© Journal of Higher Education Outreach and Engagement, Volume 26, Number 3, p. 57, (2022)

Graduate Student Participation in K-12 Science Outreach: Self-Reported Impact on Identity and Confidence of STEM Graduate Students

Allison Matthews, Renato Mazzei, Anne McAlister, Brianna Mills, and Yiqing Song

Abstract

Graduate students often serve as a liaison between a university and its surrounding community through their participation in educational outreach programs. Astronomy graduate students' responses to open-ended survey questions about their experience volunteering with an educational outreach program were qualitatively coded to investigate how participating in educational outreach influenced their identity and self-efficacy as scientists and educators. We found that "connecting with students" and "difficulty managing behavior" enhanced and diminished, respectively, participants' confidence and identity as scientists and educators. We suggest ways in which universities and departments can aid graduate students' experience in educational outreach and the myriad of benefits that the individual, university, and community may reap when a higher value is placed on participation in educational outreach in graduate programs.

Keywords: outreach, graduate education, higher education, higher-education outreach

Most universities include "community service" in their core mission statements, yet often devalue outreach efforts compared to research and teaching (Bartel et al., 2003). Tenure review for faculty historically weights publications and outside funding over outreach activities, demotivating individuals in academia from working to share their knowledge with the nonscientific community (Justice, 2006; Moskal & Skokan, 2011). This mindset has begun to change—physical science funding agencies (e.g., NASA, NSF) now include expectations for "broader impacts" on society in their grant structures. Nonetheless, academic institutions remain slow to place more value on teaching and outreach.

The central purpose of a graduate education, historically, is to prepare doctoral students to become future faculty. Current graduate students are taught under the "publish or perish" paradigm and experience a lack of faculty support for—and often resistance to—participating in educational outreach activities. As the institutional value of educational outreach and service within the tenure process increases, graduate education ought to place a higher priority on preparing students for all aspects of being a faculty member, not only on producing research results. The benefits of participating in educational outreach programs (e.g., enhanced communication skills) transcend preparing graduate students to become future faculty members, as such experiences can also improve sense of self-efficacy and belonging. A 2012 study by Laursen et al. found that STEM graduate student volunteers gained an understanding of issues related to education and its social context and the "intrinsic rewards of feeling that one's work benefits others" through participation in educational outreach. Participation in educational outreach has also been shown to increase a graduate student's sense of identity in their field of study and a sense of belonging to that field's community (Rethman et al., 2020).

Graduate students serve a vital departmental role as teaching assistants, and those involved in educational outreach felt that their teaching skills and ability to manage a classroom improved and led to improved skills as a teaching assistant (Laursen et al., 2012). Feldon et al. (2011) found that although STEM graduate students were encouraged to prioritize their research rather than their teaching responsibilities, when they taught students who were engaged in inquiry, the graduate students received valuable practice that improved their experimental design and hypothesis generation skills.

Graduate students who have training and/or prior teaching experience often demonstrated higher teacher self-efficacy, stronger belief in their ability to teach effectively in a specific context, and increased effective teaching behaviors in the role of an educator (Boman, 2013; Fowler & Cherrstrom, 2017; Prieto & Altmaier, 1994). STEM graduate teaching self-efficacy, specifically, was shown to correlate with professional development and prior teaching experience (DeChenne et al., 2012). Training and prior experience support graduate teaching assistant competence through providing foundational knowledge about teaching (Kajfez & Matusovich, 2017). Departmental or university training and mentorship in teaching were shown to significantly relate to changing beliefs about teaching and learning to be more student centered (Gilmore et al., 2014). Other factors, such as appointment structure, relationships with students, and relationships with colleagues impact graduate student teaching assistants' motivation, along with prior experience and training (Kajfez & Matusovich, 2017).

University Student Involvement in Science Education Outreach

In contrast with educator roles required by their institution, STEM graduate students may also volunteer to take on the role of an educator through involvement in educational outreach (e.g., Clark et al., 2016; deKoven & Trumbull, 2002; Gutstein et al., 2006; Houck et al., 2014; Koehler et al., 1999; Laursen et al., 2012; Moskal & Skokan, 2011; Rao et al., 2007; Wellnitz et al., 2002). University student participation in science education outreach has many documented benefits, such as improved ability to clearly express their topic to an audience outside their discipline (Clark et al., 2016; deKoven & Trumbull, 2002; Koehler et al., 1999; Rao et al., 2007) and expanded interest in outreach (Houck et al., 2014). For example, participation in a middle school outreach program gave graduate students new perspectives on their research and improved their communication skills (Clark et al., 2016).

Graduate students who volunteer for K-12 educational outreach may have positive experiences, despite time constraints and departments' placing less value on outreach experiences (Andrews et al., 2005; deKoven & Trumbull, 2002). The belief that a department values research over everything else can be a barrier for scientists to participate in outreach (Ecklund et al., 2012). In particular, graduate students may be deterred from participation in outreach by a lack of support from their research advisors (Dang & Russo, 2015). In a study on the impact of K-12 educational outreach on engineering graduate students, most participants reported negative responses to their participation in outreach from peers and faculty, along with messages that teaching is of a lower status than research (Laursen et al., 2012). Graduate students who chose to participate in outreach may also believe that volunteering with K-12 education might hinder them from getting highly regarded academic positions. However, such apprehensions may not always be realized, as many graduate students who volunteered in this way ended up in tenure-track positions and felt that they had valuable experiences as an educator (Laursen et al., 2012).

K-12 Student Benefits From University Student-Led Science Outreach

Student-led outreach programs also lead to improved attitudes toward science and increased personal interest in the K-12 student participants (i.e., Clark et al., 2016; Heinze et al., 1995; Houck et al., 2014; Koehler et al., 1999; Rao et al., 2007). For example, Clark et al. (2016) investigated an outreach program in which graduate students presented their research (in a simplified form) to middle school students and found that the middle school students' interest in science and becoming a scientist increased. Thus, these educational outreach programs can benefit both the K-12 student participants and the graduate students serving as educators.

Graduate Students as Educators

Educator identity has been studied among K-12 preservice teachers in the context of the transition from being a student in a department of education to engaging in student-teaching and being a teacher in a classroom environment (e.g., Jarvis-Selinger et al., 2010; Olsen, 2008). This transition is related to our study of graduate students serving as educators, as these students go through a similar transition between student and educator roles. Specifically, Olsen (2008) studied the development of first year K-12 teachers and revealed misalignment between expectations and the reality of being a teacher that caused identity conflict for the novice teachers. We suspect that graduate students experience similar identity conflict in the role of an educator. In another study of preservice teachers' identity transition, Jarvis-Selinger et al. (2010) discussed the importance of how reflection and discussion about identity transitions can help novice teachers recognize their new identity. No similar studies have focused on doctoral students who take on educator roles as teaching assistants and instructors of record or transition to being professors. Because these doctoral students may experience similar identity conflicts as they transition between roles, strategies of reflection and discussion may also be important in this population.

Rethman et al. (2020) examined undergraduate and graduate students' perspectives from participation in five different science outreach programs using a mixed-methods approach. Their study gave empirical evidence of students' strengthened physics identity and sense of belonging, as well as improved communication, teamwork, networking, and design skills through participation in science outreach. Our study is greatly informed by findings from this study but differs in key respects. First, our data was collected from participants at multiple points throughout participation in an educational outreach program, whereas Rethman et al. collected data at a single time point. Our data was entirely qualitative, and we explored a single educational outreach program in great detail, rather than multiple outreach programs more broadly as presented in Rethman et al.'s study. Finally, we centered the educator identity, in addition to an astronomer identity, in our data collection and analysis, and focused exclusively on doctoral students involved in both the organization of the outreach program and the outreach itself. Thus, although our work is highly aligned with Rethman et al.'s work, our work offers additional empirical evidence to support Rethman et al.'s findings and provides additional detail for the impact of outreach programs on doctoral students and their identity as educators specifically.

This work investigates the experiences of doctoral student volunteers in a science education outreach program. We examine the effects of participation in educational outreach on the volunteers' identities as educators, scientists/astronomers, and graduate students, and the strengths and weaknesses that the volunteers perceive they have as educators. This work contributes to understanding university student-led educational outreach and focuses on the benefits that doctoral student volunteers may receive. The findings highlight the benefits that doctoral student volunteers experience, and support the argument that institutions should place value on their doctoral students participating in these types of educational outreach opportunities.

Research Questions

This work explores doctoral students' experiences volunteering for a student-led and student-organized K-12 science educational outreach program. Specifically, we investigate the following research questions:

> RQ1: What strengths and weaknesses did science graduate students perceive that they have as educators?
>
> RQ2: How did participating in the outreach program affect students' perceptions of themselves as educators and scientists?
>
> RQ3: What were graduate students' perceptions of their influence on the students via the outreach program?

Methods

In this section, we describe the outreach program, give an overview of the graduate student participants, and describe the data collection and our methods of analysis.

Outreach Program Description

Dark Skies, Bright Kids (DSBK) is a primarily graduate-student-run outreach organization based out of the Department of Astronomy at the University of Virginia (UVa). The group was founded in 2009 in response to a lack of STEM enrichment opportunities at rural schools in Albemarle County, Virginia. The central mission of DSBK is to foster the natural curiosity of children through fun, hands-on, inquiry-based activities. Complementary to this central mission, the goals of DSBK are to (1) enhance upper elementary students' interest in science, (2) encourage scientific inquiry and engagement, and (3) teach basic astronomical concepts.

Program Structure

The backbone of DSBK is an 8–10-week after-school astronomy club for children in grades 3–5. A club is composed of 15–25 students and meets once per week for about 2.5 hours to focus on a specific astronomy concept (e.g., rockets, the night sky, astrobiology). At the beginning of each meeting, DSBK graduate student volunteers introduce the topic and activities for the day. After the introduction, the students participate in an astronomy-themed physical activity—"wiggle time"—to release pent-up energy from sitting in school all day. Following wiggle time, there are typically two or three hands-on, interactive activities to illustrate the astronomy concept of the day. Depending on the number of students and nature of the activity, the students are usually split into smaller groups and rotate through the various activities led by DSBK graduate student volunteers. Before the conclusion of the club, the students complete a worksheet that gives them an opportunity to ask further questions and reflect on their experience of the club that day (whether they had fun).

In summer 2016, this semester-long club was modified into a week-long astronomy summer camp hosted in rural and/or distant parts of Virginia—locations that would be inaccessible for a once-per-week club. DSBK graduate student volunteers typically run two astronomy camps per summer. In total, DSBK has visited four separate summer camp locations and has run a total of six summer camps as of summer 2019. The elementary students attend the camp for 6–8 hours with a half-hour break for lunch in the middle of the day. Each day is typically broken into two topics for the morning and afternoon sessions. The week concludes with a celebration and opportunity for the students to revisit their favorite activities or demonstrations.

Roles and Responsibilities of Volunteers

DSBK graduate student volunteers undertake many activities outside direct interactions with the students, including weekly planning meetings, annual reflection meetings, content and journal development, and event planning and facilitation. The remainder of this section will detail the roles and responsibilities of volunteers during an astronomy semester club or summer camp.

Eight distinct units are covered throughout a semester (or week in the case of summer camps): rockets, night sky, solar system, comets and impacts, invisible light, astrobiology, stars, and galaxies. Each of these units is led by an individual DSBK graduate student volunteer (the "Alpha" in DSBK jargon) who is responsible for obtaining the necessary materials, drafting the schedule, and delegating individual activities to the other volunteers. On the day-of-club, the Alpha addresses the group of students and introduces them to the topic and activities planned. Three or four activities (including a "wiggle time") are scheduled for the allotted time (~2 hours) distributed to the remaining volunteers. The graduate student volunteers leading individual activities are responsible for teaching the relevant concept and/or initiating an inquiry-based activity, while the remaining graduate student volunteers assist the activity leader or interact with the students in small groups.

At the beginning of each club, as the students are arriving, DSBK graduate student volunteers sit among the students and chat with them, often one-on-one or in groups of two to four. These conversations are an opportunity to check in with the students on how they are doing and get to know them as individuals. This time to get to know students is considered part of the role of being an educator, as the aims of DSBK are not only to teach astronomy concepts, but to teach students what it means to be an astronomer. Thus, these interactions are important opportunities for students to learn from the doctoral student volunteers more informally. At the end of each club, the Alpha traditionally instructs the students to open their club journal to the page corresponding to the day's unit, reflect on their experience, and ask lingering questions about the topic. Similarly to the beginning of the club, DSBK volunteers sit among the students and discuss their questions with them, what they enjoyed about the day, or any topic (related to astronomy or not) that they want to share.

Graduate Student Participants

Participants in this study include 14 graduate students and one undergraduate student who volunteered for DSBK over the course of a single school year. This human subjects study was approved by the University of Virginia Instructional Review Board (IRB Approval #2647). Demographic information about the participants is summarized in Tables 1 and 2. Participants attended the outreach program on various days throughout the year and thus filled out variable numbers of surveys. The *n* presented in the table represents the number of participants; the percentages shown were weighted by the number of responses to indicate the percentage of responses from participants in that demographic category. Female graduate students are represented in a larger proportion than is reflective of the department or of physical science graduate students broadly (National Center for Science and Engineering Statistics, 2021; Table 1). Most of the participants were White, so in an effort to respect the confidentiality of the participants who were not White or were of multiple races, their specific demographic categories are not reported but are shown in aggregate (Table 1). Participants came from a variety of years in graduate school (Table 2).

Each of the 14 participants responded to the daily survey a variable number of times in accordance with how frequently they volunteered. Thus, 99 complete survey responses were distributed across the 14 participants.

Table 1. Participant Gender and Race Data

Characteristic	*n* (of participants)	% (of responses)
Gender		
Male	7	52
Female	7	48
Total	**14**	**100**
Race		
Not White	4	29
White	10	71
Total	**14**	**100**

Table 2. Participants' Year Astronomy Graduate Program

Year in Astronomy Graduate Program	*n* (of participants)	% (of responses)
First year	1	1
Second year	6	47
Third year	1	12
Fourth year	3	13
Fifth year	3	27
Total	**14**	**100**

Data Sources

Open-ended survey questions asked participants about their experiences volunteering that day (Table 3). This survey was distributed via Qualtrics, and was intended to be completed within an hour of the club's conclusion by those graduate student volunteers who had consented to the study, although not all graduate students who volunteered reliably filled out the survey after every single club.

A separate survey was completed by graduate student volunteers just once at the start of each semester (also via Qualtrics) in order to collect demographic data and ask questions about each volunteer's involvement with the program, previous teaching experiences, and why they volunteer their time. These responses were predicted to be less likely to vary week to week, and so were asked just once per semester (Table 4).

The questions included in both surveys were developed collaboratively through discussions within the research team to meet the needs of both the research team and the club organizers. The purpose of these questions was twofold, as they were intended to provide researchers with data to report and

Table 3. Daily Survey Questions

Format	Question
Short Answer	1. What were you successful with today?
Short Answer	2. What could you do better tomorrow?
Short Answer	3. What made you feel like an astronomer today?
Short Answer	4. What made you feel like an educator today?
Short Answer	5. Did you feel confident teaching today?
Short Answer	6. Did you feel like you impacted all of the students?

Table 4. Demographic Survey Questions

Format	Question
Multiple Select	Race
Multiple Select	Gender
Single Select	Year in Astronomy Graduate Program
Short Answer	Please describe your current level of involvement with DSBK (What aspects of DSBK do you participate in?).
Short Answer	Please describe your previous experience as an educator (i.e. with DSBK, as a Teaching Assistant interacting with students, or in other positions where you interacted with students).
Short Answer	Why do you want to volunteer your time for DSBK?
Short Answer	What do you want to accomplish by volunteering your time for DSBK?

also to provide the outreach program with programmatic feedback. Thus, the questions were intended to both evaluate the outreach program and provide insight into graduate students' perspectives on participation in educational outreach.

Data Analysis

Survey responses were qualitatively coded by a team of six coders. Initially, for each question, two coders read through the responses individually to come up with emergent codes. Emergent coding prioritizes the voice of the participant and was therefore selected to gain insight into the graduate student's perspectives (Miles et al., 2020, p. 65). The six-person coding team then compared the two lists of codes for each question to create a specific codebook of emergent codes for each of the six qualitative survey questions.

Codes were applied using a Google spreadsheet so that all members of the team could code responses located in a single document. Each of the six coders was assigned to individually code two of the six survey questions, so that two coders coded each question. The whole coding team then came together to discuss instances where the two coders disagreed. In this way, the coding team coded all the responses for all of the qualitative survey questions, and were able to reach agreement on all items.

A list of codes was created for Question 1, and a separate list of codes for Question 2. These qualitative codes emerged from words that participants used in their responses to the survey questions. For example, for Questions 1 and 2, the code *explaining science* was defined as communicating more complex science ideas and topics clearly, and *connecting* was defined as developing personal relationships with the students and helping them with their tasks. However, *creativity*, thinking of new ways to explain things or communicate ideas to the kids, was a code for Question 1 only, whereas *teamwork/collaborating*, focusing on making the club successful as a team rather than individual responsibilities, was a code for Question 2 only.

Questions 3 and 4 asked what made participants feel like an astronomer or an educator, respectively. These questions were first coded *yes*, *no*, or *maybe* based on whether the participant indicated feeling (*yes*), not feeling (*no*), or only somewhat or in some circumstances (*maybe*) feeling like an astronomer or an educator. The same *yes*, *no*, *maybe* scale was used for both questions. Next, qualitative codes emerged from words that participants used in their responses to Questions 3 and 4. A list of codes was created for Question 3, and a separate list of codes was created for Question 4. For example, the code *knowing astronomy* was defined as having background knowledge about astronomy topics for Question 3, and *managing behavior* was defined as helping manage behavior in the classroom for Question 4. *Managing behavior* was not disciplining children for their behavior, but was defined in this study as managing the energy of students in the classroom and directing the students toward productive, rather than distracting, actions. There was a teacher in the classroom who dealt with disciplining students, if that became necessary, so any disciplinary actions were beyond the responsibility of the graduate student volunteers. Although these behavior management skills may be more relevant for elementary classrooms, elements of managing the behavior of students in a classroom are essential for educating at all levels.

For Questions 5 and 6, questions about confidence and impact, the same *yes*, *no*, *maybe* scale was initially used to indicate whether the participant felt confident or that they were impacting students. Next, for Question 5, the participants' confidence level was coded. Responses were coded as *confident* if participants seemed absolutely confident in their response (whether that response was that they did feel confident [*yes*] or that they did not feel confident [*no*]). Responses were coded as *conditional* if the participant put a qualifier or indicated a specific situation in which they felt confident in their response. For example, if a participant wrote that they felt confident "in teaching, but not in disciplining," the response would be coded as conditional. The code *unsure* was used when participants seemed unsure about their own level of confidence, with responses like "I guess so" or "maybe." After the *yes*, *no*, *maybe* coding and the confidence level coding, qualitative codes emerged from words that participants used in their responses to Question 5, and a list of codes was created. For example, the code *engaging* was defined as helping students to feel excited and engaged in science.

For Question 6, the scale of the impact that participants discussed was coded, from *individual* (impacting a single student) to *few* (impacting a small subset of students) to *entire* (impacting the entire class). Categories of *none* and *ambiguous* were created for responses that did not fit the other categories. Finally, emergent codes were also created for Question 6. For example, the code *inspiring* was defined as helping students see themselves as scientists.

All codes for the six daily survey questions are available upon request.

Findings and Discussion

In this section, we present findings and discuss trends and themes that arise from these findings in order to address each research question.

RQ1: What strengths and weaknesses did science graduate students perceive that they have as educators?

A majority of the participants felt successful as educators through participating in the outreach program. Leading activities, connecting with the students, and feeling that the students were engaged with the activities were the most common reasons participants gave in response to the question "What were you successful with today?" (Figure 1). Participants commonly cited variations of "making science fun and interesting" or "bonding with the kids" as reasons that they felt successful as educators, specifically. Thus, participants may have felt that their strengths as educators were in leading class, connecting with students, and making activities engaging. Individuals did not have a single criterion for success; there were a variety of responses across different days for a single participant.

It was unclear from the survey responses whether participants felt successful as astronomers in addition to feeling successful as educators, but it is clear that teaching effectively was of primary concern to all participants. This conclusion was not surprising—the aim of the outreach program is to make science fun and interesting through hands-on activities. Succeeding with the

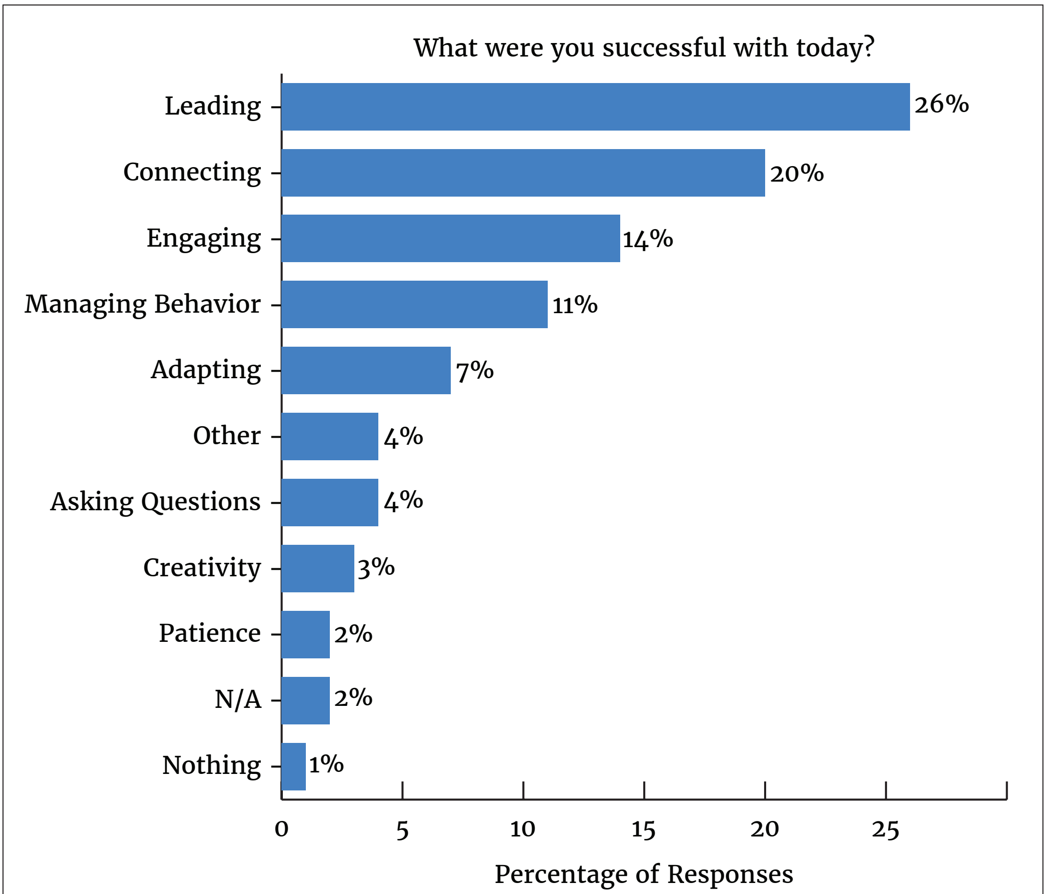

Figure 1. Distribution of Codes Related to Daily Success

act of teaching is essential to achieving this goal. Focus on this effort to be effective educators was evidenced by responses to the 99 times participants were asked "What could you do better tomorrow?" Only three times did participants (all different individuals) respond that there was "nothing" they could do better tomorrow. These responses did not occur on the same day.

Participants felt that managing the behavior of the elementary students was the most significant way that they could improve (Figure 2). Ensuring that the students were engaged with the material and not distracted was especially cited: "getting the kids to focus"; "hold the kids' attention." Engaging students was also associated with a desire to be more patient with the students: "I need to feel less anxious about making sure all the kids are paying attention at all times. They're kids, after all."

Preparation was also identified as a significant area of improvement. More than half of the volunteers (8/14) wanted to be better prepared at some point, and two participants repeated this answer more than three times.

RQ2: How did participating in the outreach program affect students' perceptions of themselves as educators and scientists?

Multiple aspects of participating in the outreach program influenced participants' perception of themselves as educators and scientists. Many of the reasons participants cited for feeling like an astronomer, unsurprisingly, involved directly talking or knowing about astronomy. Although these sorts of responses represented a majority of the reasons participants felt like astronomers, a significant fraction of responses (~50%) were also related to participants' role as educators. This result indicates that participating in the outreach program in an educational role may reinforce their perception of themselves as astronomers.

Participants did not always report feeling

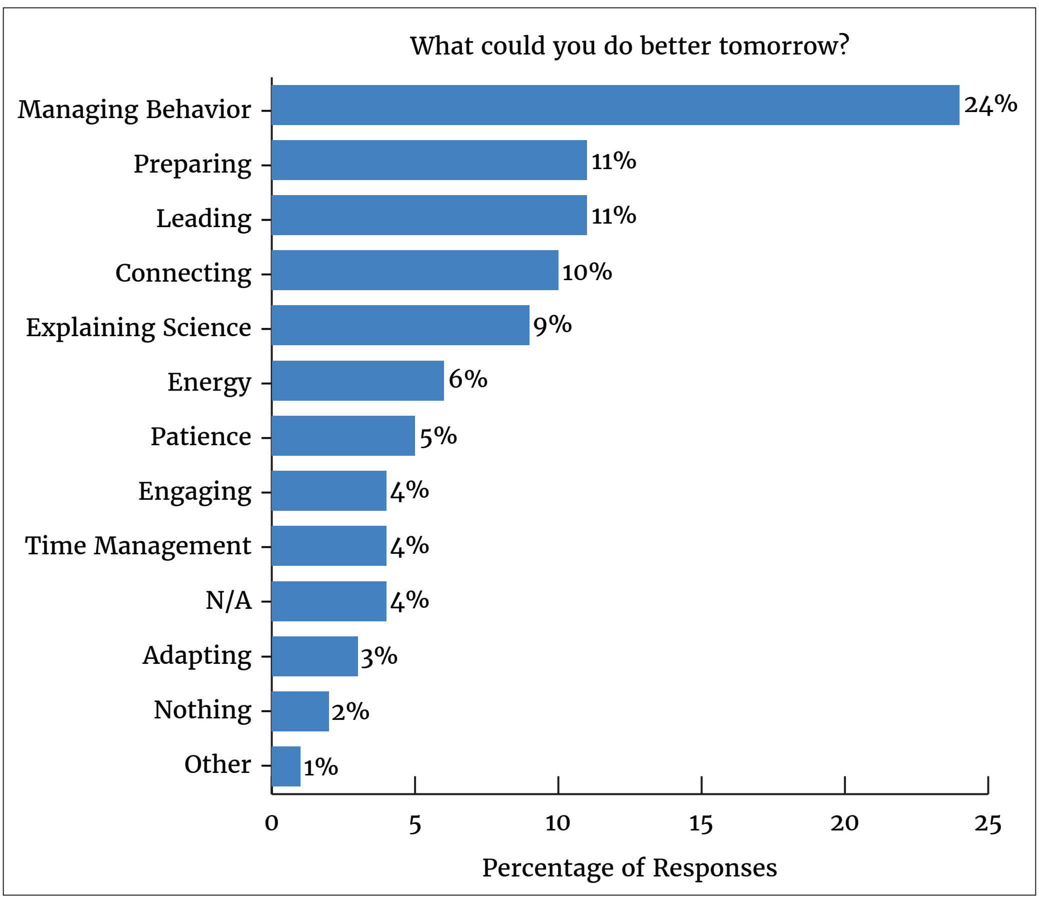

Figure 2. Distribution of Codes Related to Future Improvement

like an astronomer; 12 participants (86%) did not feel like an astronomer on at least one day. Interestingly, besides just saying that nothing made them feel like an astronomer, two participants indicated that they did not feel like an astronomer specifically because they felt like an educator instead ("Eh, not much. I felt like a teacher, not an astronomer" and "Uhhh nothing? More like a camp counselor")—suggesting a mental distinction between teaching and being an astronomer. In direct comparison to the many responses in which knowing astronomy did make participants feel like an astronomer, lacking astronomy knowledge was cited as a reason a participant did not feel like an astronomer.

There was a similar variety in responses on what made participants feel like an educator. Teaching astronomy, an activity clearly melding both education and astronomy, was a common response to "What made you feel like an educator today?" However, it was unclear whether it was the teaching (outreach) or the content (astronomy) that caused participants to feel like an educator. It's important to note that all of the participants reported having some prior experience teaching (e.g., as teaching assistants, mentors, tutors, coinstructors, instructor of record, as well as other outreach endeavors such as planetariums, outreach experiments), so these responses could serve as a reference for how participants gauge whether or not they felt like educators. Most of the participants are in the astronomy graduate program, with three in other disciplines at UVa.

Overall, 63% of responses indicated that the participant felt like an astronomer, and 91% of responses indicated that the participant felt like an educator. Participants thus were more likely to feel like an educator through volunteering for the educational outreach program than they were to feel like an astronomer. Only six participants (43%) indicated on any given day that they did not identify as an educator, whereas 12 different participants (86%) indicated that they did not identify as an astronomer on one or more days. Additionally, participants who marked that they did feel like an educator were more likely to feel like an astronomer than participants who marked that they did not feel like an educator.

There are also ties between the reported confidence of a participant and their iden-

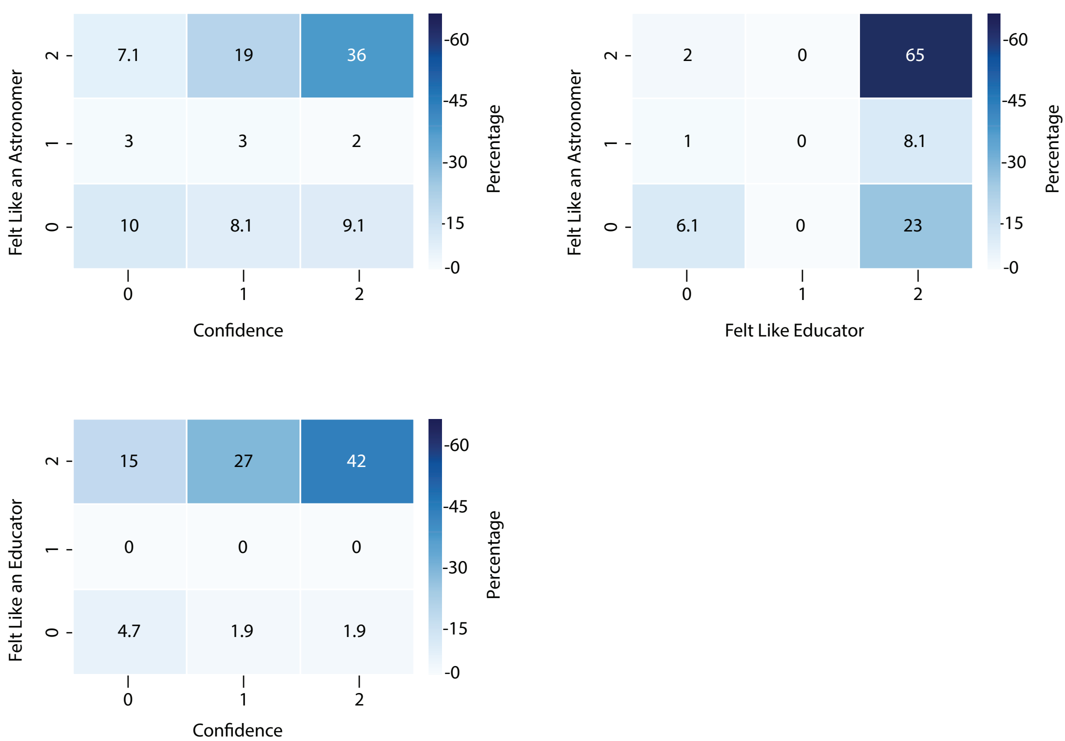

Figure 3. Relationships Between "Feeling Confident," "Feeling Like an Educator," and "Feeling Like an Astronomer"
Note. 0 = no, 1 = somewhat, 2 = yes.

tities as an educator and astronomer in the outreach program. Among participants who answered (*no*, *somewhat*, *yes*) to being confident, (35%, 63%, 76%) answered "Yes" to feeling like an astronomer, and (76%, 93%, 96%) answered "Yes" to feeling like an educator. This result may indicate that feeling like an educator is more confidence independent, whereas feeling like an astronomer depends more on personal confidence. In Figure 3, we display the relationships between the reported confidence of a participant and their identities as an educator and astronomer.

If we pair these relationships with the other finding that people who feel like an educator are also very likely to feel like an astronomer, and recognize that most participants felt like an educator, one could make the argument that in this study, outreach drove a global sense of self-efficacy for all participants (even those with lower confidence).

RQ3: What were graduate students' perceptions of their influence on the students via the outreach program?

Most participants felt that they had a positive influence on the students in the program on most days. However, it is worth noting that the responses varied significantly among participants. For example, daily responses fluctuated during participants' active involvement in the program, and only one participant responded negatively ("Not really") on all days of their participation when asked "Did you feel like you impacted all of the students?" From the survey responses, there was no clear indication that participants who responded negatively to this question reduced their participation over time.

When asked to describe what contributed to whether they felt that they had made an impact, most participants mentioned their role in "teaching" (n = 10; 71%) or "engaging" (*n* = 10; 71%) students at least once. This result reflects the main goal of the outreach program. Interestingly, the most frequently described scenario among all responses was "connecting" (*n* = 24; 24%) and five participants (35%) highlighted informal personal interactions with students, such as helping them with their learning tasks or having casual friendly conversations (e.g., "Yes! They really like talking to me and sharing their work with me. One even said I was their favorite so of course, I feel like I'm impacting them. They're definitely impacting me."), compared to three (21%) participants who separately highlighted their roles in getting students excited and interested during the learning process (i.e., "engaging"), or their experience of teaching astronomy concepts to students (i.e., "teaching"). Overall, the responses were not associated with the number of students that the participants felt that they impacted. The codified data and results are available upon request.

Making personal connections with students related to participants' self-evaluation of their impact. Although the primary goals of the outreach program are focused on teaching/learning astronomy and scientific concepts in an engaging way, participants most frequently highlighted their experience of connecting with students making their involvement impactful. For example, one participant responded, "I noticed that some kids wanted to be with me or near me, and I could see that they really enjoyed me being there with them (as do I)," and several other participants illustrated similar feelings of closeness to the students when asked to describe their impact. Although such experience is not directly associated with the specific theme of the outreach program (and the definition of "impact" likely varies among the participants), these responses do indicate that for many of the graduate participants, establishing personal connections and common understanding with students shaped their attitude regarding involvement in the program. The opportunity to interact closely and subsequently build personal connections with students, which is deeply rooted in the structure of this outreach program, may be absent in common adult-oriented astronomy public outreach programs such as planetarium shows and public lectures. A comparison of graduate volunteers' experiences in these different outreach settings may further specify what is considered impactful outreach for astronomy graduate students, who are at a unique stage of transitioning from guided learners to independent researchers.

Conclusions and Implications

Graduate students often serve important roles as university ambassadors of outreach, despite pressure to focus solely on research under the current "publish or perish" paradigm. This study examined the self-reflections of 16 graduate students after each day of participating in an astronomy outreach program for elementary students. Our results are as follows:

- The participants felt most successful as educators when engaging and leading students through an activity as well as establishing personal connections with the students. Although a majority of the responses indicated a positive attitude toward their teaching abilities, in all but three of the 99 responses participants clearly identified areas for improvement; this outcome demonstrates a concern for teaching effectively among the graduate student volunteers. The area in which participants felt weakest as educators was in managing behavior, which was often combined with concerns that this weakness hurts the learning potential of the students.

- Even though teaching is a core job requirement of a professional astronomer's role as a professor at a research university, this study provided hints that even graduate students involved in educational outreach held the perception that time spent teaching detracts from the identity of an astronomer. It was not surprising that the majority of responses indicated that the participant identified as an educator, but in multiple instances, being an educator was cited as a reason participants did not identify as an astronomer. Overall, participants identified as astronomers in a majority of the responses, with "talking about astronomy most" as the most common reason. We also found a relationship between confidence and identifying as an educator and astronomer—confidence was more tightly linked to feeling like an astronomer than it was to feeling like an educator.

- Most participants felt that they had made a positive impact on the students, but this feeling was subject to change across the days. The goal of the outreach program is to impart astronomy knowledge to young students in a fun and engaging way, yet the personal interactions and connections between participants and students were most commonly cited as the reason behind feeling impactful. Further comparison between these more intimate programs and larger public outreach events may determine whether incorporating opportunities for connection into programs leads to stronger self-efficacy as an outreach participant, graduate student, and liaison between the academic university and community.

A limitation of this study is the small number of participants. However, the small sample size of this study allowed for a more in-depth evaluation of individual experiences, a methodology not practicable with large numbers of participants. The participants reflected on their experience immediately after a day of the astronomy program concluded, resulting in an authentic view of graduate students' attitudes from and toward outreach. In the future it may be useful to survey participants before and after the entire program, in order to examine whether participating in educational outreach may lead to shifts in identities as graduate students, educators, and scientists.

The benefits to graduate students from participating in outreach programs have been well documented (Laursen et al., 2012; Rethman et al., 2020). Our study adds to this body of work by demonstrating that the graduate students involved in this astronomy outreach program developed deep personal connections with the elementary students. This sense of connection was a driving reason behind participants' feeling that they made an impact and important contribution to the education of otherwise underserved elementary school students, and may be an additional benefit to participating in educational outreach more broadly. Participants also gained classroom leadership experience, furthering their identity as both educators and astronomers through teaching astronomy. Developing this identity and self-efficacy as an educator and scientist is a fundamental goal of science graduate programs, demonstrating a benefit to both graduate students and their institution. Participating in this outreach program gave graduate students a platform to see themselves as educators. In turn, we found that when the graduate students felt like educators they were more likely to also feel like scientists, although future research is needed to investigate this connection in greater detail.

Supporting involvement of graduate students in educational outreach enhanced their confidence and identity as scientists, while also bringing the knowledge and resources of research universities to the surrounding community—a major component of nearly every academic institution's mission statement. As educational outreach is integral to this mission of university–community involvement, this study highlights a number of reasons graduate students would benefit from institutional support:

- We found that many participants felt that teaching and outreach was time lost from research. Formally valuing outreach as a component of graduate education might alleviate graduate students' concerns that time spent interacting with the surrounding community is detrimental to their standing in the eyes of their peers, professors, and university.
- We found that graduate student participants felt that they impacted the elementary students through establishing personal connections. Getting involved in local communities and making connections outside the typical academic setting via outreach may have the potential to develop or strengthen a positive sense of belonging and purpose for graduate students, a population that is frequently reported to experience depression and other mental health issues due to stress and/or emotional isolation (Woolston, 2019). Intentionally facilitating graduate students' regular participation in outreach may improve their emotional experience in graduate school.
- Managing the behavior of the elementary school students was frequently cited as an area for improvement by the graduate student participants. Providing training to help graduate students in this area might make an outreach program more effective and bolster the confidence of graduate students as educators. Further, the practice of leading a classroom and directing the attention of a group is an applicable and essential skill across educating at all levels, and in presenting information in other professional settings.
- Participating in outreach programs presents valuable opportunities to implement research-based, innovative pedagogy such as active learning in a broader nonacademic setting, and hence helps narrow the gap between research and practice. Meanwhile, by taking on educator roles during outreach, graduate students have the opportunity to practice pedagogical skills that are essential for developing a future career in higher education.
- Involvement in outreach programs exposes graduate students to aspects of a workplace both inside and outside academia, including team collaboration, project design and management, event planning, and assessment. Encouraging graduate students to familiarize themselves with these aspects via outreach programs may lessen the current lack of opportunities in graduate programs to prepare graduate students for a more diverse career path.

In this work, we studied the experiences of a small set of graduate students participating as volunteers in an educational outreach program. Though our data were sufficient to drive several conclusions, they were also inherently limited in scope. Consequently, several opportunities for future related work remain. We identify three general categories for the ways in which this study may be directly expanded on:

> ***Category 1*:** additional examination of the impact of outreach on the graduate student volunteers,
>
> ***Category 2*:** examination of the impact of outreach on the elementary students, and
>
> ***Category 3*:** expansion of the demographics included in our study.

For the first category, our main suggestion is to pursue a more robust analysis of how the volunteers are mentally and emotionally affected by their outreach work. A growing body of literature (e.g., Rethman et al., 2020) suggests that community engagement can help an individual feel professionally and personally empowered through their impact on others. Given that the mental health of graduate students is frequently threatened, it would be useful to investigate whether outreach can positively impact mental health. Furthermore, as outreach plays an increasingly important role in personnel evaluation and hiring within the field of astronomy, future work could examine the extent to which graduate students feel they have benefited professionally from their outreach experiences, particularly in job application scenarios (e.g., how common is it for interviewers to ask about outreach?). For Category 2, we are especially interested in learning how elementary students feel they are affected by such educational outreach programs. For instance, their outlook on education and personal assessment of their own aptitude may change. Our Category 3 goal might be addressed by performing similar analysis on other groups of graduate students, including other ages or geographic areas.

About the Authors

Allison Matthews *is a postdoctoral fellow at The Observatories of the Carnegie Institute of Washington.*

Renato Mazzei *is a graduate student in the Department of Astronomy at the University of Virginia.*

Anne M. McAlister *is a postdoctoral associate in the Department of Engineering Education at the University at Buffalo.*

Brianna Mills *is a graduate student in the Department of Astronomy at the University of Virginia.*

Yiqing Song *is a postdoctoral fellow at the European Southern Observatory in Santiago, Chile.*

References

Andrews, E., Weaver, A., Hanley, D., Shamatha, J., & Melton, G. (2005). Scientists and public outreach: Participation, motivations, and impediments. *Journal of Geoscience Education, 53*(3), 281–293. https://doi.org/10.5408/1089-9995-53.3.281

Bartel, A. S., Krasny, M., & Harrison, E. Z. (2003). Beyond the binary: Approaches to integrating university outreach with research and teaching. *Journal of Higher Education Outreach and Engagement, 8*(2), 89–104. https://openjournals.libs.uga.edu/jheoe/article/view/619

Boman, J. S. (2013). Graduate student teaching development: Evaluating the effectiveness of training in relation to graduate student characteristics (EJ1007032). *Canadian Journal of Higher Education, 43*(1), 100–114. https://eric.ed.gov/?id=EJ1007032

Clark, G., Russell, J., Enyeart, P., Gracia, B., Wessel, A., Jarmoskaite, I., Polioudakis, D., Stuart, Y., Gonzalez, T., MacKrell, A., Rodenbusch, S., Stovall, G. M., Beckham, J. T., Montgomery, M., Tasneem, T., Jones, J., Simmons, S., & Roux, S. (2016). Science educational outreach programs that benefit students and scientists. *PLOS Biology, 14*(2), 1–8. https://doi.org/10.1371/journal.pbio.1002368

Dang, L., & Russo, P. (2015). How astronomers view education and public outreach: An exploratory study (arXiv:1507.08552). *Communicating Astronomy with the Public Journal*, No. 18, pp. 16–21. arXiv. https://doi.org/10.48550/arXiv.1507.08552

DeChenne, S. E., Enochs, L. G., & Needham, M. (2012). Science, technology, engineering, and mathematics graduate teaching assistants teaching self-efficacy (EJ992130). *Journal of the Scholarship of Teaching and Learning, 12*(4), 102–123. https://eric.ed.gov/?id=EJ992130

deKoven, A., & Trumbull, D. (2002). Science graduate students doing science outreach: Participation effects and perceived barriers to participation. *The Electronic Journal for Research in Science & Mathematics Education,* 7(1). http://scholarlyexchange.org/ojs/index.php/EJSE/article/view/7696

Ecklund, E. H., James, S. A., & Lincoln, A. E. (2012). How academic biologists and physicists view science outreach. *PLoS ONE,* 7(5), 1–5. https://doi.org/10.1371/journal.pone.0036240

Feldon, D. F., Peugh, J., Timmerman, B. E., Maher, M. A., Hurst, M., Strickland, D., Gilmore, J. A., & Stiegelmeyer, C. (2011). Graduate students' teaching experiences improve their methodological research skills. *Science, 333*(6045), 1037–1039. https://doi.org/10.1126/science.1204109

Fowler, D., & Cherrstrom, C. A. (2017). Graduate student perception of teaching development in a college teaching course. *NACTA Journal, 61*(2), 150–156. https://www.jstor.org/stable/90021196

Gilmore, J., Maher, M. A., Feldon, D. F., & Timmerman, B. (2014). Exploration of factors related to the development of science, technology, engineering, and mathematics graduate teaching assistants' teaching orientations. *Studies in Higher Education, 39*(10), 1910–1928. https://doi.org/10.1080/03075079.2013.806459

Gutstein, J., Smith, M., & Manahan, D. (2006). A service-learning model for science education outreach (EJ752639). *Journal of College Science Teaching, 36*(1), 22–26. https://eric.ed.gov/?id=EJ752639

Heinze, K. F., Allen, J. L., & Jacobsen, E. N. (1995). Encouraging tomorrow's chemists: University outreach program bringing hands-on experiments to local students. *Journal of Chemical Education,* 72(2), 167–169. https://doi.org/10.1021/ed072p167

Houck, J. D., Machamer, N. K., & Erickson, K. A. (2014). Graduate student outreach: Model of a one-day "chemistry camp" for elementary school students. *Journal of Chemical Education, 91*(10), 1606–1610. https://doi.org/10.1021/ed400617r

Jarvis-Selinger, S., Pratt, D. D., & Collins, J. B. (2010). Journeys toward becoming a teacher: Charting the course of professional development. *Teacher Education Quarterly,* 27(2), 69–95. https://www.jstor.org/stable/23479590

Justice, G. W. (2006). Motivating university faculty participation in training and professional development of P-12 teachers. *Journal of Higher Education Outreach and Engagement, 11*(2), 3–20. https://openjournals.libs.uga.edu/jheoe/article/view/559

Kajfez, R. L., & Matusovich, H. M. (2017). Competence, autonomy, and relatedness as motivators of graduate teaching assistants. *Journal of Engineering Education, 106*(2), 245–272. https://doi.org/10.1002/jee.20167

Koehler, B. G., Park, L. Y., & Kaplan, L. J. (1999). Science for kids outreach programs: College students teaching science to elementary students and their parents. *Journal of Chemical Education, 76*(11), 1505–1509. https://doi.org/10.1021/ed076p1505

Laursen, S. L., Thiry, H., & Liston, C. S. (2012). The impact of a university-based school science outreach program on graduate student participants' career paths and professional socialization. *Journal of Higher Education Outreach and Engagement, 16*(2), 47–78. https://openjournals.libs.uga.edu/jheoe/article/view/933

Miles, M. B., Huberman, A. M., & Saldana, J. (2020). *Qualitative data analysis: A methods sourcebook* (4th ed.). Sage Publications.

Moskal, B., & Skokan, C. (2011). Supporting the K-12 classroom through university outreach. *Journal of Higher Education Outreach and Engagement, 15*(1), 53–75. https://openjournals.libs.uga.edu/jheoe/article/view/830

National Center for Science and Engineering Statistics. (2021). *Women, minorities, and persons with disabilities in science and engineering: 2021* (Special Report NSF 21-321). National Science Foundation. https://ncses.nsf.gov/wmpd

Olsen, B. (2008). How reasons for entry into the profession illuminate teacher identity development. *Teacher Education Quarterly, 35*(3), 23–40. https://www.jstor.org/stable/23478979

Prieto, L. R., & Altmaier, E. M. (1994). The relationship of prior training and previous teaching experience to self-efficacy among graduate teaching assistants. *Research in Higher Education, 35*(4), 481–497. https://doi.org/10.1007/BF02496384

Rao, S., Shamah, D., & Collay, R. (2007). Meaningful involvement of science undergraduates in K-12 education outreach (EJ766673). *Journal of College Science Teaching, 36*(6), 54–58. https://eric.ed.gov/?id=EJ766673

Rethman, C., Perry, J., Donaldson, J., Choi, D., & Erukhimova, T. (2020). Creating a physicist: The impact of informal/outreach programs on university student development (ArXiv:2012.13981). *Physical Review Physics Education Research, 17*(2). ArXiv. http://arxiv.org/abs/2012.13981

Wellnitz, T., MacRury, N., Child, A., & Benson, D. (2002). Spreading the wealth: Graduate students and educational outreach. *Conservation Biology, 16*(2), 560–563. https://www.jstor.org/stable/3061385

Woolston, C. (2019). PhDs: The tortuous truth. *Nature*, 575, 403–406. https://doi.org/10.1038/d41586-019-03459-7