The Impact of Participation in STEM Outreach on Persistence of Diverse Students in Physics, Math, and Engineering

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Abstract

The STEM Public Outreach Team (SPOT) at the University of Washington Bothell (UWB) provides training and community building opportunities for diverse STEM students that impact their persistence in STEM majors and careers. The University of Washington Center for Evaluation and Research for STEM Equity (CERSE) evaluated the experiences of SPOT Student Ambassadors to identify and strengthen the program elements that lead to motivation, confidence, and belonging for students from groups underrepresented in STEM fields. Current and former UWB SPOT Student Ambassadors participated in interviews for both formative and summative evaluation over two years identifying motivations, rewards, challenges, and improvements.

Introduction

The Space Public Outreach Team (SPOT) began in 1996 as the Mars Pathfinder Outreach Project (MPOP) through the Montana Space Grant Consortium (MSGC) at Montana State University (MSU). The SPOT program has grown to explore topics in science, technology, engineering, and mathematics (STEM) in states across the country (Williamson et al., 2014). West Virginia hosts the Science Public Outreach Team (SPOT) and the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) SPOT program reaches across North America focusing on pulsars, black holes, and gravitational wave astronomy (Des Jardins et al., 2020). SPOT programs train Student Ambassadors to visit K-14 classrooms and community groups to share current STEM topics through interactive presentations and activities. SPOT benefits Student Ambassadors who gain valuable experience, K-14 students and educators, the host organization, and funding agencies.

SPOT programs serve the need to recruit more students into STEM fields through near-peer mentoring, with Student Ambassadors helping younger students envision themselves as future scientists (Markus & Nurius, 1986). Near-peer interactions are particularly important for underrepresented groups (Trujillo et al., 2015), with SPOT programs focusing on reaching minority, underserved, low-income, and rural students. Student Ambassadors who are themselves members of underrepresented groups serve as role models and connections to regional colleges and universities.

Persistence of Diverse STEM Students

There is a recognized lack of diversity in STEM fields including underrepresentation of women, ethnic minorities, individuals with disabilities, individuals from low-income backgrounds, and first-generation college students (Beasley & Fischer 2012, Foor et al. 2007, Geisinger & Raman 2013, Lundy-Wagner et al. 2014). Factors have been identified that contribute to the persistence and success in STEM for underrepresented groups including active learning, undergraduate research, service learning, and building community (Kuh 2008, Watkins & Mazur 2013, Dika et al. 2018, Ahmad 2019, Detweiler-Bedell 2019, Seymour et al. 2004, Kardash 2000). Research has also demonstrated that STEM outreach programs result in the development of social and personal responsibility and skills that are beneficial for pursuing careers in the future (Fitzallen & Brown, 2017).

Through the University of Washington Bothell (UWB) SPOT program, we seek to identify and study factors that contribute to persistence in STEM for underrepresented groups, especially for the fields of physics, mathematics, and engineering. A diverse team of undergraduate students participate in STEM outreach activities to build community, confidence, purpose, and content knowledge. The program impacts recruitment and retention of students from underrepresented groups in STEM as well as expands their opportunities after graduation and ultimately contributes to an inclusive campus culture, community connections, and regional partnerships. The UW Center for Evaluation and Research for STEM Equity (CERSE) evaluates and studies the experiences of the SPOT Student Ambassadors in order to identify and strengthen factors that contribute to their persistence and success.

SPOT Program Description

The STEM Public Outreach Team (SPOT) at the University of Washington Bothell (UWB) partners with faculty in the UWB School of STEM to share their research with regional K-14 schools and community groups and is a member of the NANOGrav SPOT program. The UWB SPOT Student Ambassadors gain a sense of community as they work together to build their communication, outreach, and leadership skills while learning complex technical topics and serving as STEM role models in the local community. UWB SPOT topics started with the NANOGrav presentation Tuning in to Einstein's Universe and NASA LISA Ambassadors for the Laser Interferometer Space Antenna (LISA) mission, adding Math Adventures: Tessellating with Polygons developed with UWB math faculty funded by a seed grant from the UWB Office of Sponsored Research. SPOT presentations incorporate background information, exciting new research, and audience participation into a fun and educational show using concepts and vocabulary appropriate for the age and level of the audience. Presentations are developed in partnership with STEM faculty to provide an accessible introduction to their field and highlights from their research.

The SPOT Student Ambassadors develop their abilities to share complex STEM topics with a wide range of audiences. Each presentation includes slides with notes and background information. Students work together to learn the concepts and storyline, giving practice presentations with their peers in order to be certified as Student Ambassadors. Newly certified ambassadors then accompany veteran presenters to observe and assist with a SPOT presentation for a class, club, or community group. Ambassadors continue to improve their skills through group meetings including science communication and public speaking training. SPOT Student Ambassadors visit formal education institutions including universities, community colleges, high schools, middle schools, and elementary schools as well as information education organizations including the Pacific Science Center, GeekGirlCon, AAAS Family Science Days, Inspire STEM Festival, and UW STEM summer camps (Table 1). The program reaches hundreds of students, teachers, and educators each year. In the 2021-2022 academic year, the UWB SPOT program engaged eight Student Ambassadors from UWB and from the UWB Physics Research Experience for Undergraduates (REU) program with 100% of the current Student Ambassadors members of groups underrepresented in STEM fields. Since 2017, there are 21 Student Ambassador alumni with 12 continuing to graduate school and 9 working in STEM professions after graduation. Over 65%

of the current and former Student Ambassadors are members of groups underrepresented in STEM fields. To date, all the Student Ambassadors alumni are currently students or are employed in STEM fields, indicating a retention and graduation rate of 100% for the life of the program.

Organization type	# of visits	examples
Elementary Schools	1	Kokanee
Middle Schools	4	Evergreen, Timberline
High Schools	22	Eastlake, Fife, Lynnwood, Sammamish
Community Colleges	7	Highline, Edmonds, Bellevue, Cascadia
Universities	7	Washington, Portland
Community STEM Programs	5	Pacific Science Center, GeekGirlCon

Table 1. University of Washington Bothell (UWB) STEM Public Outreach Team (SPOT) visits by organization type 2019 to 2022.

The organization of SPOT programs involves students from pre-K through graduate school as well as educators and staff. Faculty advisors oversee the program financially, work with faculty to develop new presentations, recruit and train managers and Student Ambassadors, and connect with groups within the institution and in the community. SPOT student managers recruit and train Student Ambassadors and are responsible for coordinating visits, arranging travel when necessary, creating new presentations, keeping presentations up to date, and helping collect reporting and evaluation data. Student Ambassadors earn a stipend as they learn presentation content and skills, connect with fellow ambassadors, and serve as near-peer STEM role models. The SPOT program engages young students in their classrooms or as part of an education or community group. Teachers and group leaders connect with regional STEM experts and are provided with online and printed materials to extend exploration of related STEM topics.

Each SPOT program is organized and operated based on local factors, institutional assets, and community needs. The Montana SPOT program is run by the Montana Space Grant Consortium (MSGC), reaching thousands of young people each year with a focus on engaging rural and native populations. Student Ambassadors from colleges and universities across the state support an active program engaging diverse populations for less cost due to reduced travel time with additional impact from local presenters visiting rural classrooms.

The Green Bank Observatory adapted the SPOT model to West Virginia, training hundreds of Student Ambassadors at seven West Virginia colleges and universities (Williamson et al., 2014). The WV SPOT program is directed by education officers at the Green Bank Observatory (GBO), and each participating college campus has a faculty advisor. As part of their experience, Student Ambassadors travel to GBO for an immersive training weekend in the National Radio Quiet Zone. WV SPOT partners with the West Virginia University Research Office to support researchers to collaborate across disciplines via education and outreach.

NANOGrav is a distributed scientific collaboration with scientists and students at over 30 institutions across the US and Canada and a SPOT program coordinated through the NANOGrav Student Team of Astrophysics Researchers (STARS). NANOGrav SPOT Student Ambassadors gain experience that supports their research training, including learning the basics of gravitational wave astronomy and pulsar timing arrays and developing their public speaking skills. The benefits of a distributed SPOT program include a broad geographic and demographic reach for presenters and audience members. Undergraduate students at institutions without similar outreach programs can engage with the NANOGrav network to contribute to and benefit from the distributed collaboration.

There is evidence that the SPOT program is successful through quantitative and qualitative data collected over the last 26 years from students, educators, presenters, managers, and program sponsors (Des Jardins et al., 2020). The UWB SPOT program contributes to evaluation data in partnership with the UW Center for Evaluation and Research for STEM Equity (CERSE) with a focus on the experiences of the Student Ambassadors. The evaluation recommendations are implemented to improve the structure of the program and the outcomes for the participants.

Evaluation Methods

The second author serves as evaluator of the SPOT program at UWB, utilizing both formative and summative evaluation approaches. In July 2020, 18 current and former SPOT Student Ambassadors were invited to participate in a focus group discussion; five individuals participated for a response rate of 28%. Due to scheduling challenges, interviews were conducted instead of a focus group discussion. In July 2021, the five then current SPOT Student Ambassadors were invited to participate in individual interviews; four individuals agreed, for a response rate of 80%. Six of the participants identify as women and three identify as men. Eight of the participants majored in STEM fields and one majored in a Humanities field.

Interviews were conducted via Zoom conferencing software with audio recording. Extensive notes were taken during the interviews and the audio-recordings were used for clarification and transcription of quotations. In both years, the topics discussed included: student motivations to become SPOT Student Ambassadors, the recruitment process, orientation and training, the rewards and challenges of participating in the program, and suggestions for improvement. Separate thematic analyses were conducted in 2020 and 2021. These analyses are combined in the findings below, and the few differences that were found between the two time periods are noted.

Evaluation Findings

Motivations for Becoming an Ambassador and Recruitment

Seven students mentioned the content of the SPOT presentations as a motivating factor for joining, and two students were already participating in the UWB Gravitational Wave Astronomy research group before joining SPOT. Getting other students excited about STEM and/or research was a motivating factor in their decisions to become Ambassadors. Two students mentioned they were motivated by the opportunity to build confidence and improve their public speaking skills.

In general, the students had been mostly unaware of SPOT unless they were already participants in a related research group, or until they were introduced to it by someone they knew. Student recruitment mainly happened in one of three ways: students were nominated or encouraged to apply by someone they knew, faculty invited those participating in their research group to join SPOT, or students actively looking for opportunities asked about the program.

In discussing ways to improve recruitment, four students suggested giving presentation demonstrations in UWB classes. Two students said presentations would help raise awareness among undergraduate students and would be an effective means of recruitment. One student thought the presentations would clear up misperceptions that presenting with SPOT is too hard. Another described the class demonstrations as a way to draw students who are interested in "art, public speaking, code, performance arts, data analysis, story writing." In addition to suggestions about giving presentation demonstrations, one student highlighted that it would be useful to reframe participation as a public speaking opportunity for students who are interested in science. One participant shared that reaching out one-on-one to students had been significantly more effective than emailing people, contacting student organizations, or posting in the campus class management platform. Similarly, one student suggested that peer recruitment would be more effective than professor-led recruitment tactics. Finally, one participant recommended developing a social media presence for

getting more students involved as well as for marketing SPOT to schools for outreach opportunities.

Training and Preparation

The Ambassador training was described as observing the program manager give a presentation, then giving a presentation to the program manager and asking for feedback and/or clarification. One participant said they wished the training had been more structured, because they did not feel prepared to answer difficult or unanticipated questions in a "real-world scenario". Another student mentioned that giving practice talks with the Gravitational Wave Astronomy research group was helpful, because research group members provided tips on phrasing and presentation content, which made the student feel more confident about presenting.

In general, students felt prepared to successfully give the presentations themselves. Two students thought presenting in K-12 settings did not require "super in-depth" knowledge. However, one student mentioned that disciplinary expertise was important, because they personally would not have felt prepared to present on non-astronomy topics solely on the basis of the presentation materials. One student remembered that early on they wished to observe an experienced facilitator to learn how to be effective. However, the same student mentioned that not learning through imitation ultimately helped them find their "own way of doing things."

Beneficial Impacts and Outcomes for Student Ambassadors

Interviewees clearly stated that they valued participating in SPOT, expressing enjoyment as well as personal and professional benefits. Six students expressed that they gained confidence through SPOT. Science communication, scientific knowledge, improvising and responding to questions, organizational skills, and presentation skills were all mentioned as areas where the students felt more confident. One participant, whose personal involvement in research led to their becoming an Ambassador, expressed excitement about "enticing everyone to do research." While acknowledging that being an Ambassador was a "team effort", they also mentioned how SPOT helped them hone their leadership skills because they were presenting on their own. One participant who mentioned feeling more confident said that they enjoyed getting people interested in research from a young age. Another student shared that they gained practical knowledge about planning presentations for content, length, and tailoring to an audience.

Challenges

Students overall reported that the biggest challenges of being an Ambassador were overcoming a lack of confidence in presentation, scientific knowledge, and/or public speaking skills. One student shared they were still trying to overcome anxiety about presenting, while another student said they lacked confidence in answering difficult questions. Three students discussed challenges related to the responsibility of conducting science outreach. One of them expressed their anxiety about saying the wrong thing to a child and being responsible for misconceptions about science. Another discussed "imposter syndrome" and their concerns about not being perceived as an expert on the material without having an undergraduate degree. The third student shared that they were initially nervous about not knowing enough to present the material.

Challenges reported by students in 2020 and 2021 exhibited several differences due to the pandemic and the transition from in-person to virtual events. One student in the 2020 study reported that transportation to SPOT presentations had been a challenge without a car, while another student shared that it had been a challenge to meet family and work obligations as well as participate in SPOT. Meanwhile, all participants in 2021 said they wished they could have presented more often. Ambassadors shared that navigating online presentations and finding enough opportunities to present have been especially challenging. One participant mentioned Zoom as the most challenging aspect of being an Ambassador, as it was difficult for them to figure out on their own how to share their screen and audio, as well as making sure the presentations went smoothly in a virtual environment. All participants in 2021 expressed feeling disconnected from fellow SPOT Ambassadors: one student shared that the team felt "a little bit scattered", while another student who lived out of state expressed that this prevented them from connecting with others in person. Two students stated that they did not get to know others in the program beyond those with whom they happened to co-present.

Opportunities for Improvement

When CERSE asked about suggestions to improve the program, participants made recommendations to address existing challenges, improve recruitment strategies, and modify presentation activities for public outreach. To address challenges they experienced as Ambassadors, two students said that it would be useful to develop an FAQ to help prepare presenters to answer common questions from the audience. One of them discerned the training structure as their major issue, recommending that the training give students a better feel for the mechanics of a successful presentation. This student then suggested that the training provide more public speaking tips and give new Ambassadors a chance to sit in on a live presentation to observe the flow. Another participant recommended adding a personal and professional development piece for facilitators, for example, identifying a communication skill to learn, practice in a presentation, and then reflect on. The same student also suggested it would be useful to practice strategies for overcoming imposter syndrome. In addition to suggestions about the training, one student shared they felt like an outsider in STEM and suggested that SPOT would benefit from more diversity. The participant expressed that they want the SPOT program to focus more on inclusivity for people of color. More broadly publicizing SPOT to undergraduates was recommended to combat the misconception that research participation is a prerequisite for SPOT. Another student suggested that adding another presentation or two and broadening the topics of presentation would help recruit new Ambassadors.

In terms of modifying presentation activities for public outreach, several students suggested increasing the number and the variety of interactive activities. One student explained that experiential rather than conceptual activities spur interest and help people fall in love with science. Two students recommended increasing the number of available activities to allow presenters to choose an activity that best matches the energy levels of their audience. Noting that in-person presentations were not possible during the pandemic, two participants suggested incorporating podcasts, videos, and/or videotaping experiments to build on virtual presentations.

In addition to addressing existing challenges and modifying presentation activities, students also made general suggestions for SPOT. Two students recommended expanding the program to be "more than just space public outreach" by developing presentations related to other STEM fields. In contrast, another participant said they preferred maintaining the focus on space and gravitational waves. Finally, one student suggested being more proactive in finding facilitation opportunities by developing relationships with schools and reaching out to offer presentations.

Program evaluation can be expanded and improved through collection of feedback from teachers and leaders who host SPOT presentations and activities. Additional interviews with academic advisors and faculty mentors for SPOT Student Ambassadors will further support professional development for the Ambassadors.

Discussion

The evaluation findings demonstrate that the SPOT program at UWB is positively impacting the Ambassadors. Participants reported that through serving as SPOT Student Ambassadors they gained confidence, science communication skills, scientific knowledge, organizational skills, and presentation skills. Much research has suggested that being a part of a learning community has a positive effect on student outcomes especially for students most at risk of not graduating (Brownell & Swaner, 2009; Otto et al., 2015), including improving their persistence in STEM (Graham et al., 2013). Overall, all of the participants described serving as a SPOT Student Ambassador as a rewarding experience.

As data collection occurred first at the beginning

of the COVID pandemic and then again a year later, differences were found in terms of presentation delivery method as well as relationship-building among the Ambassadors. The shift to virtual presentations helped resolve challenges related to traveling to presentation sites but added new challenges around feeling comfortable with virtual conferencing technology. The participants in the 2021 interviews also reported feeling more disconnected from one another, as they lacked the in-person interactions that earlier cohorts of Ambassadors were able to experience with one another.

The evaluation findings suggested several recommendations for the UWB SPOT program:

- Recruit Ambassadors through brief classroom presentations.
- Continue to have new Ambassadors give practice presentations to their peers.
- Develop more training content for Ambassadors.
- Develop and implement more interactive activities for presentations.
- Increase opportunities for public outreach.
- Offer social interaction opportunities for the Ambassadors.

These recommendations are expanded below and will likely be applicable to others interested in adapting the SPOT program to their institution.

Participants in both 2020 and 2021 expressed a desire for SPOT to become a more well-known program on campus that served a wider variety of students. Visiting UWB classrooms and giving brief SPOT presentations and/or introducing details of the program may help attract a diverse array of students to serve as Ambassadors, while also clearing up misperceptions that advanced topical knowledge or research experience is a prerequisite for participation. This recruitment tactic should center students, as Ambassadors noted the value of peer influence on the decision to become an Ambassador.

While participants noted that giving practice presentations and receiving feedback on their SPOT presentations from peers helped them feel prepared to do outreach, students articulated how they felt underprepared in navigating the presentation experience, especially answering difficult or unanticipated questions. Research suggests that it is essential for students to practice listening and speaking skills by participating in verbal discussion and exchange of thoughts and information to give inspiring presentations and interact with diverse audiences (De Grez et al. 2009). In addition to practice presentations, it would be helpful to integrate more content and structure into the training. Including content to develop public speaking skills and to anticipate common audience questions may help bolster students' confidence. Giving new Ambassadors a chance to observe live presentations by experienced students may give new facilitators a feel for the flow and mechanics of a successful presentation.

The SPOT presentations facilitated by UWB Student Ambassadors engage audiences through interactive learning. Participants recommended increasing the number and variety of activities for public outreach. Expanding the pool of available activities to choose from would allow facilitators to choose the most appropriate one to match the energy and interest levels of their audience. Especially in virtual environments, activities can incorporate media for experiential activities to engage the audience. In addition to increasing the pool of interactive activities, students expressed a desire for more opportunities to present. Developing relationships with schools, reaching out to offer presentations, and using social media to raise awareness about SPOT will generate more facilitation and public outreach opportunities for Ambassadors.

Finally, the students interviewed in 2021 expressed feeling disconnected from fellow Ambassadors due to the pandemic. In contrast, many of the students interviewed in 2020 described the close friendships that had developed through serving as Ambassadors. Offering students more opportunities to interact may not only facilitate building friendships, but it could also help students feel a stronger sense of belonging at UWB and within STEM. Engagement in peer discussions outside of the classroom was shown to increase the likelihood of women persisting in STEM (Espinosa 2011). Furthermore, a sense of belonging and feeling valued as a member of a collaborative team predict retention in STEM (Yosso, 2005). Social events and more practice presentations with fellow Ambassadors may strengthen relationships within SPOT.

Conclusion

The National Science Foundation (NSF) Evaluation Policy (NSF, 2020) states that program evaluation is critical to serve the information needs of stakeholders; in particular, using the findings to make program improvement. The UWB SPOT program organization and activities have been improved based on the recommendations from the evaluation of the Student Ambassador experiences. Student Ambassador training and cohort activities have been expanded and the program continues to build recruiting strategies and community connections. Community building, student leadership, and peer mentoring have been identified as especially valuable aspects of the Student Ambassador experience. The evaluation of the SPOT Student Ambassador experiences will continue with annual participation and exit surveys. Recommendations can be applied to other SPOT programs as well as other STEM outreach efforts, especially those that engage STEM students from underrepresented groups.

The UWB SPOT program provides training and community building opportunities for diverse STEM students that impact their persistence in STEM fields. Evaluation of the experiences of SPOT Student Ambassadors by CERSE identifies and strengthens program elements that lead to confidence, belonging, and motivation for students from groups underrepresented in STEM. Community outreach programs such as SPOT impact classrooms, teachers, community partners, students and faculty contributing to the program, and the host institution. Successful structures and practices can be used and adapted across programs to continue to improve outcomes for participants and organizers. It is crucial to evaluate, assess, and update programs to address goals and outcomes.

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