.00	56.00	40.00	39.00	65.00	52.00	-4.786	<.001
STOE[2]	29.00	41.00	36.00	32.00	47.00	37.00	-2.476	.013

Note: [1]Personal Space Science Teaching Efficacy; [2]Science Teaching Outcomes Expectancy. *The difference in the participants' responses were statistically significant, $p < .05$.

Draw-A-Space-Scientist Test

Table 2 displays descriptive statistics for PSTs' scores on the Draw-A-Space-Scientist Test. Application of the Wilcoxon Matched Pairs Signed Ranks test indicated that the PSTs made statistically significant gains in their perceptions of the location of where space scientists conduct their work ($Z = -4.686$, $p < .001$). Although the median scores for teachers increased on *Appearance* and *Activity* themes, pre/post scores of these subscales were not statistically significant.

Table 2

Changes in preservice teachers' (n=31) scores on the Draw-A-Space-Scientist Test (DASST).

DASST Subscale	Pretest			Post-test				
	Min.	Max.	*Mdn*	Min.	Max.	*Mdn*	*Z*	*p**
Appearance	0.67	3.00	2.33	0.67	3.00	2.33	-.858	.391
Location	0.00	2.67	2.00	1.00	3.00	0.67	-4.868	<.001
Activity	0.67	2.67	2.00	0.67	2.67	2.00	-.797	.425

NOTE: *The difference in participants' responses were statistically significant, $p < .05$.

While reviewing PSTs' illustrations of a space scientist, researchers became interested in understanding how the pre-to-post illustrations differed qualitatively in terms of the realism of the space science portrayed. To supplement the DASST analysis, researchers completed a post hoc qualitative analysis of the PST's illustrations (n = 93). Independently, researchers examined the images and followed an iterative open coding process to identify common themes related to misconceptions or misunderstanding about space science. Then, each of the PST's pre-to-post images were coded along six emergent themed categories: Realistic and Current, Realistic but Outdated, Fantasy/Science Fiction, Classroom Teacher, Naïve Conception, and Vague Conception. See Table 3 for explicit descriptions of each category.

Table 3

Themes for holistic qualitative analysis of Draw-A-Space-Scientist Test

Themed Category	Theme Description
Realistic and Current	Image displays a space scientist doing realistic and current work (i.e., designing a rover to land on Mars; working on the International Space Station).
Realistic but Outdated	Image displays a space scientist doing realistic work but the work is outdated (i.e., landing on the moon).
Fantasy/Science Fiction	Image displays nonrealistic work of scientist as science fiction or fantasy (i.e., driving a rocket past Saturn; talking to aliens in space).
Classroom Teacher	Image portrays the space scientist as a teacher in a classroom setting.
Naïve Conception	Image portrays immature ideas about the work of a space scientist (i.e., stargazing with naked eye; using a home telescope).
Vague Conception	Image does not provide enough information to classify.

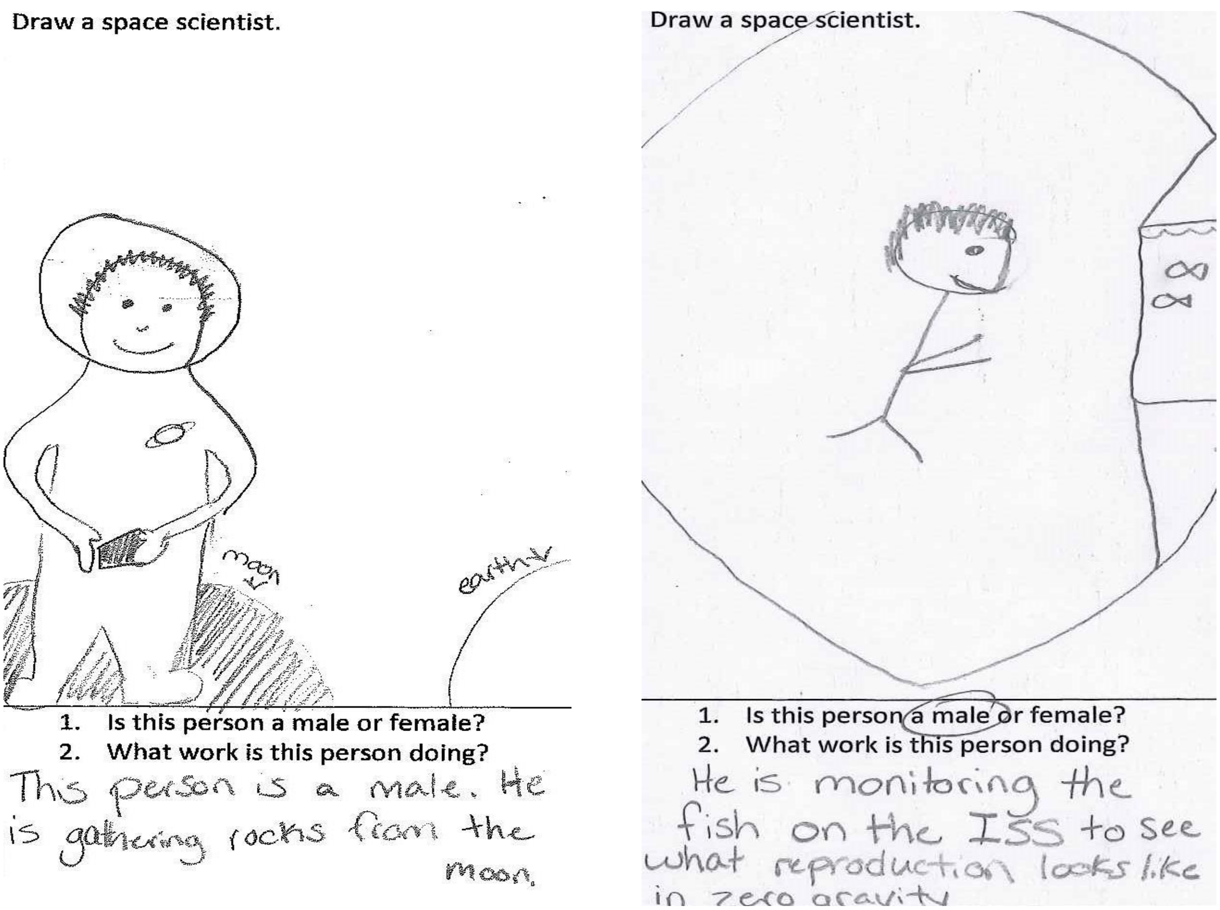
Qualitative changes in PSTs' space scientist illustrations are displayed in Table 4. This view of the space scientist illustrations suggests PSTs' overall experience in the *Pioneers in Space* project helped to replace naïve, outdated, fantastical ideas about the work of space scientists with more current, realistic understanding of space scientists' work.

Table 4

Distribution of preservice teachers' space scientist illustrations (n=93)

Theme	Pre (%)	Post (%)
Realistic and current	40.86	68.82
Realistic but outdated	20.43	12.90
Fantasy/Science Fiction	16.13	2.15
Naïve Conception	10.75	5.38
Vague Conception	7.53	3.23
Classroom Teacher	4.30	7.53

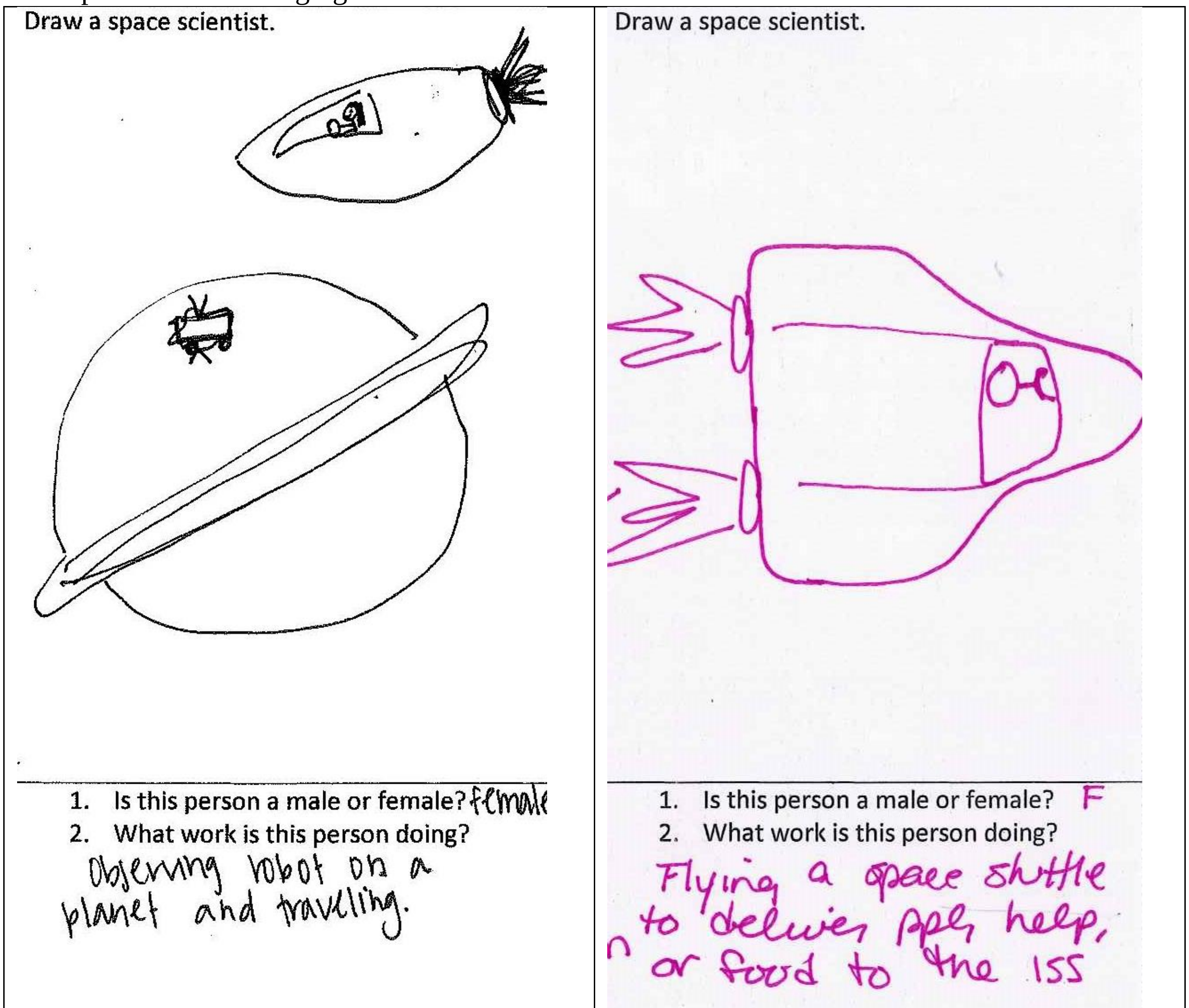
Figure 1 provides an example of how one PST's illustrations of a space scientist evolved from realistic-and-outdated to realistic-and-current. The image on the left depicts a realistic-and-outdated image of a space scientist collecting rocks on the moon. In the image on the right, the same PST drew a more current depiction of a space scientist observing fish on board the ISS (reflective of actual research taking place on the ISS).



PRE **POST**

Figure 1. Example of pre-to-post changes in PST's illustrations of space scientists: from realistic-and-outdated to realistic-and-current.

Figure 2 provides an example of how another PST's illustrations evolved from science fiction/fantasy to realistic-and-current. The image on the left depicts a science fiction view of the work of space scientists (the astronaut is "driving" the space ship past another planet to observe a robot). In the post-illustration, the same PST drew a more realistic and current image of a space scientist bringing items to the ISS.



PRE	POST

Figure 2. Example of pre-to-post changes in PST's illustrations of space scientists: from science fiction/fantasy to realistic-and-current.

End of Project Reflections

Researchers identified three major themes in a qualitative analysis of PST's final project reflections: Teaching is Learning, Students are Interested in Space, and Space Science is the Future.

Teaching is learning. These PSTs first identified themselves as learners in the *Pioneers in Space* project. While they were initially concerned about their limited knowledge of space science and their great fear of teaching sixth graders at the middle school, these PSTs came to recognize their own prior misconceptions – about space science and about themselves. As one PST summed it up, "[When we began this project,] I knew random facts about space (such as people float in space and wear very heavy suits) [but] I had to relearn the idea of gravity in order to explain to students the idea of weightlessness in space." Another of the PSTs recognized her misconceptions going into the lesson development and classroom teaching, but discovered that "Teaching is definitely a doorway to learning. I learned so much as I taught the lessons." The ideas of teaching-as-learning were common across the class and seemed to encourage these PSTs. For one thing, the *Pioneers in Space* project introduced them to NASA websites which the PSTs found to provide "great resources and information about space science." As these PSTs came to learn more space science content, in the context of developing and teaching a space science lesson for sixth graders, they recognized new awareness of their own interest in science, which caused them to think about themselves as science teachers. One PST explained, "I never really thought about being a science teacher but this experience was so great. [It] showed me just how curious I am about space science."

Middle school students are interested in space. One theme that evolved was that the *Pioneers in Space* project helped the PSTs develop a new awareness of sixth graders' enthusiasm about space science learning. One surprised PST explained, "Teaching NASA space science opened my eyes . . . students were fully involved, engaged, and excited throughout the lessons." While PSTs recognized students' fascination with space created opportunity to "engage" and "foster students' ability to learn concepts of science such as mass and gravity," they also came to realize "space science is not just about creating the solar system with Styrofoam balls like [we] did in middle school." Further, PSTs were impressed by Commander Ford's enthusiastic interaction with the students during the ISS downlink. As one PST remarked, "Commander Ford inspired a whole new group of students to pursue space science careers. He was so relatable . . . just a normal guy who had an extraordinary dream."

Space science is the future. These PSTs developed new enthusiasm about space science as a result of their participation in the *Pioneers in Space* project. First, they came to think of space science as important science and "not just some silly dream for some students to think about but rather an interesting and important area [for all students] to learn about." As one PST reasoned, "It is important to teach our students about space science because it could be our future and could impact our society greatly." Once PSTs had completed their sixth grade space science teaching experiences and experienced the live, ISS downlink with Commander Ford, they had come to recognize how middle school science teachers might inspire the STEM workforce of tomorrow. As one PST reflected, "Even if I could reach one student with space science content, it would be completely worth it to push these future STEM and aerospace careers."

Summary and Discussion

The purpose of this study was to examine how participation in a NASA learning opportunity for middle school students affected preservice elementary educators. This study focused on a novel approach to introduce PSTs to space science education by including them in experiential space science learning opportunities. This section provides a discussion of the results.

First, these findings indicated that the *Pioneers in Space* project positively affected the PSTs' science teaching efficacy. The significant gains made by the PSTs on both subscales of the space-STEBI indicate that this experiential space science experience positively affected PSTs' personal space science teaching efficacy and their student outcome expectancy. Further, the quantitative findings from the Space-STEBI are further supported by the narrative, qualitative data in that the preservice teachers began to identify themselves as teachers of space science. These findings are consistent with other studies that examine the relationship between experiential learning and increases in science teaching efficacy in educators (Woolfolk & Hoy, 1990) and science content specific teaching efficacy (e.g., Rubeck & Enochs, 1991; Thomas, Ivey, & Puckette, 2013).

Second, the findings from this study indicate that the project positively influenced the PSTs' perceptions of space science careers. Results from the mDAST suggest that PSTs made significant gains in understanding the work location of space scientists (but not space scientists' appearance or activity); these results are likely due to the science lessons focused on the ISS and corresponding downlink experience. Notably, however, these gains also include an improved understanding of the context for space science on Earth, as well as space. This study helped to address the call from other researchers about the need for educational research and outreach programs to promote STEM career awareness (e.g., Morton et al., 1997; Tai et al., 2006) and to expand career options (Bobo et al., 1998; McMahon et al., 2001; McMahon & Watson, 2008). Additional holistic analysis of the mDAST images indicate that PSTs tended to draw more realistic illustrations (i.e. less fantasy or historical) of space scientists' work following their experiential learning experience. Supported by situated learning theory (e.g., Billett, 1996; Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), it is possible that the learning *and* teaching of these space science lessons provided the PSTs with an authentic context in which they had to immediately apply their learning as they taught middle school students.

Finally, this project positively impacted PSTs' ideas about the teaching and learning of space science. Qualitative analysis revealed PSTs observations of middle school students' excitement about space science learning and its' valuable pathway to better instruction and engagement in the middle school classroom. Nearly 20 years ago, Schoon (1995) found that preservice teachers help many of the same Earth and space science misconceptions as their students. The findings of this study indicate that preservice elementary teachers also hold misconceptions about space science and space scientists. Finally, the qualitative analyses indicated that PSTs had a new realization of space science as an important topic that needs to be included in the elementary classroom because today's elementary students have the potential to be tomorrow's space scientists.

This experience positively impacted PSTs' space science teaching efficacy beliefs, perceptions of space scientists and space science careers, and ideas about the teaching and learning of space science. In this study, PSTs made a connection between space science teaching and student STEM career preparation. Additionally, some PSTs found new interest in elementary science teaching and others found new interest in middle school teaching. Further, opportunities to repeat-teach the same space science lesson allowed them to solidify their understanding of the content and their pedagogy and provided important reflective opportunity between classes. Elementary teachers, who typically teach a lesson once to one group of students throughout a school year, do not get similar opportunity to reflect on and revise their teaching according to student responses.

Similar to middle school students (Bobo et al., 1998), PSTs' understanding of possible careers is influenced by their experiences. Events like the NASA ISS downlink offer a distal layer to PST education that influences their perceptions of potential space science careers; one which compliments other individual and socio-cultural influences (Ji, Lapan, & Tate, 2004), especially since many students may not have exposure to such space science careers. Further, this research suggests that, similar to elementary students (Auger, Blackhurst, & Wahl, 2005), PSTs' perceptions about space science careers are often based in fantasy and history. However, after this experiential learning experience they developed a more realistic, less fantasy-based, understanding of the work of a space scientist. As science educators work to raise awareness about space science careers and STEM workforce issues, the training of elementary teachers will be vital to helping children see that space career are indeed attainable. Certainly, these PSTs changed perceptions about the location of space science research, on both the ISS and on Earth, indicates that in-flight education downlink experiences and NASA curriculum are effective in this broader goal.

Overall, prior to this experience, the preservice teachers had a very limited understanding of space science content and space science careers. The assignment of teaching middle school space science lessons provided the PSTs with an authentic opportunity to learn and teach the material. It seems that multiple opportunities to experience the space science lessons, wearing both the student and teacher hats, afforded the PSTs an opportunity to become comfortable with the content so that they could successfully teach the lessons to and facilitate the questions of middle school students. The PSTs appreciated the learning and teaching of these space science lessons, but needed more explicit practice to become more competent in the teaching of other space science content. Further, the PSTs needed practice navigating and utilizing NASA resources for instructional purposes.

Implications/Recommendations

These results clearly justify the need to provide PSTs with more experiential learning opportunities related to space science content. The downlink with the International Space Station provided a capstone to the activity that also provided relevance for learning to both the preservice teachers and the middle school students. As such, it is important that science educators provide PSTs with more opportunities to authentically learn (and learn by teaching) space science content. Further, although it will be a challenge, science educators should find more ways to incorporate these types of learning opportunities into the methods classroom. Opportunities may include collaborating with neighboring schools or community centers to provide a family space science night much like the Family Science events (www.familyscience.org). Faculty may also collaborate on a proposal for an In-flight Education experience of their own.

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