

Midshipmen-Facilitated Informal STEM Education

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Abstract

The nation's security relies heavily on future STEM talent with scientific and technical skills, which is why the United States Naval Academy (USNA) encourages midshipmen (all USNA undergraduates) to facilitate informal STEM education outreach events for K–12 students and teachers. This experience prepares the midshipmen as problem solvers, effective communicators, and leaders—all necessary attributes for officers in the United States Navy and Marine Corps— while encouraging more young people to be STEM-literate citizens and pursue STEM careers in Navy-relevant fields. Using event-specific pre- and post-surveys, we measured the gains that midshipmen made in communication, confidence, and leadership as a result of their facilitation experience. In addition, analysis of overall STEM Impact Survey results reveals that midshipmen's participation in informal STEM outreach improves their motivation to remain in the STEM pipeline. This study will be useful for assessing gains made by activity educators, judges, mentors, or facilitators of other informal STEM outreach programs.

Introduction

It is not a sight you see every day: a midshipman from the United States Naval Academy (USNA) helping a fifth-grader glue washers onto a small piece of metal. After the midshipman describes how an underwater glider moves through the ocean, the student chooses a launch angle and releases her newly ballasted glider into the tank. She is delighted when it travels farther than previous attempts. This student is engaged in Navy-relevant project-based learning, and the midshipman is one of many who facilitate informal STEM education through USNA's STEM Center for Education and Outreach (STEM Center).

Many organizations (educational, private, commercial, and governmental) offer, host, or support informal STEM education opportunities (Bonney et al. 2009; Committee on Science and Technology 2009; Harlow 2012; Phillips et al. 2007). This can take many forms such as hosting a Family Science Night, judging a science fair, mentoring future scientists and engineers, promoting citizen science, or supporting competitions such as the FIRST Robotics or MathCounts.

The primary goal of these activities is to increase STEM awareness and access community-wide. In order to gauge these efforts, organizations study participant gains made as a result of the informal event, usually through the use of surveys. Often overlooked in this process is the impact of the informal STEM activity on the educator, judge, mentor, or facilitator.

The Navy's interest in STEM education comes as a response to the military's struggle to recruit people with essential STEM experience, especially those from underrepresented groups, for both civilian and military positions (Committee on STEM Workforce Needs for the U.S. DOD 2012). Nationwide, policymakers and scholars often lament leaks or reduced input into the STEM pipeline of future science and engineering talent (Committee on STEM Workforce Needs for the U.S. DOD 2012; Hernandez et al. 2013; Korpershoek et al. 2013; Kubel 2012).

The STEM pipeline is a common metaphor describing the ever-narrowing conduit of people flowing from high school graduation, entering college, choosing a STEM major, graduating from college with a STEM major, and entering a STEM career (Cannady et al. 2014). Indeed, the Department of Defense (DOD) "hires more scientists and engineers, and sponsors more research and development projects than any other federal employer" (Miller 2011, 42). With that in mind, the goal of the USNA STEM Center is to encourage more young people to pursue STEM careers (especially in technical fields relevant to the Navy), to engage K-12 students and teachers in STEM innovation and project-based learning (PBL) methodology, and to increase retention of USNA STEM majors by engaging them in education outreach.

For STEM Center events, the informal learners are K-12 students or teachers nationwide, and the facilitators are USNA faculty and undergraduate midshipmen volunteers. Representing a cross-sector collaboration between the Navy, education practitioners, our sponsors (Office of Naval Research, Office of the Secretary of Defense, Naval Academy Foundation), and event-specific partners (Maryland Mathematics Engineering Science and Achievement [MESA] and National Oceanic and Atmospheric Administration [NOAA]), these events fulfill a civic need to engage participants in STEM education and innovation in order to meet national security needs. Events include SeaPerch competitions and builds, Girls Days, MESA Days, Summer STEM Camps, STEM Educator Training (SET) Sail workshops, and Mini-STEM events. Most events utilize a workshop format in which participants

join 30- to 60-minute modules focused on a particular topic (fluid mechanics, alternative energy, applied math, robotics, engineering design, applied science, and others). Modules are largely hands-on, combining the scientific method with the engineering design process, and emphasize essential naval applications of STEM innovation.

The autonomy and magnitude of midshipmen facilitator roles vary from event to event. For example, Girls Day events have a USNA faculty lead facilitator for each module and two to four midshipmen assistant facilitators, whereas MESA Day modules are entirely operated by midshipmen facilitators. They have complete control over the module setup, organization, and presentation; only the content is loosely provided to them by STEM Center faculty, and active learning pedagogy encouraged. Both Girls Day and MESA Day events will be explored later in this article.

Review of Literature

Although considerable literature has focused on the impact of informal education among participants (Committee on Science and Technology 2009; Dierking and Falk 2010; Falk and Dierking 2000; Falk and Storksdieck 2010; Learning in the Wild 2010; Schwan 2014), research exploring facilitator gains made as a result of informal education is limited, focusing on either preservice teachers, formal service-learning, or mentorships. An informal education facilitator is one that arranges resources, establishes rich experiences, and engages with participants to promote learning (Schunk 2012). Harlow (2012), McDonald (1997), and McCollough and Ramirez (2010) investigated gains made by preservice teachers serving as Family Science Night facilitators. They each found that, as a result of informal science facilitation experience, preservice teachers gained confidence in their ability to teach and communicate science, improved in their understanding of the public's prior science knowledge and preconceptions, and honed STEM education techniques to maximize public engagement. Similarly, Crone et al. (2011) found that the training of science and engineering graduate students in informal education yielded gains in student communication and evaluation skills.

Other researchers specifically explored undergraduate science majors involved in K-12 outreach as part of a formal service learning project (a combination of formal classroom learning with community service). Roa et al. (2007) found that undergraduate participation in K-12 science outreach

increased confidence, boosted communication skills, linked knowledge with application, promoted identity-building, influenced career choices, and assisted in undergraduate retention of science majors. Both Gutstein et al. (2006) and Sewry et al. (2014) noted enhanced learning, academic development, and improved perceptions of science applications in society among undergraduate facilitators. LaRiviere et al. (2007) reported undergraduate chemistry majors learning and appreciating how children conceptualize science as a result of science education outreach.

Additional research investigated STEM undergraduate gains after mentoring young women who were considering a STEM career. Mentoring involves advising others on strategies and skills in a professional context (Schunk 2012). Chan et al. (2011) found that female undergraduate mentors majoring in biomolecular science experienced improved patience and communication as a result of their outreach mentoring experience to seventh graders. Furthermore, Amelink (2009) argues that mentoring benefits both mentor and protégé. Specifically, the mentor gains a sense of accomplishment, a boost in self-confidence, an augmentation in communication skills, and a feeling of personal validation. In addition, mentoring likely improves the retention of undergraduates in STEM fields (Amelink 2009).

Purpose

The above literature review indicates observable advantages for higher education students serving as outreach facilitators. However, no study yet exists investigating undergraduate STEM majors serving voluntarily as ISTEM facilitators for the K–12 community. Therefore, the purpose of this study is to explore the gains that USNA midshipmen made as a result of facilitating ISTEM outreach events. Guiding questions include (1) Do midshipmen demonstrate improvements in leadership, communication, and confidence after facilitating ISTEM events? and (2) Does participation in ISTEM improve midshipmen's motivation to continue in the STEM pipeline? These questions can help to assess the gains made by activity educators, judges, mentors, or facilitators of other STEM outreach programs.

Theoretical Framework

Constructivist learning theory presupposes that learners actively construct their own knowledge (Kruckeberg 2006; Schunk 2012). STEM Center events are designed under the constructivist assumption that knowledge develops inside active learners through engagement in hands-on activities (Piagetian constructivism) and social interactions (Vygotskian constructivism). Furthermore, constructivists also assume that educators serve as facilitators, structuring environments for learners to actively engage with content and materials (Schunk 2012). In this sense, we postulate that informal education facilitators also actively learn from their experience in facilitating hands-on activities and interacting with event participants. Alan Friedman expressed a similar view in an interview with Ellen Mappen: “When you try to teach a concept to others your own understanding is really tested and improved. So I think undergraduates who learn to communicate science to informal audiences...have a unique experience that sharpens their own knowledge and communication skills” (Friedman and Mappen 2011, 35).

Methodology

USNA midshipmen involved in STEM Center outreach were surveyed for particular ISTEM events (Girls Day and MESA Day) and overall STEM outreach impact in 2013 and 2014. Survey questions were adapted from Assessing Women and Men in Engineering mentor surveys (Assessing Women and Men in Engineering 2014).

Event-Specific Surveys

Girls Day. Printed, anonymous pre- and post-surveys were administered to midshipmen facilitators of two Girls Day events: one on October 19, 2013 and the other on March 1, 2014. Survey responses were later entered into an electronic survey created using Google Forms for compilation and analysis. Girls Day is a one-day ISTEM event hosted at USNA in which 215 (on October 19, 2013) and 221 (on March 1, 2014) middle-school girls participated to explore STEM concepts and careers using PBL. Activities at each Girls Day include modules on astronomy, weather, fluids, bioterrorism, rockets, robotics, physics, engineering design, and others. Each Girls Day module has a lead USNA faculty facilitator, who supervises two to four midshipmen facilitators. Approximately forty-eight midshipmen facilitated the October 19, 2013 event.

Twenty-four pre-surveys and seventeen post-surveys were collected on that day. The March 1, 2014 event was facilitated by approximately thirty-one midshipmen, with twenty-one pre-surveys and eighteen post-surveys being collected (Table 1). Pre-survey questions employed multiple choice or Likert scale. Post-survey questions employed multiple choice, Likert scale, and open-ended response. Similar Likert scale questions appeared on both pre- and post-surveys to measure changes as a result of event participation:

1) *As a leader for a STEM activity, how much ability do you have for each of the skills listed below? (Likert scale response: None, Some, Good, Excellent)*

- *Ensure that participants are satisfied with their participation in an activity*
- *Deliver an effective explanation of an activity to the participants*
- *Take charge of leading a portion of a student activity*
- *Solve a conflict between participants effectively*
- *Motivate participants to actively engage in an activity*
- *Teach a hands-on skill, after being trained*
- *Adjust activities when things aren't going as planned*
- *Positively influence younger children through your leadership*
- *Communicate with diverse audiences (age, ethnicity, region)*

Other questions appeared only on the post-survey:

2) *Please respond to these items that will help us improve the activity that you participated in. (Likert scale response: NO, Strongly Disagree; Disagree; Neutral; Agree; YES, Strongly Agree)*

- *The organizers adequately supported me in fulfilling my assigned duties.*
- *If I needed help in solving problems during an activity, it was readily available.*
- *I had adequate information about the activity and my role in order to do a good job.*
- *I had adequate training to prepare me to effectively perform my leadership role.*
- *From my point of view, the students I led are satisfied with my performance.*
- *From my point of view, the students I led found participation worthwhile.*
- *This activity was well organized.*

- *This activity should be offered again.*
- *My participation in this activity led me to a better understanding of a STEM field.*
- *My participation in this activity led me to a fuller exploration of my own career goals.*
- *My participation in this activity makes me more confident in my own ability to succeed in a STEM field.*
- *My participation in this activity improved my leadership skills.*

3) *What are two things you learned by participating in this STEM event?*

4) *What was effective about the way this event was organized?*

5) *What needs to be improved the next time this event is offered?*

Finally, a paired sample t-test was conducted to compare pre- and post-survey questions that appeared on both instruments.

MESA Day. Printed, anonymous pre- and post-surveys were administered to midshipmen facilitators of two MESA Day events: one on November 22, 2013 and the other on November 5, 2014. Survey responses were later entered into an electronic survey created using Google Forms for compilation and analysis. Pre- and post-survey questions were exactly the same as Girls Day survey questions. MESA Day is an event held in collaboration with Maryland Mathematics Engineering Science Achievement (MESA). For each MESA Day, midshipmen stage and facilitate a full day of hands-on modules (robotics, buoyancy, water properties, polymers, engineering design, and more) for approximately 250 fifth-grade students from local schools at the Johns Hopkins Applied Physics Laboratory. Thirty-three (on November 22, 2013) and thirty-four (on November 5, 2014) midshipmen facilitated each MESA Day, exercising complete control over module set-up, organization, and presentation. Thirty-three pre-surveys and twenty-seven post-surveys were collected for the November 22, 2013 event, and thirty-four pre-surveys and thirty-four post-surveys were collected on November 5, 2014 (Table 1). A paired sample t-test was conducted to compare pre- and post-surveys. For the November 5, 2014 post-survey, responses to the open-ended question “What are two things you learned by participating in this STEM event?” were categorized and tabulated based on subject occurrence such as communication, leadership, or facilitation.

TABLE 1. Rate of return for event survey responses.

Event	Number of Midshipmen Facilitators	Rate of Return (Pre-Survey)	Rate of Return (Post-Survey)
Girls Day (Oct 19, 2013)	48	50%	35%
Girls Day (Mar 1, 2014)	31	68%	58%
MESA Day (Nov 22, 2013)	33	100%	82%
MESA Day (Nov 5, 2014)	34	100%	100%

TABLE 2. Rate of return for STEM Impact survey responses.

Survey	Number of Midshipmen Emailed Survey	Rate of Return
STEM Impact Survey 2013	84	50%
STEM Impact Survey 2014	104	63%

STEM Impact Survey

An anonymous STEM Impact Survey was created using Google Forms and administered via email on December 20, 2013 to eighty-four midshipmen with over six hours of STEM outreach participation during fall semester of 2013, and on December 12, 2014 to 104 midshipmen with over six hours of participation during fall of 2014. The 2013 survey had forty-two midshipmen respondents, and the 2014 survey had sixty-five respondents (Table 2). Survey questions employed multiple choice or Likert scale:

1) *Please respond to these items to describe how participation in STEM outreach has impacted you. (Likert scale response: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree, Not Applicable)*

- *My participation in STEM outreach made me more confident in my own ability to succeed in a STEM field.*
- *My participation in STEM outreach influenced me to choose a STEM major.*
- *My participation in STEM outreach influenced me to stay in a STEM major.*

2) *How has your participation in STEM outreach influenced you as a student?*

3) *If applicable, please describe how participation in STEM outreach influenced you in selecting or staying in a STEM major.*

Question 3 appeared only on the 2014 STEM Impact Survey, not on the 2013 survey. All other questions were the same on both instruments. Likert responses indicating “Not Applicable” were removed from the analyzed data set.

Results and Discussion

Event-Specific Surveys

Comparison of pre- and post-surveys for the March 1, 2014 Girls Day (Figure 1) and the November 5, 2014 MESA Day (Figure 3) indicated improvement in all leadership categories as a result of event participation: communication, improvisation, teaching ability, conflict resolution, module management, and concept clarification. Specifically, midshipmen facilitators on Girls Day experienced the greatest gains in their ability to motivate module participants (10.9 percent), adjust activities spontaneously (10.1 percent), communicate with diverse audiences (8.7 percent), and teach a hands-on activity (6.5 percent) (Figure 2). Three of these gains were statistically significant using a paired sample t-test: motivate module participants, $t(12) = 1.90, p = 0.08$; communicate with diverse audiences, $t(12) = 2.74, p = 0.018$; teach a hands-on activity, $t(11) = 2.16, p = 0.054$. Midshipmen facilitators on MESA Day indicated greatest gains in their ability to adjust activities spontaneously (9.5 percent), solve a conflict between participants effectively (8.8 percent), positively influence younger children (5.2 percent), and ensure participants are satisfied with their participation (4.4 percent) (Figure 4). All of these gains were statistically significant according to the paired sample t-test: adjust activities spontaneously, $t(30) = 3.24, p = 0.003$; solve a conflict effectively, $t(30) = 1.97, p = 0.058$; positively influence children, $t(30) = 2.24, p = 0.03$; ensure participants are satisfied, $t(30) = 2.52, p = 0.017$.

Originally, we anticipated that MESA Day would yield greater leadership gains overall compared to Girls Day, because the event allows midshipmen greater ownership and influence as facilitators. However, this was not consistently the case. The 2014 MESA Day event, in which midshipmen had more control over module execution, yielded greater gains in midshipmen’s ability to solve conflict between participants and to positively influence young children than did Girls Day. On the other hand, 2014 Girls Day midshipmen reported greater gains in ability to motivate and engage girls in activities, to teach a hands-on skill, and to communicate with a diverse audience compared to MESA Day. We suspect the greater gains displayed among Girls Day midshipmen was due to the large number of first-time outreach midshipmen participants for that event. Eight of the twenty-one midshipmen (38 percent) facilitating the 2014 Girls Day rated themselves as “I have not yet participated in a STEM activity” on the pre-survey. On the other hand, only three of the thirty-four midshipmen

FIGURE 1. Midshipmen self-evaluation of STEM leadership abilities as a result of facilitating Girls Day on March 1, 2014.

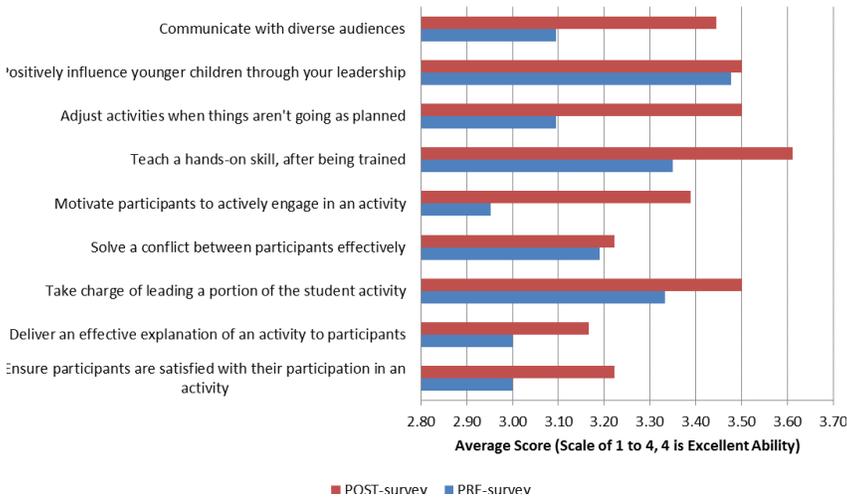


FIGURE 2. Percent positive increase in midshipmen self-evaluation of STEM leadership abilities for Girls Day on March 1, 2014.

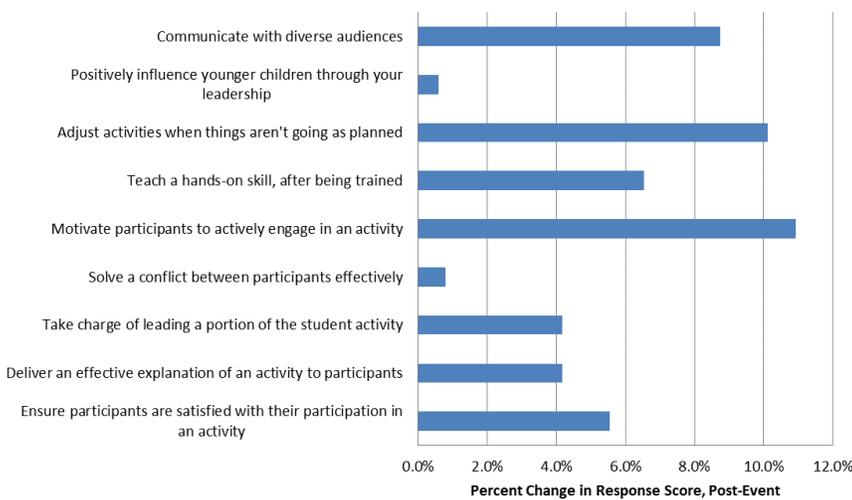
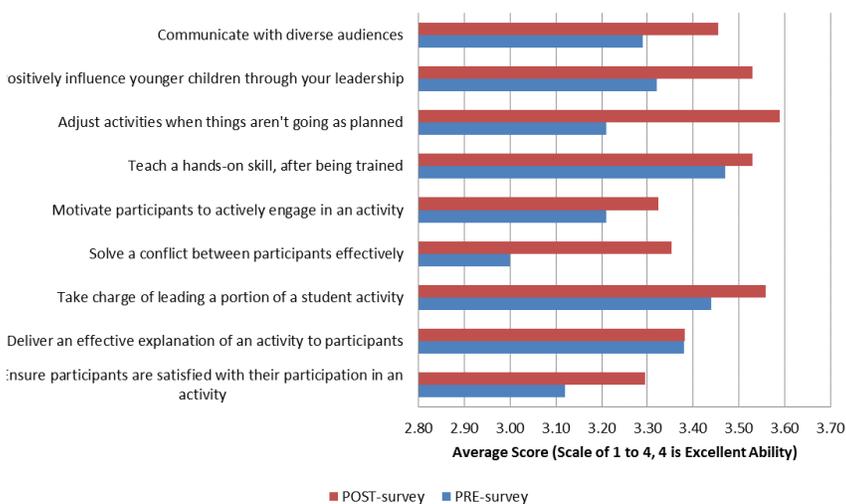


FIGURE 3. Midshipmen self-evaluation of STEM leadership abilities as a result of facilitating MESA on November 5, 2014.



(9 percent) facilitating the 2014 MESA Day rated themselves in that category. In our experience, first-time ISTEM midshipmen tend to rate their leadership abilities lower on administered pre-surveys than experienced midshipmen facilitators. Furthermore, the data indicate that newer facilitators report greater gains in leadership abilities due to a single ISTEM event.

The November 5, 2014 MESA Day post-survey responses to “*What are two things you learned by participating in this STEM event?*” were coded and tabulated based on subject occurrence (Figure 5). One midshipmen wrote “I learned how to better communicate with children and how to lead groups of kids” (MESA Post-survey 2014). Therefore, this response was coded under communication, leadership, and audience (kids). Overall, responses mentioning working with children (26 percent), communication (22 percent), and facilitation experience (22 percent) occurred most frequently.

Midshipmen from all four events (Girls Day on October 19, 2013 and March 1, 2014; MESA Day on November 22, 2013 and November 5, 2014) rated their leadership abilities between 3.1 and 3.7 on post-surveys, with (3) being *Good Ability* and (4) being *Excellent Ability* (Figure 6). The highest skill averages occurred for ability to take charge of leading a student activity (3.6) and ability to teach a hands-on skill (3.6). Midshipmen facilitators are placed in the role of subject matter expert for each event and subsequently draw on their own STEM background to engage and lead participants. Prior training in event-specific project-based learning helps to prepare midshipmen as hands-on activity facilitators. The lowest skill averages occurred for ability to solve a conflict between participants (3.2) and ensuring participant satisfaction (3.3). This is possibly due to the nature of module execution. Children may be less inclined to argue in the presence of a stranger (the module facilitator). Moreover, module brevity (thirty to sixty minutes) makes it difficult for midshipman facilitators to thoroughly assess participant satisfaction.

FIGURE 4. Percent positive increase in midshipmen self-evaluation of STEM leadership abilities for MESA Day on November 5, 2014.

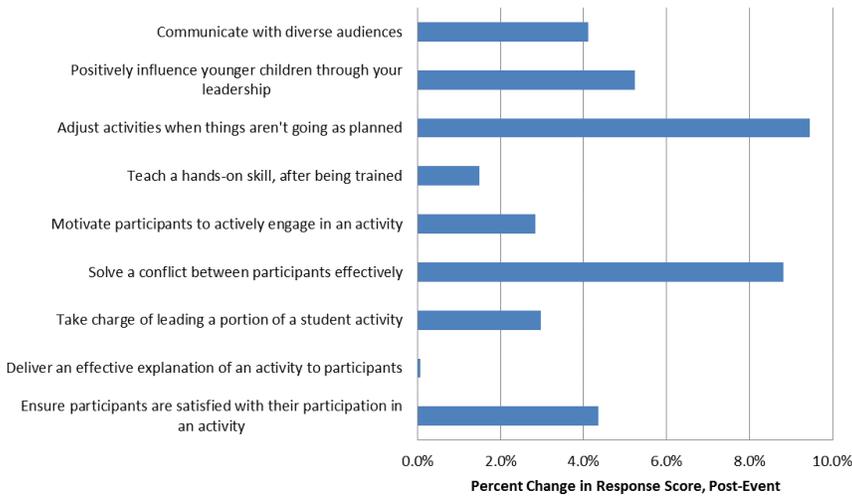


FIGURE 5. Occurrence of midshipmen open-ended response subjects regarding learning as a result of facilitating MESA Day on November 5, 2014.

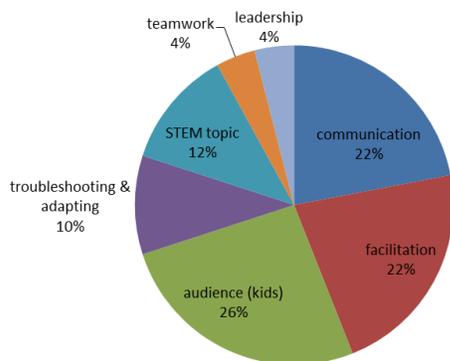
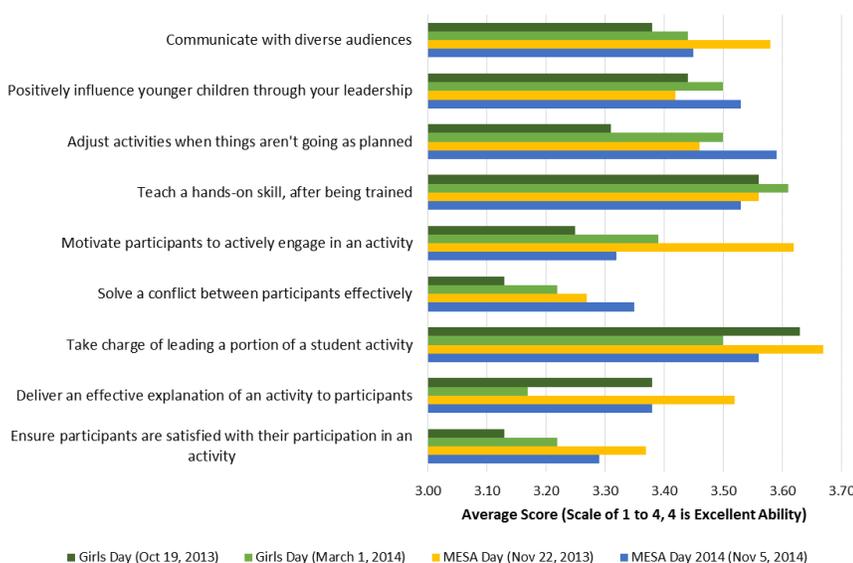


FIGURE 6. Comparison of 2013-2014 Girls Day and MESA Day midshipmen post-survey responses regarding STEM leadership abilities.



Comparison of post-survey midshipmen responses regarding effects of participation for all four events revealed overall gains in leadership skills, confidence to succeed in STEM, and understanding of a STEM field (Figure 7). The scores ranged between 3.8 and 4.6 with (3) being *Neutral*, (4) being *Agree*, and (5) being *Strongly Agree*. As a result of event participation, midshipmen indicated improved leadership skills (average = 4.4), more confidence in their ability to succeed (average = 4.2), and a better understanding of a STEM field (average = 4.0). A relatively weaker agreement occurred in response to “this activity led me to a fuller exploration of my own career goals” (average = 3.9). This may be due to the midshipmen’s service commitment. Unlike traditional undergraduates, USNA midshipmen must serve at least five years in the Navy after graduation, making their career paths somewhat fixed.

STEM Impact Survey

General assessment of midshipmen ISTEM facilitators for the fall 2013 and 2014 semesters revealed gains in motivation to improve academic performance and to stay in a STEM major (Figure 8). Midshipmen also indicated a boost in confidence to succeed in a STEM field as a result of ISTEM participation, averaging 4.0 for 2013 and 4.2 for 2014 where (3) is *Neutral*, (4) is *Agree*, and (5) is *Strongly Agree*. As the following excerpts from the STEM Impact Survey 2014 show, open-ended responses support Likert question findings and also indicate gains in STEM application, communication, and enthusiasm:

Response 1: “I had a better understanding of some of [my] courses by applying them in STEM activities. For example, I applied some knowledge about cryptography (that I learned in Plebe [freshman] Cyber) in one of the STEM activities I participated [in]!”

Response 2: “It seems simple, but the act of teaching younger kids about how cool STEM is actually makes me think about how interesting it actually is. It makes me

more curious when I learn about the simple ways the world works and drives me to do research on my own.”

Response 3: “Participating in a STEM outreach event helps me apply what I’ve learned in the classroom to a situation where I have to break down concepts in order to explain the science behind the math.”

Response 4: “STEM outreach influenced me to stay within my STEM major because of how applicable it is to everyday life.”

Response 5: “It makes me appreciate my major more. Being able to educate others in the basics of engineering is a great way to see how my efforts in school are benefiting others and their futures.”

Many respondents indicated that facilitating ISTEM outreach influenced them to continue in a STEM major, thereby supporting our hypothesis that midshipmen’s participation in ISTEM outreach improves their motivation to stay in the STEM pipeline. This is particularly interesting for policy-makers and scholars interested in strengthening the metaphorical STEM pipeline in order to ensure future science and engineering talent for our nation’s workforce.

Conclusion

The purpose of this study was to explore gains made by volunteer undergraduate STEM majors serving as ISTEM facilitators for USNA’s STEM Center. Driving questions were (1) Do midshipmen demonstrate improvements in leadership, communication, and confidence after facilitating ISTEM events? and (2) Does participation in ISTEM improve midshipmen’s motivation to continue in the STEM pipeline?

We found that Girls Day facilitators experienced gains in their ability to motivate module participants, communicate with diverse audiences, and teach a hands-on activity. MESA Day facilitators reported gains in their ability to adjust activities spontaneously, solve conflict between participants effectively, positively influence children, and ensure participant satisfaction. Indeed, our findings correlate with existing literature that undergraduate facilitation of ISTEM yields improved confidence in discussing STEM concepts, greater communication skills, experience taking charge of an activity, practice improvising and adapting to the unexpected, and an improved understanding of STEM fields and their importance to society. Other STEM outreach programs might consider assessing gains made by educators, judges, mentors, or facilitators in a similar manner in order to better determine the impact of their event.

Furthermore, based on midshipmen’s responses to the culminating STEM Impact Survey, experience facilitating ISTEM events appears to increase motivation to stay in the STEM pipeline and improve academically. This finding is significant for other outreach and education programs dedicated to improving retention in

FIGURE 7. Comparison of 2013-2014 Girls Day and MESA Day midshipmen post-survey responses regarding STEM event participation.

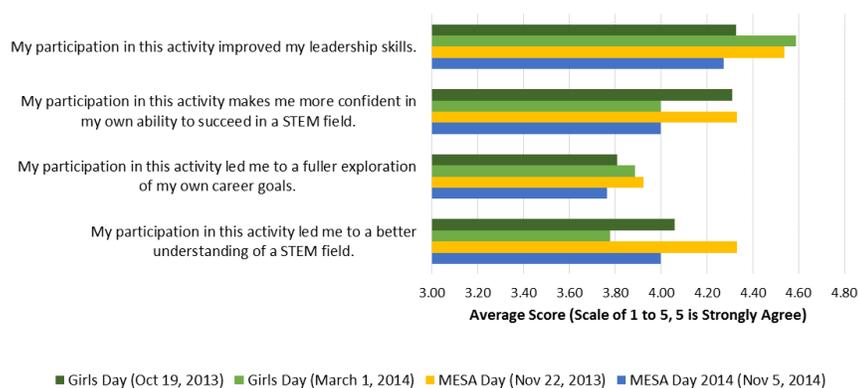
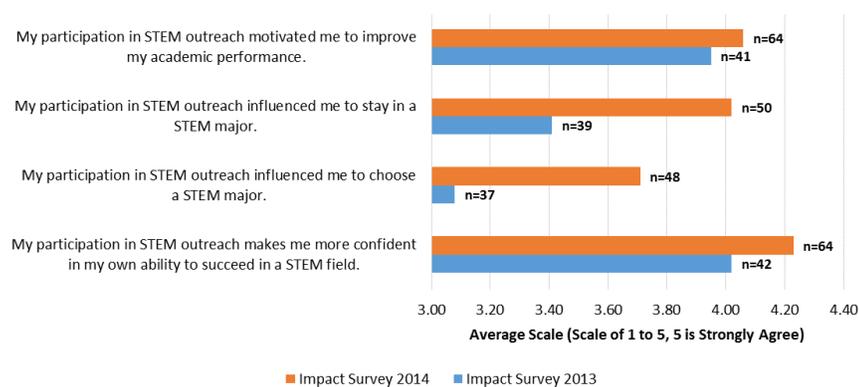


FIGURE 8. Midshipmen self-evaluation of ISTEM participation impact on academics for fall 2013 and 2014.



the STEM pipeline. Further research is needed to explore whether skills honed while facilitating ISTEM outreach help midshipmen after graduation—while serving in the fleet, or later, when some of them enter the civilian workforce.

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