Astronomers’ and Physicists’ Attitudes Towards Education & Public Outreach: A Case Study with The Dark Energy Survey

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ABSTRACT
We present a case study of physicists’ and astronomers’ attitudes towards education and public outreach (EPO) using 131 survey responses from members of the Dark Energy Survey. We find a disparity between the types of EPO activities scientists deem valuable and those in which they participate. Most respondents are motivated to engage in EPO by a desire to educate the public. Lack of time is the main deterrent to engagement, but a perceived cultural stigma surrounding EPO is also a factor. We explore the value of centralized EPO efforts and conclude with a list of recommendations for increasing scientists’ engagement.

KEYWORDS
Public Engagement; Science Communication; Outreach

1. Introduction

Over the past twenty years, the need for improved communication between scientists and the general public has been recognized worldwide (Burns, O’Connor, & Stockmayer, 2003; Kenney, Dukes, Lips, & Hellmann, 2016; National Research Council, 2010). Advances in science and technology have transformed life in the 21st century, and institutions ranging from government agencies to business conglomerates are calling for change in the perception and understanding of science. Such a paradigm shift has been discussed in the context of the science, technology, engineering, and mathematics (STEM) disciplines, eliciting reform in education materials spanning from the classroom to informal education spaces. This demand for STEM professionals to participate in education and public outreach (EPO) has made evident, however, that the public does not know much about the scientific process or academic culture, nor do the scientists know much about the public interest (Lévy-Leblond, 1992; Miller).
Therefore, scientific societies such as the American Association for the Advancement of Science are advocating a new model in which scientists engage with the public in meaningful dialogue that positively impacts the attitudes and behaviors of not only the general public, but of the scientists themselves.

Of the many STEM topics available to captivate an audience, astronomy is one of the most popularly used to spur public interest (Heck & Madsen, 2013). The night sky is accessible across the globe and provides a spark for curiosity. Astronomical images can be both scientifically discussed and aesthetically admired. Questions surrounding the origin and fate of the Universe inspire scientific, moral, and philosophical debate. Given the natural curiosity inspired by the subject, it is no surprise that there is overwhelming evidence that the public is interested in astronomy programming. Each year nearly 28 million people visit planetaria (National Research Council, 2001), and hundreds of thousands make their way to astronomical observatories. On social media, the NASA Twitter account has nearly 30 million followers to date.

It would seem that such a public demand for astronomy material would encourage the larger community of astronomy professionals (including self-identified physicists, astrophysicists, astronomers, telescope engineers, and technical support staff) to engage in EPO. However, as in many other STEM disciplines, there remains a disconnect between the duties of the professional and engagement in EPO. This is particularly evident in the perceived “Sagan Effect,” a stigma imposed by colleagues in academia on those research professionals who are actively involved in EPO (Shermer, 2002). In a survey of 59 physicists, Johnson, Ecklund, and Lincoln (2014) observe that EPO is considered to be outside the realm of professional tasks and that those who participate in EPO activities are “perceived as occupying a marginal status.”

How and why professional physicists and astronomers engage in EPO has recently become a topic of research. In one of the first systematic surveys of a large international group of astronomers (Dang and Russo, 2015) observed that 79% of respondents (n = 155) expressed belief that EPO initiatives are essential. In addition, only 43% of a subsample of respondents (n = 116) were explicitly funded to engage in EPO programming. Dang and Russo (2015) also asked about barriers to EPO engagement, finding that lack of time and grant funding were significant deterrents. Such barriers were confirmed by survey responses and interviews by Johnson et al. (2014) and Thorley (2016). However, as Johnson et al. (2014) assert, better “understanding how scientists interpret outreach” is crucial for both research and policy. Furthermore, understanding these scientists’ perspectives of EPO will be essential for professionals developing future astronomy-related EPO programs.

In this article we present an analysis of scientists’ EPO experience as compiled from 131 survey responses from physicists, astronomers, and astrophysicists who are part of the Dark Energy Survey (DES, Dark Energy Survey Collaboration et al., 2016). DES is an international collaboration of hundreds of scientists primarily working together to study the effects of dark energy. The project, which was conceptualized in 2004 and officially began taking data in 2012, is composed mainly of faculty, staff scientists, postdoctoral researchers (post-docs), and graduate students. The collaboration

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2https://mcproadaas.s3.amazonaws.com/s3fs-public/content_files/2016-09-15_AAAS-Logic-Model-for-Public-Engagement_Final.pdf

3https://twitter.com/NASA

4This survey was conducted at the 2012 International Astronomical Union General Assembly.

5Several respondents elected not to answer survey items concerning funding.

6https://www.darkenergysurvey.org/
is structured into several working groups, each with a particular scientific focus. Since
its inception in 2014, the Education and Public Outreach Committee has acted as a
working group, developing and cultivating a diverse repertoire of online and in-person
EPO initiatives. For more on DES science, infrastructure, and the EPO program, see
Wolf, Romer, and Nord (2018).

We present an analysis of DES members’ attitudes towards, motivations for, and
deterrents from STEM EPO programming. We consider both general EPO engagement
and involvement specific to the DES EPO program. Throughout this article, we refer to
the collective group of DES members as “scientists,” and emphasize that the attitudes
expressed do not reflect the opinions of all people who self identify as professional
scientists and/or researchers.

2. Methods

2.1. Survey Structure

Although DES scientists are experts in physics and astronomy, we aimed to investigate
their opinions not only about EPO related to these particular disciplines, but about
STEM education and outreach in general.

As such, we designed an anonymous online survey using the Google Forms platform
which could be electronically disseminated to collaboration members. The survey was
composed of three sections: 1) an introduction, 2) questions about general STEM EPO
engagement, and 3) questions about EPO attitudes specific to the structure of and
resources available to DES and other large science collaborations. A final section collecting
demographic information (i.e., gender, ethnicity, age, and position) concluded
the survey. While all questions in the demographic section of the survey were manda-
tory, each question provided respondents with the option to decline a response. The
survey was open to participants for two weeks; reminder emails were sent with one
week, three days, and one day remaining in the open survey period.

We investigated scientists’ dispositions from multiple perspectives by including sur-
vey items related to diverse components of the EPO experience. Respondents were
asked about the types of activities in which they have engaged and how frequently
that engagement takes place. We inquired about personal and professional motives
for engagement, as well as any barriers. Furthermore, we asked scientists to describe
how their peers view EPO and to provide their feedback on more centralized EPO
organizational efforts. The complete survey and data are provided on the DES EPO
research website.

In the survey introduction, we defined STEM EPO under the umbrella of the Burns et al.
(2003) “vowel analogy” of science communication: “the use of appropriate skills,
media, activities, and dialogue” to produce “awareness, enjoyment, interest, opinions,
and understanding” of science. The survey consisted of mixed question types including
Likert measures, multiple choice and checkbox questions, and free response. We note
that due to nuances with the survey platform, in some cases respondents could not
change an incorrectly submitted response.

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7 https://www.google.com/forms/about/
8 https://www.darkenergysurvey.org/education/des-education-outreach-science-communication-research/
9 Scaling method used to gauge response to a statement, i.e., the extent to which a respondent agrees or disagrees.
2.2. Respondents

All DES members are encouraged to subscribe to a DES-wide LISTSERV (electronic mailing list), which is frequently used for collaboration-wide announcements and updates. The survey described in Section 2.1 was emailed to the DES LISTSERV, which at the time of this study, included 606 subscribers. Subscribers include current active DES members, as well those who are either inactive or have since left the field.

In total, 131 current and former DES members (22% of the LISTSERV membership) participated in the online survey, of which 115 self-identified as “Active Members.” Figure 1 displays distributions of respondent gender, age, ethnicity, and position (e.g., faculty or graduate student). Respondents were predominantly male and white. Most were relatively early career scientists: 65% reported they were under the age of 40 and 37% were younger than 30. Respondents were more evenly distributed with respect to current position. Post-docs, graduate students, and faculty each composed roughly a quarter of those surveyed. The remaining quarter consisted of staff scientists and people with other occupations (such as science educator, scientist emeritus, and software developer).

The DES membership database records are not current or detailed enough to allow us to make demographic comparisons of the respondents to the full DES collaboration. It is, however, possible to compare to recent data drawn from the larger astronomy community, such as the American Astronomical Society (AAS) Workforce Survey of 2016 US Members. The AAS survey results consist of responses from 1795 AAS members living in the United States. Of the AAS respondents, 73% identified as male compared to 72% in our survey. One percent of AAS respondents and 3% of DES respondents preferred not to indicate their gender. The distribution of ethnicities for AAS respondents was 84% white, 9% Asian, 3.5% Hispanic or Latino, and 1% black or African American. The corresponding fractions for our DES respondents were 72%, 10%, 5% and 1.5%. Four percent of AAS respondents and 11% of DES respondents preferred not to indicate their ethnicity. Given this comparison, we conclude that our survey sample is fairly representative of the astronomy community in the United States, at least in terms of gender and ethnicity.

For cases in which we had both hypotheses about response differences between demographic groups and sufficient sample size, we performed chi-squared tests of independence to quantify any significant effects. Respondents were grouped as follows: gender [male, female], ethnicity [white, non-white], age [18-30, 31-40, 41+], and academic position [tenured (i.e., Staff Scientist, Faculty/Professor, or Scientist Emeritus), non-tenured (i.e., Undergraduate Student, Graduate Student, or Post-Doc)]. The results of these tests are presented in Sections 3.1 and 3.2.

Since participation in the survey was entirely voluntary, we could not ensure that all DES members responded or that those who did were a representative sample of the full DES collaboration. Therefore, selection bias is a factor that impacts the results presented here. It is likely that many of the study respondents were members who already had some interest in EPO. Roughly 79% of respondents stated that they were (or have been) involved in some type of EPO project local to their institution or community, and 66% responded that they had participated in a DES-specific EPO initiative.

[10] https://aas.org/files/aas_members_workforce_survey_2017.pdf
3. Results

3.1. Types of Engagement and Time Commitment to EPO

In the first main section of the survey, we provided a list of nineteen EPO activities (see Figure 2), spanning a range of engagement audiences, environments, and media, and asked scientists to indicate how frequently (if at all) they had engaged in each. The five most popular responses were: Public presentations/lectures (82%), Undergraduate Teaching (79%), Science fairs/festivals (67%), Mentoring (64%), and Social media (Personal, i.e., from a personal Twitter account) (54%). We find these most common answers unsurprising, as participation in these activities is accessible to, and commonly asked of, scientists at many academic institutions.

However, participation in specific EPO activities may not be indicative of the importance scientists place upon them. One could posit that pragmatic and logistical factors such as ease, cost, and required time likely influence how scientists elect to engage in EPO. Furthermore, it is possible that these factors are more influential than the perceived value of the activities themselves. To explore this hypothesis, we asked survey respondents to rank the nineteen EPO activities on a 5-point Likert scale: 1 = Least Impactful/Valuable to the Audience to 5 = Most Impactful/Valuable to the Audience. They were also given the option to choose Not Impactful/Should not count as EPO or I Don’t Know. To determine which activities respondents

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Choosing a response indicates that the respondent had participated in this activity at least once.
deemed the most impactful (highest value), responses were scored using the following metric for each activity:

\[ \text{Value} = \frac{R}{5n}, \quad \text{where} \quad R = \sum_{i=1}^{n} R_i \quad \text{and} \quad n = n_{\text{resp}} - n_{\text{IDK}}. \]  

(1)

Here \( R_i \) is the rank from 0-5 (Not Impactful responses were counted as 0), \( n_{\text{resp}} \) is the total number of responses, and \( n_{\text{IDK}} \) is the number of “I Don’t Know” responses (which are excluded from the sum). Using Eq. (1) we find the top five activities with the highest value are: On-air media (e.g., TV, radio), \( \text{Value} = 0.86, n = 125; \) Elementary/High School Teacher Development, \( \text{Value} = 0.85, n = 128; \) Mentoring, \( \text{Value} = 0.81, n = 124; \) Science journalism/science writing/science blogging, \( \text{Value} = 0.80, n = 127; \) Public presentations/lectures, \( \text{Value} = 0.80, n = 128. \) Figure 2 directly compares reported participation and perceived value for all 19 activities. Among the largest disparities found in this comparison include Elementary/High School Teacher Development, Science journalism/science writing/science blogging, and On-air media (e.g., TV, radio), which are ranked high in value, but are not as commonly engaged in as the other highly-valued activities. Among the activities with the least participation are Audio Media (e.g., Music, Podcasts) and Comedy/Plays/Open Mic Nights which are also among the lowest-valued.

We also included several questions designed to learn how much time DES scientists commit to EPO. We asked survey respondents to indicate their average weekly time commitment to preparing and engaging in EPO activities by checking corresponding boxes. In addition, we asked how much time they would like to spend on such tasks. A summary of these responses is shown in Table 1. It is clear that, on the whole, respondents would like to spend more time on both preparing and engaging in EPO than they currently are. Thirty-five percent of respondents would like more time to prepare for EPO activities, while 62% are satisfied with their current preparation time. Similarly, 45% of respondents would like to spend more time actually engaging in EPO, while 54% are content with current engagement. Furthermore, while nearly 10% of respondents do not engage in EPO, only 3% lack the interest.

We also asked respondents to choose answers corresponding to when they primarily engage in EPO. The majority chose the response I engage in EPO during work hours and during my free time (63%). The remaining responses were as follows: I only engage in EPO during my free time (i.e., during evenings and on weekends (21%), I do not engage in EPO (8%), and I only engage in EPO during work hours (7%). Two percent of respondents chose I Don’t Know. We analyzed this question by the demographic groups outlined in Section 2.2 and divided respondents into two categories: those who engage in EPO only in their free time, and those who engage in EPO at work. Chi-squared tests show that differences between most demographic groups are not significant. However, we do find some evidence that a larger fraction of non-tenured (26%) versus tenured (6%) respondents engage in EPO only during their free time (\( \chi^2 = 9.02, p = 0.0027 \)).

\[ ^{12} \text{This grouping was chosen such that we would have sufficient statistics for a chi-squared test. The group of respondents who engage in EPO during work hours and during free time was collapsed with the group who engage in EPO during work hours only.} \]
3.2. Motives and Deterrents

Several survey items were intended to probe why respondents may or not engage in EPO activities. Through these items we also sought to understand if respondents feel that engaging in EPO is part of their duty as a member of the larger scientific community.

When asked whether they think engaging in EPO is part of their professional responsibility as a scientist, 69% of respondents answered with an unequivocal Yes. When asked if it should be part of their professional responsibility, this fraction rose to 76%. When asked instead whether they believed it should be a personal responsibility of a scientist, 80% responded Yes unequivocally. Some respondents instead answered these
(a) How long do you spend (on average) per week on EPO?

| Time Spent   | On Preparation | On Engagement |
|--------------|----------------|--------------|
| I don’t participate in EPO | 13 (10%)       | 13 (10%)     |
| 0-1 Hrs      | 77 (59%)       | 69 (53%)     |
| 1-3 Hrs      | 30 (23%)       | 33 (25%)     |
| 3-5 Hrs      | 7 (5%)         | 9 (7%)       |
| 5-10 Hrs     | 3 (2%)         | 5 (4%)       |
| >10 Hrs      | 1 (1%)         | 2 (2%)       |

(b) How long would you like to spend (on average) per week on EPO?

| Time to Spend | On Preparation | On Engagement |
|---------------|----------------|--------------|
| I don’t want to participate in EPO | 4 (3%)         | 4 (3%)       |
| 0-1 Hrs       | 60 (46%)       | 41 (31%)     |
| 1-3 Hrs       | 45 (34%)       | 55 (42%)     |
| 3-5 Hrs       | 13 (10%)       | 15 (12%)     |
| 5-10 Hrs      | 5 (3%)         | 10 (8%)      |
| >10 Hrs       | 4 (3%)         | 6 (5%)       |

Table 1. Current (a) and desired (b) time commitment to EPO.

questions with a conditional. In each case, less than 12% responded Yes, but only education (i.e., undergraduate teaching or mentorship) and less than 4% responded Yes, but only public outreach (i.e., public lectures or volunteering at science festivals). We further examined these results by comparing the responses regarding perceived responsibility across the different demographic groups outlined in Section 2.2. After performing chi-squared tests of independence we find that the differences between the fraction who selected Yes among these groups are not statistically significant ($p > 0.05$ for all comparisons).

Furthermore, we asked respondents about their general motivations for engaging in EPO and any factors which deter their engagement. Parts of these questions explicitly addressed how funding (or lack thereof) affects these motives and/or deterrents. Figure 3 presents the distribution of responses for motivating factors. The most popular motivating factor for participating in EPO is the desire to educate the general public (80%); this is closely followed by respondents engaging in EPO because they find it personally enjoyable (73%). When asked how funding impacts EPO engagement, 17% of respondents indicated they are currently funded specifically to participate in EPO, and 21% indicated they hope engaging in EPO will help them secure future funding.

When asked about barriers to engagement, lack of time was overwhelmingly the most popular response (52%). We note that in this survey item, there was no distinction made between time spent at work or personal time, or any conflict between
Figure 3. Distribution of checked motivating factors towards EPO engagement. Respondents were provided a list of possible motivating factors for EPO engagement and asked to check all that apply. Complete descriptions for provided list of factors, some of which are present in the legend, are given in Table A1.

spending time on EPO and research. Funding was also indicated to be an issue, as 19% of respondents indicated they “are not funded to do EPO.” Additionally, respondents indicated that they felt they lacked the skills and/or training to engage in EPO activities (16%). A subset of respondents noted that cultural (3%) and language (6%) barriers prohibited their involvement in EPO activities.

Issues with program logistics were another barrier to engagement. In a free-response option, several respondents reported that they did not want to participate in the organization or administration of activities and/or that they were not aware of current opportunities for engagement. The desire for an “EPO specialist” to facilitate scientists’ EPO engagement was prominent amongst those who reported barriers.

We concluded this portion of the survey by asking scientists about factors which might encourage increased participation in EPO activities. Results are displayed in Figure 4. Three important themes emerged from the responses. The first is a response to the previously discussed barrier of lack of time. Many respondents indicated they would be more inclined to participate in EPO if they felt they could allocate more time during the work week (53%) and if EPO were listed as an explicit component of their job descriptions (46%). In addition, the desire for changes in the cultural value of EPO within the astronomy community was evident. Respondents indicated that they would feel more inclined to participate in EPO if doing so would help with career development (26%), if doing so were encouraged by supervisors/managers (34%), and if doing so were more highly regarded among peers (39%). These responses suggest that amongst ≥ 30% of respondents there exists a perception that 1) EPO does not
positively contribute towards successful careers in academia, and 2) there is a perceived stigma surrounding participation in EPO in academic culture, at least in the context of physics and astronomy.

**Figure 4.** Distribution of checked factors which would encourage future EPO engagement. Respondents were provided with a list of possible incentives to encourage participation in EPO activities and asked to check all which might increase their motivation. Respondents could also write in their own responses; these have been combined into the “Other” category. Complete descriptions for provided list of factors, some of which are present in the legend, are given in Table A2.

### 3.3. Centralization

As a primarily grass-roots effort, analysis of the development and implementation of the DES EPO program offers important insight for future large collaborations (Wolf et al., 2018). The final section of our survey focused on EPO in large collaborations, both for the purpose of self-reflection for the DES EPO organizational team, and to offer suggestions for future EPO programs.

#### 3.3.1. Views of EPO Across the DES Collaboration

Survey respondents were asked to rank the value they believe four DES-related groups place upon EPO. Respondents were asked to provide an answer using a 5-point Likert scale: 1 = NOT AT ALL to 5 = VERY MUCH. Respondents were also given an I DON’T KNOW option. Table 2 summarizes the responses for four DES-related groups. The groups chosen for this item were intended to span the scope of an individual scientist’s involvement with DES, from a collaboration-wide level (A. the DES collaboration as a whole and B. those in collaboration management positions) to more personal...
interactions with other DES members (C. within a scientific working group or D. local to an institution).

Generally, respondents indicated that each of the four DES groups place mid to high value upon EPO. When asked to rank the view of the DES collaboration as a whole, the mean (standard deviation) of the responses was 3.7 (0.97). When asked to rank the value DES management places upon EPO, the mean (standard deviation) of the responses was 3.5 (1.05). Notably, the number of I Don’t Know responses was also highest when asked about the value DES management places on EPO ($n = 28$).

**Rank how much you think the following DES groups value EPO.**

| DES Group                  | (Very Little) | 2 | 3 | 4 | (Very Much) | I Don’t Know |
|----------------------------|---------------|---|---|---|-------------|--------------|
| DES Collaboration          | 1 (1%)        | 10 (9%) | 40 (35%) | 36 (31%) | 29 (25%) | 15 |
| DES Management             | 4 (4%)        | 10 (10%) | 38 (37%) | 29 (28%) | 22 (21%) | 28 |
| Your DES Working Group     | 11 (10%)      | 28 (26%) | 29 (27%) | 21 (20%) | 18 (17%) | 24 |
| DES Members at Your Institution | 5 (4%)       | 22 (19%) | 29 (25%) | 35 (30%) | 26 (22%) | 14 |

Table 2. Responses for the Likert survey item: “Rank how much you think the following DES groups value EPO.” Respondents were asked to rank on a 5-point scale: 1=“Very Little” to 5=“Very Much.” Respondents were also given the opportunity to answer “I Don’t Know.” Percentages listed in the table correspond to the fraction from the total responses using the Likert scale only.

The reported value placed upon EPO in the smaller DES groups was less favorable than that of the groups on the collaboration-wide level. The mean values (standard deviations) of the responses for the working groups and individual institutions were 3.1 (1.24) and 3.5 (1.15), respectively. But it is important to note that 36% of respondents ($n = 107$) indicated little value (response of 1 or 2) when asked to rank the value of EPO amongst individual science working groups, and 23% of respondents ($n = 117$) indicated little value when asked about DES members at their own institutions.

### 3.3.2. Centralized Support for EPO Engagement

Respondents were asked how DES and other large science collaborations could best support collaboration-wide engagement in EPO. The most popular response (57%) suggested that collaborations build and maintain a repository of talks, slides, curricula, etc., that can be used in various EPO activities (including both DES-sponsored and locally-organized programs). The second most popular response involved funding: 54% of respondents suggested collaborations could incentivize EPO participation by explicitly allocating funding for EPO projects. Another popular response (52%) suggested that collaborations consider EPO as valuable time spent toward science infrastructure, and that this would ultimately lead to returns with high scientific value. These returns might include the ability to access data even after one leaves a collaboration member institution (i.e., data rights) or the ability to be a co-author on any collaboration publication (i.e., authorship rights). Other popular responses included that collaborations hire dedicated EPO staff (48%) and that collaborations could provide communication training for scientists (37%).
In addition to checking predetermined answers for this survey item, respondents had the ability to write in responses. Of the seven written responses, four mentioned the role of collaborations in changing the cultural perspective of EPO within the physics community. Responses included calling for a change of community value, instituting EPO engagement as an important factor in job applications for early career scientists, and calling for changing the perceived cultural norm that engaging in EPO is secondary, in terms of time and status, to research. Another point illuminated by the written responses was the desire to see a quantitative measure of the impact of EPO.

Finally, scientists were asked to answer an open-ended question regarding the value of centralizing EPO efforts for large science collaborations. Of the 81 responses, 70 were for centralization, seven were against, and four found the question unclear and/or were unsure of the value of a central EPO program. Responses not immediately in favor of centralization included thoughts that an international collaboration should develop EPO programs specific to each participating country and that scientists should not spend their time on efforts not directly related to the project’s primary science goals. These responses also illuminated that respondents had differing views of the meaning of “centralization.” Some respondents interpreted it as an effort to facilitate EPO via making repositories or other means of coordination, while others had a more reductionist view, in which centralized EPO is a mechanism which replaces individual EPO activities. In the latter responses, respondents expressed that collaboration-organized EPO does not provide support to more localized or community-oriented events.

4. Conclusions

In this article we presented survey results from a case study of the attitudes of astronomers, physicists, and astrophysicists towards EPO. The study was conducted using 131 responses from scientists in the international Dark Energy Survey collaboration. The survey was designed to explore general attitudes towards STEM EPO as well as those in the context of large-scale science collaborations. We note that as participation in the survey was voluntary, it is likely that respondents already had an interest in EPO engagement, resulting in a possible selection bias.

As discussed in Section 3.1, we find a disparity between the EPO activities in which respondents are involved (e.g., public presentations and teaching) and those that, in their opinion, would have more impact on the general public (e.g., on-air media and elementary or high school teacher development). We speculate that perhaps the respondents do not know how to personally effect change in the arena of formal education, specifically since it is outside of their professional responsibilities, and that the opportunity to achieve such development via official organizations may be lacking. The low engagement we find in science writing and on-air media may be similarly explained due to their specialized and freelance nature — not many people have the skill or opportunity to perform such tasks. The true reason for these differences would be interesting to pursue in future studies.

Similar sentiments are reflected in the responses to questions of time commitment to EPO. Respondents reported that they spend less time preparing and engaging in EPO than they would like. This lack of time was also mentioned in Section 3.2 as the largest barrier preventing engagement in EPO, along with lack of funding, training and/or skills, and interest in performing organizational duties for EPO activities. As for what currently motivates them to engage in EPO, respondents stated a desire to educate the general public, reach minorities and under-served communities, and
inform taxpayers of the work they are doing. Respondents also reported that they experience personal enjoyment from engaging in EPO, consider it as an opportunity for personal growth, and view it as a means to secure future funding (some government agencies require EPO components in their grant proposals). Furthermore, the majority of respondents believe that engaging in EPO-related activities is and should be a personal and professional responsibility of scientists.

Where possible, we performed chi-squared tests to determine any statistically significant differences between the opinions and behaviors of various demographic groups described in Section 2.2. In a comparison of when respondents engage in EPO, we find a significant difference in the behaviors of tenured versus non-tenured scientists. We hypothesize that this may be because non-tenured scientists feel that engaging in EPO during work hours is not appropriate or that their supervisors would not approve of such a use of work time. Respondents with tenure, however, may feel more in control of their time, or are perhaps even mandated by institutions and/or funding agencies to engage in EPO (particularly undergraduate education and mentorship) during work hours. Unfortunately, our small sample size prohibited our ability to perform this type of analysis for the majority of survey items. We believe that a similar analysis with a much larger sample size, as well as more carefully designed demographic groupings (e.g., for organizations wishing to increase EPO engagement amongst early career scientists), would be a compelling pursuit for a future study.

Another interesting result of this study is the comparison between individual feelings about EPO, as summarized above, and how scientists perceive the feelings of their colleagues. When consolidating responses from various sections of the survey, we observe that the perceived culture surrounding engagement in EPO in the physics and astronomy academic communities can have an (often negative) effect on scientists’ engagement. This perception is consistent with results from other studies exploring physicists’ and astronomers’ attitudes towards EPO. As more empirical evidence for this effect is collected, it has become clear that to facilitate EPO engagement, scientists in leadership (or mentoring) roles who support EPO engagement will need to better express their opinions in order to cultivate a more supportive and conducive environment.

This perceived stigma is particularly interesting when discussed in the context of broader scientific collaborations. When asked to rate how four different DES groups value EPO, we find that respondents believe working groups and members of their own institution place less value on EPO than the management and collaboration as a whole. We believe this could be due to two factors. First, the primary goal of the science working groups is to engage in research, and thus communicating scientific results outside of academia is not prioritized. The second contributing factor may be that the centralized EPO coordination did not extend throughout the hierarchy of DES infrastructure, i.e., there were no DES EPO representatives actively liaising between the EPO Committee and the working groups. Therefore, there was not an established channel of communication to regularly inform individual working-group members of EPO events. We recognize that despite this disparity across groups, the perceived value placed on EPO is a medium to high value for all groups (Table 2). Yet in Figure 4 respondents claim that they would be encouraged to engage in more EPO if it were more highly regarded among their peers. It may be that there are general perceptions that 1) while EPO is valued, it must be secondary to other duties, such as research, or 2) EPO is not valued by the people scientists interact with most regularly (and is instead only valued by funding agencies or those in leadership positions).

Furthermore, the fraction of respondents that indicated that they do not know the
value that DES management places upon EPO is curious, given the various communication vehicles available to DES leadership. It is possible that, in general, collaboration members feel removed from the DES leadership and do not feel confident in assigning a value to someone else’s opinion. For example, an individual collaboration member may have a much closer rapport with a colleague at his/her institution than someone on the DES management committee. We also posit that while verbal support was given by the DES leadership to the DES EPO Committee (Wolf et al., 2018), the same support was not effectively communicated to the collaboration as a whole.

Responses to items throughout Section 3.3 highlight three key messages about centralizing EPO for collaborations. First, the responses suggest that effective collaboration-sponsored EPO programming, at least in the minds of collaboration scientists, requires a team dedicated to program organization, communication, and implementation. For example, building and maintaining a presentation slide and image repository is a substantial task which would require significant time and infrastructure expertise. Second, responses suggest the potential need for reevaluation of the allocation of EPO funding and the associated explicit directives for EPO engagement. This reconsideration of the funding stream is essential with respect to the collaboration leadership who are responsible for managing funds, but also possibly with respect to the greater sources of collaboration funding (i.e., government agencies and private foundations). Third, we find evidence that if collaborations want to foster EPO participation, collaboration leadership and others in positions to affect collaboration culture should work to cultivate a community where spending time on EPO is viewed as a positive use of time and resources.

Based on the results presented here, we propose the following recommendations for those wishing to increase EPO participation amongst physicists, astronomers, and astrophysicists:

(1) **For the scientist**
   (a) Engage in discussion about EPO activities with peers to foster open dialogue. Suggested points for discussion include: merits of EPO engagement, time spent on activities, and assumed perceptions versus reality of beliefs within the academic community. (Sections 3.1 and 3.2)
   (b) Seek expertise of social science and EPO professionals to learn more about EPO evaluation, assessment design, and impact metrics. Collaborate with these professionals to measure impact of EPO engagement for both intended audiences and participating scientists. (Section 3.2)

(2) **For scientists in positions of leadership**
   (a) Explicitly discuss expectations concerning time spent engaging in EPO in scientific job descriptions and interviews, independent of interviewee status, i.e., for graduate students, post-docs, faculty, etc. (Section 3.2)
   (b) Clearly outline EPO-related policies and support through different channels: emails, official communications, Memoranda of Understanding (e.g., with science collaborations), and presentations. (Section 3.3.1)
   (c) Institute discussion about how science goals and policies can align with EPO goals. (Section 3.3.1)
   (d) Create incentives like rewarding investment in EPO with benefits such as data rights and authorship on papers. Collaborate with EPO facilitators

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13 As discussed in Wolf et al. (2018), collaboration meetings, collaboration-wide telephone conferences, and the DES LISTSERV are available to the DES leadership to make announcements and update collaboration members.
and funding agencies to develop further incentives (Section 3.3)
(e) Open communication with funding agencies to discuss sources of EPO funding and how these funds are managed. (Sections 3.2 and 3.3.2)
(f) Consider hiring dedicated staff to organize, develop, facilitate, and evaluate EPO activities. (Sections 3.2 and 3.3.2)

(3) For EPO organizers and facilitators
(a) Survey participating scientists to inform program organization. Develop activities which align with the types of activities in which scientists are already involved. (Section 3.1)
(b) Provide an estimate of required time necessary to participate in an EPO event, keeping in mind that most scientists want to spend 0-3 hours per week on average engaging in EPO activities. (Sections 3.1 and 3.2)
(c) Devote resources and time towards infrastructure (e.g., organize and prepare for events, curate presentation materials) to increase scientist engagement during events. (Section 3.3.2)
(d) Clearly identify the roles of EPO organizers and facilitators amongst scientists. Describe how centralized EPO efforts fit into the context of EPO with local institutions and communities, as well as within the greater project. (Section 3.3.2)
(e) Discuss EPO program evaluation design and results with scientists interested in measures of impact. (Section 3.3.2)
(f) Collaborate with scientists in leadership positions and funding agencies to develop incentives for EPO participation. (Section 3.3)

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Appendix A. Full list of survey item options for responses presented in Figures 3 and 4.

In general, what are the motivating factors for your engagement in EPO? Check all that apply.

| Figure Key | Item Response Text |
|------------|--------------------|
| A1         | I want to educate the general public |
| A2         | I personally enjoy engaging with/in EPO - it’s fun |
| A3         | I want to inform taxpayers about my research |
| A4         | I want to teach science to school children and/or underserved communities |
| A5         | I am looking for personal growth or experience |
| A6         | I like the creative outlet that EPO activities offer |
| A7         | I hope that my engagement in EPO will help earn me future funding |
| A8         | I am funded to engage in EPO |
| A9         | I am on the job market and think EPO will boost my resume/CV |
| A10        | I want to be famous |
| A11        | I am mandated to engage in EPO by my local institution/department |
| A12        | I am not interested in participating in EPO |

Table A1. Complete list of possible answers for the survey item presented in Figure 3. Responses are listed in descending order, i.e., A1 was the most popular response, rather than the order in which they were presented in the survey item.
Which of the following would encourage you to get involved (or more involved) in EPO activities? Check all that apply.

| Figure Key | Item Response Text |
|------------|--------------------|
| B1         | If I felt that I could allocate time during the work week toward EPO |
| B2         | If EPO were an explicit and official part of my job description |
| B3         | If EPO were more highly regarded among my peers |
| B4         | If the necessary EPO infrastructure already existed and someone else told me how I could help |
| B5         | If EPO were encouraged by my supervisor or the managers of my department/institution/collaboration |
| B6         | If I saw more evidence that EPO makes a positive impact on society |
| B7         | If EPO helped with my career development |
| B8         | If it were easier to obtain funds for EPO activities |
| B9         | If I knew how to efficiently communicate the technical aspects of my work to the public |
| B10        | None of the above |
| B11        | If I shared the same language as my local community |
| B12        | Other |
| B13        | If I shared the same culture as my local community |
| B14        | If I shared the same ethnicity as my local community |

Table A2. Complete list of possible answers for the survey item presented in Figure 4. Responses are listed in descending order, i.e., B1 was the most popular response, rather than the order in which they were presented in the survey item.