Mission to Space: Evaluating One Type of Informal Science Education

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Abstract

Informal science education (ISE) programs serve as a method for developing, encouraging, and increasing both participation in, and enthusiasm for, STEM learning. One type of ISE program is provided by Challenger Centers through their space education curricula. Unfortunately, published evaluations related to space education programs are rare. The lack of research on informal space education programs has created a gap in our knowledge about the effectiveness of these programs in developing students' understanding of STEM related topics, their interest in STEM careers, and the connections they make to formal science learning outcomes. Even less is known about how subgroups of students respond to ISE space education programs. The purpose of this study was to report on the effectiveness of the space education program at one Challenger Center. Specifically, the attitudes and perceptions of middle school students on STEM related constructs were investigated at three points (pre, during, and post space mission), to determine how their beliefs changed over time. Additionally, we examined subgroups of students to further explore how involvement in the program influenced beliefs about STEM related constructs. Results demonstrate that students (N = 2945) felt very positive about their experience in the program and reported positive changes in attitudes and perceptions two weeks post-mission experience. Males (n = 719) had significantly greater changes in beliefs when compared to females (n = 748), and the program had a greater influence on the beliefs of students who are typically well represented in ISE programs (n = 949) compared to the subgroup of students who are typically underrepresented (n = 519) in ISE programs. Study limitations, future research, and implications are provided.

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Introduction

Informal science education (ISE) engages students in the excitement of scientific exploration and discovery, helps them recognize the importance of the scientific enterprise, and encourages their further involvement in science education (National Research Council, 2009; Brisson et al., 2010; National Science Teachers Association [NSTA], 2009). Increasing science and mathematics achievement over the next decade is one objective in President Obama's

"Educate to Innovate" campaign (White House, 2010). One approach toward meeting this objective is the establishment of partnerships between ISE and formal science systems (Brisson et al., 2010). ISE connects to formal education systems in a number of ways and can be an important part of science learning for students, in experiences that involve both "formal" and "informal" science. ISE presents itself in various formats such as informal education organizations (e.g., libraries, after-school programs) or science-rich cultural institutions (e.g., museums, zoos, centers). For many years science-rich environments, such as those available through ISE, have collaborated with schools to provide students, teachers and families with opportunities to enhance experiences with, and comprehension of, science-related information (Bevan, et al., 2010). Phillips, Finkelstein, and Wever-Frerichs (2007) found that more than 70% of science-rich cultural institutions in the United States have programs specifically designed for school audiences. These settings offer experiences that promote different kinds of engagement and support various types of learning styles (Bevan, et al., 2010; Lemke, 2001; Munley & Rossiter, 2013).

Literature Review

Benefits of ISE

The short-term benefits of ISE have been researched more extensively than the long-term benefits of ISE. Evaluations of informal science programs have been found to improve children's attitudes about science (Birinci Konur, Şeyihoğlu, Sezen, & Tekbiyik, 2011; Wulf, Mayhew, & Finkelstein, 2010), stimulate their interest in pursuing careers in STEM fields (National Research Council [NRC], 2009; Tai, Lui, Maltese, & Fan, 2006), and increase their self-confidence about science (Birinci, et al., 2011; Mielke, LaFleur, Butler, & Sanzone, 2012). The importance of informal science programs, particularly in meeting the needs of specific subgroups of students (e.g., females; non-Caucasians), has also been well documented (Banks et al., 2007; Basu & Calabrese-Barton, 2007; Dotterer, McHale, & Crouter 2009; Falk & Dierking, 2010; McCreedy & Dierking, 2013; Munley & Rossiter, 2013; Schwartz & Noam, 2007).

Research on the benefits of ISE for females is fairly extensive. Although some researchers have found no differences between boys and girls as related to attitudes about science (Greenfield, 1996), extensive research reviews have found that girls' tend to hold less positive attitudes toward science than do boys (Brotman & Moore, 2008; Weinburgh, 1995), and women exhibit less persistence in their pursuit of science careers than do men (Xie & Shauman, 2003). Statistics are clear that females do not earn as many mathematics, engineering, or physical science degrees as males (Rosser & Taylor, 2009), nor are equally represented in STEM related careers, specifically in engineering, computers, and technology (Landivar, 2013). In light of these findings, researchers have identified variables that tend to support girls in ISE settings. Munley and Rossiter (2013) conducted a review of the literature on female students and STEM education in ISE settings and reported that when compared to males, females benefit from learning that takes place in science education centers, incorporates hands-on learning, includes collaboration, and occurs within environments that foster positive relationships. Girl Scouts of the USA (2008) reported similar findings.

Short-term benefits of ISE have also been found for students typically underrepresented in science fields (e.g., students who are Hispanic or African-American and who are reported to have less exposure to ISE than their non-Hispanic, Caucasian peers). For example, Sorge and

Newsom (2000) investigated the attitudes of Hispanic middle school students toward science in an ISE program and found that participants reported positive attitudes toward science. In the first semester of the program Hispanic males made significant gains on post-test survey items related to science attitudes and in the second semester Hispanic males and females both made significant improvement. Similarly, a 10-year retrospective evaluation of Project Exploration found that participating in one or more of its ISE programs led to increased student interest and confidence as reported by 200 of its 1,000 alumni (85% of whom were from low-income groups typically underrepresented in informal science activities). Moreover, Project Exploration staff report that 95% of their students who had attended a "field program" related to informal science graduated from high school (Chi & Snow, 2010). Beyond attitude and identity formation, positive academic outcomes for students from underrepresented groups have also been associated with learning science in informal settings (NRC, 2009). Despite reports of short-term ISE gains for underrepresented racial and ethnic populations, they continue to be sorely underrepresented in STEM degree programs and careers (Atwater, 2000; Landivar, 2013).

Long-term benefits of ISE have also been reported in the literature. Gibson and Chase (2002) found that middle school students who attended a two-week informal summer science program retained a more positive attitude toward science and a higher interest in pursuing a science career than students who wanted to attend the program but were not randomly selected to attend (keeping the motivation variable consistent), and students who chose not to apply for the program. This outcome was measured for five years after completion of the program. A different, but frequently reported long-term outcome is the relationship between ISE and the choice of a science degree in college (Allison & Hibbler, 2004; Bouzo, 2012; Rahm & Ash, 2008). For example, graduate students in science interviewed by Wang (2004) reported that their motivation to earn an advanced science degree was fueled in part by their positive experiences in informal science settings while they were growing up. A related finding is the reported relationship between ISE and the pursuit of a career in a STEM field (Tai et al., 2006). Similarly, NRC (2009) reported that participation in ISE programs as children increases the likelihood of adults choosing science-related careers. Interestingly, researchers have found that an interest in science and development of a science identity at a young age play a larger role than levels of academic achievement when it comes to pursuit of careers in math and science; specifically, science-related aspirations held by middle school students was found to be a much better predictor of continuance in the STEM pipeline than science-related achievement (Tai, et al., 2006). Academic achievement and/or innate ability contribute to students' sustained interest in STEM but, alone, are insufficient predictors (Riegle-Crumb, King, Grodsky, & Muller, 2012; Xie & Shauman, 2003).

Evaluating ISE programs

Evaluations of ISE programs continue to pose challenges as programs are often "individualized, complex, and multifaceted" (Friedman, 2008, p.12), and validated instruments to measure student engagement are not readily available (NRC, 2008). However, as ISE programs proliferate, experts strongly encourage program evaluation in order to better understand the impact of these programs on individual student outcomes (Friedman, 2008). Despite their diversity, ISE programs share many common goals and the NRC provides one possible framework that could "serve as a conceptual tool for organizing and assessing science learning" (NRC, 2009, p. 4). The NRC's framework is composed of six strands and each strand represents a student-learning outcome. For example, strand 1 includes the potential for learners to experience interest and excitement about scientific phenomena, strands 2 through 4 focus on the opportunities for students to improve their conceptual knowledge and observation and prediction skills, strand 5 includes participatory activities that involve cooperation and communication with others, and strand 6 focuses on the development of a science identity. All of these strands have been identified as important science outcomes for students and most have been identified as predictors to students' interest in, and pursuit of, STEM careers (Bolling, 2012; Chun & Harris, 2011; Diamond, 1999; Eccles & Barber, 1999; Falk, Randol, & Dierking, 2012; Larson & Verma, 1999; McCreedy & Dierking, 2013; NRC, 2009). Professionals involved in the development of ISE programs could use the NRC framework to articulate program goals, identify desired student outcomes, and create evaluations aligned with these outcomes. In this way, diverse ISE programs would be able to share a common framework to help define their individual program goals and outcomes.

Space Science as One Type of ISE

Evaluations of informal space science programs, in particular, are not readily available. The National Aeronautics and Space Administration (NASA), through its Informal Education Program (IEP), provides funding to support ISE programs including but not limited to after-school programs, museums, and science centers (NASA Informal Education website, 2010), but the IEP has been evaluated as making "relatively few demands on projects to document their activities and/or accomplishments" and this "lack of tracking, documenting, and reporting practices appears to be the result of absent or inadequate internal systems and minimal accountability requirements" (Rulf Fountain & Jurist Levy, 2010, p. ii). An entity closely tied to NASA's IEP is its Elementary and Secondary Education Program (ESEP) and ISE programs that receive funding through NASA are sometimes funded through this agency (Rulf Fountain & Jurist Levy, 2010). Like the IEP, the ESEP has also been critiqued as lacking a systematic evaluation system (NRC, 2008). In a comprehensive evaluation of the ESEP, the NRC concludes that "Few of NASA's projects have been formally evaluated, and none has been evaluated rigorously" (p. 4).

Although published evaluations of space programs are scarce, two space science programs have reported positive outcomes in the literature. Specifically, the Space Science Education Program (SSEP) hosted by the University of New Mexico and attended primarily by middle school students of Hispanic ethnicity (88%), reports positive pre-post survey gains for both males and females on attitudes and perceptions about science and scientists (Sorge, et al., 2000). In their evaluation of NASA's IEP, Rulf Fountain & Jurist Levy (2010) reported outcomes of one longstanding program specifically focused on space sciences, Astro Camp. Located at Stennis Space Center in Mississippi, this camp caters to middle grade students with the primary goal of educating and inspiring students to consider futures in space science and STEM fields. The Center hosts approximately 600-700 students per year during spring Saturday and summer multi-day sessions, 95% of whom "reported that they learned something new about science" when surveyed (p. 20). Most of the data reported by space science programs, however, pertain to input variables such as participation rates.

Challenger Centers. One example of ISE in the field of space sciences can be found within the opportunities provided to students at Challenger Centers. Rising from the loss of the

Challenger 7 space shuttle in 1986, the first Challenger Center for Space Science Education (Challenger Center for Space Education, 2014a) opened in 1988 in Houston, TX. Presently 46 Challenger Learning Centers (designed specifically for school-aged students) exist in four countries with the United States housing 40 of these Centers (Challenger Center for Space Education, 2014b). The mission of the Challenger Centers is to "Engage students and teachers in dynamic, hands-on exploration and discovery opportunities that strengthen knowledge in science, technology, engineering, and mathematics (STEM), inspire students to pursue careers in these fields, and provide an outlet to learn and apply important life skills" (Challenger Center for Space Education, 2014c). The Centers collectively serve close to 400,000 students per year nationwide. At the core of the Challenger Learning Centers is the delivery of high-intensity, exciting STEM-focused space missions in multi-million dollar simulators. During each space mission, students engage in realistic role-playing as they assume the roles of Mission Control personnel and Space Station astronauts.

Colorado's Challenger Learning Center. One Challenger Learning Center is located in Southern Colorado and typically serves over 50 school districts, 300 educators, and 10,000 students per year focusing primarily on grades 6, 7, and 8. Each year the Center provides a comprehensive program that blends formal and informal learning environments. At the center of the students' experience is a simulator mission performed at the Center; this mission is supported through standards-based curriculum materials and teacher training. The Challenger experience includes a rigorous teacher-training program and instructional units with fully defined lesson plans that set the groundwork for the simulator mission so that students arrive with the appropriate background to succeed in the space station and mission control jobs they will perform. The Challenger Learning Center is one of numerous partners in the Colorado Consortium for Earth and Space Science Education (CCESSE, n.d.). For approximately 10 years, CCESSE has partnered with the United States Air Force Academy (USAFA) to provide National Defense Education Program funding for numerous local STEM non-profits. The U. S. Air Force and the Office of the Secretary of Defense have both lauded the CCESSE's partnership with USAFA and it has been recognized as a national model for STEM outreach (Crisler, 2011).

Evaluation of Challenger Learning Centers. As previously noted, a need has been identified in the literature for the expansion of the research base on ISE programs (Bevan et al., 2010; NRC, 2009); Challenger programs provide one kind of ISE. Although, it has been over 25 years since the first Challenger Center opened its doors in Houston, like other space science programs, research studies and evaluation reports of the effects of these Centers are limited. Questions remain unanswered about how students respond to their experiences at the Centers and how their engagement in one or more simulations influences their attitudes and beliefs about STEM fields. The Challenger Center website (2013) cites the McLain Report of 2011 as synthesizing over 20 years of data collected from student evaluations of their mission experience. Although the Challenger Center website shares that findings were positive, the report is not readily available. Despite the collaborative efforts of the CCESSE to initiate innovative changes to the Challenger Center program, few outcomes of the Center's success have been analyzed and published broadly. Therefore, it is necessary to evaluate how or when learning occurs within this program to inform not only the Challenger Center program, but the field of ISE. Thus, the current study has three main objectives: (1) evaluate changes in the attitudes and beliefs of middle school students after participating in a Challenger Center space mission, (2) investigate differences in attitudes and beliefs among subgroups of students, and (3) share the evaluation process used in the Challenger program as a potential model for other ISE space education programs.

Methods

Setting and Participants

The simulated space missions evaluated in this study occurred on site at the Challenger Learning Center in Southern Colorado. Data are reported for all students who attended the Challenger Learning Center for an on-site mission. Students ranged from grades 6-8 and attended 50 different schools representing 25 school districts across Southern Colorado. Student demographics can be found in Table 1. The race/ethnicity variable was dichotomized into two categories with subgroups typically well-represented in ISE programs (i.e., Asian/Pacific-Islanders, and Caucasians) classified into one subgroup and the typically underrepresented groups of African-American, Hispanic/Latino, and Native American classified as another subgroup. Students who identified as "Other" were also classified as underrepresented.

Race/ethnicity data were dichotomized for three reasons. First, because the evaluation was never intended to recommend specific actions for any specific subgroup, a need to analyze data by more specific subgroups was unwarranted. Second, previous ISE research has dichotomized this variable and has identified significant differences on some variables between under- and well-represented groups (Mielke, et al., 2012). Third, challenges exist with conducting post-hoc analyses across the various subgroups in the race/ethnicity variable when analyzing non-parametric data. The recommended procedure is pairwise permutations with a Bonferroni correction, a method used to address the problems associated with multiple comparisons (Siegal & Castellan, 1988). Because ethnicity had six levels in this study, it would have been necessary to conduct 15 pairwise permutations resulting in an alpha of .05/15, which would be overly conservative as well as tedious to interpret.

Table 1
Student Demographic Data

Ethnicity	Male	Female	Unknown	Total
African-American	93	97	2	192
Asian/Pacific Isl.	75	79	0	154
Caucasian	836	837	5	1678
Native American	68	79	0	147
Latino/Hispanic	205	221	0	426
Other	193	197	1	391
Unknown	4	4	7	15
Total	1474	1514	15	3003

Note. Students who selected "Other" as a category and students who selected multiple categories were coded as "Other"

Simulated Space Missions

Students completed one of three missions: (1) Return to the Moon, (2) Rendezvous with a Comet, or (3) Voyage to Mars. The three missions share a common role-playing element with students acting as astronauts, engineers, scientists, and/or mission controllers. The element of teamwork is embedded throughout all of the missions and if students do not learn to work together during their mission, it inevitably fails. Specifically, in Return to the Moon, students establish a permanent lunar base in order to conduct scientific observations and studies. In Rendezvous with a Comet, students plot a course to rendezvous with a comet, deploy a probe and collect scientific data. The mission appears to be routine but students are faced with unexpected challenges that can only be surmounted with the help of one another. Finally, in the Voyage to Mars mission, one crew of astronauts arrives on Mars to replace the existing crew but faces unexpected emergencies during their arrival. Students often complete missions across three years of visits to the Center, beginning with Return to the Moon, but completing missions in order is not required.

Student Survey Development and Validation

To draw conclusions on the effectiveness of the Challenger Learning Center Program, two surveys were created as evaluation tools. The majority of the survey items evaluated student perceptions of their content knowledge and their interest and enthusiasm toward STEM learning. These items were formed and placed into constructs based on literature provided on the evaluation of ISE as well as addressing goals from the six strands framework for ISE (NRC, 2009). Individual items align with strands 1 (sparking and developing interest and excitement), 2 (understanding science content), 4 (reflecting on science), 5 (cooperation and communication), and 6 (identifying with the scientific enterprise) (NRC, 2009). After developing an initial pool of items, seven were chosen for the “day of mission” survey and eight for the “pre-post” survey. Items were then placed into one of the targeted constructs (a) interest and enthusiasm, (b) content knowledge, (c) teamwork, and (d) gender equity in STEM. These constructs align with the NRC framework as well as other literature on evaluation of ISE programs. For example, interest and/or engagement has been recognized as an important and often measured variable in evaluating ISE programs (Rulf Fountain & Jurist Levy, 2010), “despite the inherent bias in such self-report data” (p. 4). Previous attitudinal surveys also have included items measuring interest and enthusiasm in STEM (Gibson & Chase, 2002; Policy Studies Associates Inc., 2012). Understanding and/or content knowledge is a construct proposed by Friedman (2008) and used by others in their evaluations of program impact (Arnold & Bourdeau, 2009; National Assessment of Educational Progress, 1996). Teamwork, our third construct, aligns with strand 5 of the NRC (2009) framework and with the goal of applying important life skills identified by Challenger Learning Centers (2013). Finally, we measured one item related to gender equity as aligned with developing a science identity (strand 6 of the NRC framework). The gender equity item was also included in light of previous research reporting differences across girls and boys in their perceptions about their own competence in science (Kahle & Meece, 1994), and particularly in physical science (Andre, Whigham, Hendrickson, & Chambers, 1999). Cronbach’s alpha scores were calculated to determine the internal reliability for the comprehensive evaluation tool as well as each identified construct (see below for scores).

Survey items for each of the missions reflected a five-point Likert scale with a score of “1” being strongly disagree to a score of “5” being strongly agree. Both directions and items were written at or below a 5th grade reading level (Flesch-Kincaid, n.d.). Each mission allowed for data to be collected at three points in time: (1) approximately one week prior to the mission (in the students’ classrooms), (2) during the day of the students’ visit to the Center (after completion of the mission), and (3) approximately two weeks after completion of the mission (in the students' classrooms). Because pre-and post-survey completion was conducted online in students' classrooms before and after attending the Challenger Learning Center, and not all classrooms completed the post-mission survey, the pre-post data do not reflect the total number of students who participated in a space mission at the Challenger Learning Center.

Data Collection

Day of evaluation. Students completed seven Likert-scale items (Cronbach's alpha = .86) and one open-end question on the day of their visit to the Challenger Learning Center (after completing their space mission). The primary aim was to evaluate the effectiveness of the mission experience on students' beliefs about their content knowledge, the importance of teamwork, and interest and enthusiasm related to space exploration, science and mathematics. The constructs demonstrated adequate internal consistency with Cronbach's alpha scores ranging from (.72 -.76). Three items aligned with the construct of interest and enthusiasm ("I had a lot of fun during this experience; I liked learning about science and math the way it was presented during this experience; I would like to be part of another Challenger Learning Center experience."). Two items aligned with the construct of content knowledge ("I have a greater understanding of science and math concepts because of my Challenger Learning Center mission; I learned a lot about science, math, and teamwork from my flight directors"), and two items aligned with the construct of teamwork ("I helped to make the mission successful; The mission taught me teamwork skills). Students also provided a written response to the question, "What did you like most about your Challenger Learning Center experience?" These data were analyzed qualitatively.

Pre-post evaluation. Students also completed an eight-item online survey approximately seven days before engaging in the mission and two weeks after completing the Challenger mission (Cronbach's alpha =. 69). These items were completed in their classrooms at their respective schools. Items were reflective of the three previously described constructs of interest/enthusiasm, content knowledge, and teamwork while adding an additional item on beliefs about gender equity (e.g., "Women and men are equally good at space exploration."). Internal reliability of constructs with multiple items ranged from .46 -.70. Four items aligned with the construct of interest and enthusiasm ("I am interested in finding out more about careers in science and math; I like math; I like science; I like technology"). Two items aligned with the construct of content knowledge ("I understand what scientists and mathematicians do; People who explore space "think like scientists"). One item aligned with the construct of teamwork ("I like working in teams rather than by myself"), and one item focused on student beliefs about gender equity in space exploration ("Women and men are equally good at space exploration"). It is important to note that none of the items duplicated those asked on the day of mission evaluation.

Data Analysis

As previously described, students participated in one of three missions and each of these missions had content-specific evaluation items. All missions, however, shared a core set of evaluation items. Responses to these items were collapsed and analyzed across the three missions. For each survey (day-of, pre, and post), Cronbach's alpha scores were calculated to assess the internal reliability of each measure (e.g., pre, post, and day of).

Quantitative data for all surveys were analyzed similarly. First, means and standard deviations were calculated for the Likert-scale items on each survey. Although data were ordinal in nature, means and standard deviations were calculated because these scores provide information related to the general "direction [of] the average answer" (University of Northern Iowa, n.d.). Then, to examine group differences across well-represented and underrepresented subgroups, a Mann-Whitney U test was conducted. This non-parametric test was chosen due to the ordinal nature of the data. Finally, for the pre-post surveys only, a paired sample t-test was conducted to examine changes at pre- and post-mission for the entire group as well as changes within each sub-group. Then, a Mann-Whitney U test was conducted to examine the significance of differences between subgroups at pre- and post-mission.

Qualitative data analysis was used to evaluate student responses on the day of, open-ended item asking students to reflect on what they enjoyed most about the mission experience. Several steps were implemented to enter and analyze qualitative data and to identify patterns of responses across participants. Initially, open coding was conducted to inspect responses for over-arching themes or key points. Second, analytical coding of participant responses was conducted. This approach allows for continuous grouping of open codes on participant responses to generate tentative categories (Corbin & Strauss, 2008; Merriam, 2009). Once preliminary categories were established, participant responses were recoded to target specific categories. Finally, themes were generated into seven categories: (1) impact on learning (e.g., "[I liked] the new information and the new perspective on space travel"); (2) learning style (e.g., "I enjoyed the hands on experience the best"); (3) STEM learning (e.g., "That I learned more about science and it got me more interested in space science and math . . ."); (4) real-life experience (e.g., "I liked that the mission was realistic and we had a chance to be space control and the astronaut"); (5) problem-solving (e.g., "I liked the unpredictability of the problems presented to us and the help given in solving those problems"); (6) collaboration (e.g., "I liked how we had to be a team and work together in order to have fun and stay safe); and (7) other (e.g., "I don't know"). Each response was coded for three separate variables: (1) positive or negative, (2) type of comment (i.e., general or specific), and (3) theme (to evaluate student perceptions of the program).

Results

Data were collected from over 3,000 students who completed a Challenger mission during 2011-2012. Online data were collected prior to students' visit to the Challenger Learning Center, during the day of their visit (after completing a space mission), and at post-mission.

Day of Mission Experiences

Results indicate that students rated their experience at the Center on the day of their mission as exceptional (see Table 2). The mean of each item was never lower than 4.04 (SD =1.02) on a five-point scale with the item "I had a lot of fun during this experience" rated as the highest by students (M = 4.61; SD = 0.88). However, when examining for differences between males and females, the Mann-Whitney U test revealed significant differences on three specific items, two under the interest/enthusiasm construct and one under the teamwork construct (see Table 3), with the mean scores for females being significantly higher than for males. A Mann-Whitney U test also revealed significant differences on five of the seven items when investigating differences between well- and underrepresented subgroups (see Table 4).

Specifically, the well-represented group reported higher scores on all five items; however, mean scores never varied by more than .19 of one point across the underrepresented and well-represented subgroups.

Table 2
Mean Scores on Day of Mission Items

Day of Mission Item	*N*	*M*	*SD*
I had a lot of fun during this experience.	2945	4.61	0.88
I have a greater understanding of science and math concepts because of my Challenger Learning Center mission.	2941	4.04	1.02
I helped to make the mission successful.	2944	4.41	1.01
I learned a lot about science, math, and teamwork from my flight directors.	2940	4.11	0.99
I liked learning about science and math the way it was presented during this experience.	2875	4.35	0.91
I would like to be part of another Challenger Learning Center experience.	2944	4.44	1.02
The mission taught me teamwork skills.	2945	4.25	1.05

Table 3
Day of Mission Items with Significant Differences for Gender

Day of Mission Item	*N*	*M*	*SD*	*z*
I liked learning about science and math the way it was presented during this experience.				-2.60**
Males	1409	4.31	0.93	
Females	1450	4.40	0.90	
I would like to be part of another Challenger Learning Center experience.				-1.96*
Males	1449	4.41	1.04	
Females	1479	4.47	0.99	
The mission taught me teamwork skills.				-2.01*
Males	1450	4.22	1.06	
Females	1483	4.29	1.03	

* $p < .05$. ** $p < .01$

Table 4
Day of Mission Items with Significant Differences for Race/Ethnicity Subgroups

Day of Mission Item	N	M	SD	z
I had a lot of fun during this experience.				-3.52**
Underrepresented	1113	4.54	0.96	
Well-represented	1817	4.66	0.82	
I have a greater understanding of science and math concepts because of my Challenger Learning Center mission.				-2.63**
Underrepresented	1113	3.98	1.05	
Well-represented	1813	4.09	1.00	
I learned a lot about science, math, and teamwork from my flight directors.				-2.49*
Underrepresented	1114	4.04	1.05	
Well-represented	1812	4.16	0.95	
I liked learning about science and math the way it was presented during this experience.				-5.33**
Underrepresented	1073	4.24	0.97	
Well-represented	1787	4.43	0.87	
I would like to be part of another Challenger Learning Center experience.				-3.26**
Underrepresented	1112	4.34	1.12	
Well-represented	1817	4.50	0.95	

* $p < .05$. ** $p < .01$

The day of evaluation also included student responses to an open-ended item asked at the conclusion of their mission experience. Student answers to this item were coded and analyzed thematically. A total of 427 open-ended responses were collected across missions investigating what students reported as “liking most” about their experience. An overwhelming majority (98.1%) reported positive responses related to their experience in the program Slightly more than 90% of those who reported positive experiences identified specific aspects of the mission that enhanced their experiences versus 9.1% who provided general information. For those participants that provided positive responses the highest percentage, 23.2%, shared a comment related to a direct impact on learning and 19.1% shared a comment about STEM learning in particular. Specific comments related to collaboration and teamwork were also noted by a large percentage of participants (17.8% and 20.8% respectively (Table 5). Responses were further examined using Chi-square analyses to identify group differences between gender and race/ethnicity subgroups on coded categories. No significant differences were found between subgroups on any of the categories.

Table 5
Student Perceptions of Challenger Center Space Mission

	n(%)
Type of Comment	
General	38(09.1%)
Specific	381(90.9%)
Themes	
Collaboration/teamwork	75(17.8%)
Impact on learning	97(23.2%)
Learning style	56(13.4%)
Problem solving	23(05.5%)
Real life experience	87(20.8%)
STEM learning	80(19.1%)
Other	1(0.20%)

Note. Frequencies and percentages are reflective of participants that had positive responses (n = 419).

Change Scores from Pre- to Post-Mission

In order to evaluate changes in student perceptions after completing the Challenger program, a pre-post survey was administered. The number of respondents who completed items at both pre- and post-mission ranges from 1,459-1,467; this does not equal the total number of students who attended the missions because of challenges associated with survey completion occurring in classroom environments prior to and following students' visit to the Challenger Learning Center. A paired sample t-test revealed significant differences on all items from pre- to post-mission (Table 6). More specifically, the entire sample reported higher scores post-mission, indicating a positive change in perception for all of the targeted constructs.

Table 6
Overall Mean Scores on Pre- and Post-Mission Items

Item	N	M	SD	*t***
I am interested in finding out more about careers in science and math.				-20.96
Pre-Mission	1464	2.52	1.12	
Post-Mission	1464	3.56	1.12	
I like math.				-18.11
Pre-Mission	1466	2.42	1.32	
Post-Mission	1466	3.54	1.32	
I like science.				-31.51
Pre-Mission	1459	2.20	1.11	
Post-Mission	1459	3.81	1.14	
I like working in teams rather than by myself.				-42.03
Pre-Mission	1467	2.04	1.09	
Post-Mission	1467	4.05	1.15	
I like technology.				-40.68
Pre-Mission	1461	2.02	1.04	
Post-Mission	1461	4.00	1.16	
I understand what scientists and mathematicians do.				-38.83
Pre-Mission	1464	2.23	0.94	
Post-Mission	1464	3.89	1.06	
People who explore space “think like scientists.”				-52.29
Pre-Mission	1464	2.11	0.80	
Post-Mission	1464	4.12	1.04	
Women and men are equally good at space exploration.				-74.51
Pre-Mission	1465	1.62	0.94	
Post-Mission	1465	4.53	0.97	

** $p < .01$

Table 7
Change Scores on Items with Significant Differences for Gender

Item	N	M	SD	*z*
I am interested in finding out more about careers in science and math.				-4.86**
Males	719	1.29	1.86	
Females	745	0.79	1.90	
I like math.				-5.34**
Males	718	1.45	2.24	
Females	748	0.79	2.41	
I like science.				-5.32**
Males	714	1.89	1.87	
Females	745	1.34	2.00	
I like technology.				-11.89**
Males	716	2.55	1.64	
Females	745	1.44	1.91	
I understand what scientists and mathematicians do.				-3.24*
Males	718	1.77	1.67	
Females	746	1.54	1.58	
Women and men are equally good at space exploration.				-6.14**
Males	717	2.66	1.65	
Females	748	3.16	1.29	

* $p < .05$. ** $p < .01$

Table 8
Change Scores on Items with Significant Differences for Race/Ethnicity Subgroups

Item	N	M	SD	*z*
I am interested in finding out more about careers in science and math.				-3.07*
Underrepresented	519	0.82	1.95	
Well-represented	944	1.15	1.85	
I like math.				-3.23*
Underrepresented	518	0.87	2.33	
Well-represented	947	1.25	2.35	
I like science.				-4.35**
Underrepresented	516	1.31	2.00	
Well-represented	943	1.77	1.91	
I understand what scientists and mathematicians do.				-3.42*
Underrepresented	517	1.45	1.72	
Well represented	946	1.77	1.57	
People who explore space think like Scientists.				-3.28*
Underrepresented	517	1.85	1.49	
Well-represented	947	2.10	1.42	
Women and men are equally good at space exploration.				-2.98*
Underrepresented	516	2.73	1.63	
Well-represented	949	3.02	1.42	

* $p < .05$. ** $p < .01$

Paired sample t-tests were also performed on subgroups of students. Mean scores were significantly different on all items at pre-post mission for males ($p < .001$) and on all items for females ($p < .001$). Similar results were found when analyzing pre-post changes for both of the race/ethnicity subgroups (well-represented and underrepresented). Both of these groups also recorded significant changes between pre- and post-mission on all items at $p < .001$.

Additional analyses were conducted to examine group differences on changes made from pre- to post-mission. Change scores were calculated by subtracting pre-mission score from post mission score on each item for each subgroup. A Mann-Whitney U test revealed significant differences between change scores for males and females on all eight items. Males' perceptions changed more significantly than females on five out of the eight items (Table 7) indicating males made greater gains. On these five items, the four items representing the interest/enthusiasm construct revealed the greatest differences with all of them revealing at least one-half point difference between the two groups: (a) I am interested in finding out more about careers in science and math, (b) I like math, (c) I like science, and (d) I like technology. Females made significantly greater gains (one-half of one point) than males on only item: "Women and men are equally good at space exploration."

Table 8 shows significant differences on change scores across the race/ethnicity subgroups on six out of the eight items. The subgroup classified as well-represented in ISE activities made significantly greater gains than the underrepresented group on all six of the items that revealed significant differences. Significant differences were found on both of the content items, three out of four of the interest/enthusiasm items, and the only item related to beliefs about gender equity. No change scores across subgroups varied by more than one-half of one point.

Table 8
Change Scores on Items with Significant Race/Ethnicity Differences

Item	N	M	SD	*z*
I am interested in finding out more about careers in science and math.				-3.07*
Underrepresented	519	0.82	1.95	
Well-represented	944	1.15	1.85	
I like math.				-3.23*
Underrepresented	518	0.87	2.33	
Well-represented	947	1.25	2.35	
I like science.				-4.35**
Underrepresented	516	1.31	2.00	
Well-represented	943	1.77	1.91	
I understand what scientists and mathematicians do.				-3.42*
Underrepresented	517	1.45	1.72	
Well represented	946	1.77	1.57	
People who explore space think like scientists.				-3.28*
Underrepresented	517	1.85	1.49	
Well-represented	947	2.10	1.42	
Women and men are equally good at space exploration.				-2.98*
Underrepresented	516	2.73	1.63	
Well-represented	949	3.02	1.42	

* $p < .05$. ** $p < .01$.

Limitations

Several limitations of this study should be acknowledged before interpreting results. First, the pre-post survey data reflected responses from approximately half of the students who actually attended the Challenger Learning Center. As noted, this lack of data is due to the limitations associated with having students complete pre-post items in their classrooms. The Challenger staff had no control over whether or not teachers required students to complete these items (even though it was in the stated agreement with participating teachers). Second, lack of specific grade level data is also a limitation. Students attended middle schools but their exact grade levels were unknown. Finally, many of the evaluated constructs were narrowly defined, contained few items, and not all items were supported, psychometrically, with one construct scoring well below an acceptable Cronbach's alpha score of .70. Some of the items were space mission specific and previously validated items in this realm could not be located. Other items, however, have been previously validated, particularly items related to interest and enthusiasm developed by the Program in Education, Afterschool & Resiliency (PEAR; n.d.) and validated by Policy Studies Associates Inc. (Mielke, et al., 2012).

Discussion

Methods for increasing student achievement in the content areas of science and mathematics continue to be a focus of many educational initiatives, including the "Educate to Innovate" campaign. Research has shown that ISE settings such as the Challenger Learning Center can play an important role in engaging students in scientific exploration and discovery, and encouraging their involvement in science education while possibly stimulating interest in pursuing careers in STEM fields (NRC, 2009; Tai et al., 2006). Unfortunately, research studies and evaluation reports of the effects of ISE space programs are limited. Therefore, the objectives of this study were to conduct a program evaluation of the Challenger Learning Center by examining the perceived effectiveness of the student-completed space missions, as well as examine how student attitudes and perceptions, as aligned with the NRC's six-strand framework, changed after completion of one of the missions provided by the Challenger Learning Center. Additionally, this study sought to investigate differences between gender and race/ethnicity subgroups regarding space-mission experiences and STEM learning. These findings are meant to inform both the Challenger Learning Center program and the field of ISE.

Changes in Attitudes and Beliefs toward STEM Related Constructs

Overall, students reported very positive experiences with the space missions at the Challenger Learning Center. Quantitative analyses revealed very high scores on the day of mission items and significant gains on all of the pre-post mission items measuring the following constructs: (1) perceptions of the importance of teamwork, (2) interest and enthusiasm for STEM subjects, including space exploration, (3) perceptions related to content knowledge, and (4) gender equity beliefs. These data highlight the success of the activities that occurred at the Challenger Learning Center during one academic year and emphasize students' desire to return to the Center for another mission. Moreover, items within these constructs relate to at least four of the six strands of science learning (NRC, 2009), indicating the promise of Challenger Centers nationwide in developing scientifically literate students that develop an enthusiasm for STEM concepts in everyday life as citizens – both of which serve as prerequisites to pursuit of STEM careers (Archer et al., 2010).

Changes Recorded by Subgroups of Students

Students, as a whole, scored quite high on all of the evaluation items and made significant gains between pre- and post-mission, but this finding must be interpreted in light of the significant differences found across gender and race/ethnicity subgroups. Not all student subgroups rated their experience similarly. On the day of evaluations, students categorized as well-represented in ISE opportunities (Asian/Pacific Islanders and Caucasians) responded more positively than the underrepresented group of students on five out of the seven items. And, all three of the items related to interest/enthusiasm favored the well-represented subgroup. Calabrese-Barton and colleagues have reported similar findings related to a lower interest in STEM fields reported by minority youth in urban settings (Basu & Calabrese-Barton, 2007; Zacharia & Calabrese-Barton, 2012). Significant differences were also found on three out of the seven "day of" items favoring females. These differences, however, never registered greater than .08 (on a 5-point scale). Both of the content items favored females revealing that they perceived learning more content knowledge during the mission than males perceived to have learned.

Although females scored higher than males on some of the items asked on the day of the mission, males revealed significantly greater gains on five out of eight pre-post items asked of students. Gains made by males on these items were greater than gains made by females, regularly equaling or exceeding .50 (one-half of one point) at pre- and post-mission. Females made significantly greater gains than males on only one item, the gender equity item: "Women and men are equally good at space exploration." Important to note, however, is that females had more to gain on average than males on this item as they scored lower than males on this item at pre-mission [M=1.49; SD= 0.82 versus M= 1.75; SD =1.03 respectively]. This finding aligns with those of Farenga and Joyce (1999) who reported that middle school boys believed that life science courses were more appropriate for girls and middle school girls believed that physical science courses were more appropriate for boys. However, our finding contrasts with that of Sorge & Newsom (2000) who reported no significant differences in pretest scores or pre-post gains on a similar item in their survey, "scientists can be either men or women" (2000, p. 339).

Particularly revealing were significant change score differences across the race/ethnicity subgroups on six out of the eight items, favoring the well-represented subgroup. Change scores for the six items differed by at least .25. Differences included both content knowledge items, three out of four of the interest/enthusiasm items, and the only gender equity item. One positive finding is that no difference was found between the two groups on the item that read, "I like technology," nor were differences found on the one and only teamwork item. Disconcerting is the fact that a significant difference was found across race/ethnicity subgroups on the item that read, "I am interested in finding out more about careers in science and math." This latter item about career interests is critical in that others have reported differences in well-represented and underrepresented groups as it relates to their interest in STEM fields (Basu & Calabrese-Barton, 2007; Zacharia & Calabrese-Barton, 2012), and their reported interest in pursuing STEM careers even after participating in the same 4H ISE programs (Mielke et al., 2012).

Overall, these findings across subgroups are of concern. The effect of the mission on increasing interest and enthusiasm related to STEM fields, changing student perceptions about their levels of content knowledge, and influencing student perceptions of teamwork favored both the males and the well-represented race/ethnicity subgroup. Lower change scores across subgroups are disappointing in that one goal of the Challenger Learning Center in Colorado and a stated goal of other ISE programs is to reduce the gaps between these subgroups. According to our results, this goal was not fully met. In terms of race/ethnicity the same subgroup of students who are typically well-represented in ISE programs scored higher on items asked during the day of the mission and also displayed the most positive changes between pre- and post-mission. And, the significant differences favoring females on the day of mission were not found when data were analyzed for changes between pre- and post-mission. In this study, the reported persistent gaps between gender and race/ethnicity remained persistent with most (but not all) of the items favoring white males.

Unlike quantitative results, no significant differences were found across any of the subgroups on the only item that collected qualitative feedback on students’ excitement about the program. Feedback from all students was authentic and very positive. Much of this success seems to stem from the “real-life” and “collaborative” nature of the missions, echoing the importance of these variables on ISE success, particularly for girls (DeHaven & Weist, 2003; Liston, Paterson, & Ragan, 2008; Munley & Rossiter, 2013).

Conclusions, Implications, and Recommendations for Future Research

As previously described, ISE programs have demonstrated effectiveness with America’s youth, and in some cases have been particularly beneficial for subgroups historically underrepresented in STEM programs and careers (Bouzo, 2012; Rahm & Ash, 2008). As one type of ISE activity, space missions conducted at Challenger Learning Centers have the potential to affect changes in student perceptions and attitudes about STEM learning and STEM careers. This evaluation of one Challenger program found that the experience resulted in positive changes across all students; the entire group of students made statistically significant gains between pre- and post-mission. Evaluations such as the one reported herein are a necessary step in maximizing the potential of Challenger Learning Centers.

Although it is important that participation in ISE programs relates to positive change, we found, in this evaluation, that changes were not consistent across student subgroups. Researchers tend to agree that although we are making progress in closing the science achievement gap between racial/ethnic subgroups and males and females, this progress is very slow (Price, 2013). For example, when it comes to any K-12 STEM program (formal or informal), “few or no programs have reported long-term impact data specific to the ethnicity of student participants” (Winkleby, Ned, Ahn, Koehler, & Kennedy, 2009, p. 536). Our results echo previous findings in that we found many differences across subgroups (although these differences were not found on every item). Our non-uniform findings prompt us to ask this question: Why do subgroups of students responded similarly to some items but significantly different on others? If in fact Challenger Learning Centers have what it takes to support the learning of girls and underrepresented racial/ethnic groups (i.e., a focus on teamwork, low-stakes environment, hands-on learning), then evaluation results should be similar across subgroups or, at least the experience should help minimize differences across subgroups.

Reasons behind the differences found in this evaluation are unknown. Further research and evaluation is necessary in order to validate or refute our findings and inquire into why possible differences exist. A need also exists to develop measures that include more psychometrically validated items per construct, as some but not all of the constructs demonstrated strong reliability. A final recommendation is related to the evaluation of the effectiveness of other Challenger Center programs in improving attitudes, beliefs, and interests of *all* students, and to publish the findings of these evaluations. A focused and sustained research effort in this particular ISE arena will contribute to the development of improved programs and possibly assist in reducing differences across subgroups as related to their interest and enthusiasm about STEM subjects and careers.

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