Chicken and the egg: does outreach lead to a growth mindset or vice versa?

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Recent studies on growth mindset have noted their significant benefit to students, in both supporting higher academic achievement and being correlated with greater levels of persistence in STEM disciplines. In spring 2023, the first national survey of the impact of student facilitation of informal physics outreach programs on student development was distributed to Society of Physics Students chapters. This survey, which received 704 responses, noted an important connection between self-reported measures of students' growth mindset and their engagement in informal physics outreach programs. This work explored the relationship between having a growth mindset and engaging in outreach—specifically, whether a growth mindset encourages students to participate in outreach or if outreach itself fosters a growth mindset. To investigate this, we examined student responses to three open-ended questions, looking for indicators of mindset and directionality. Across 239 student responses, we identified 26 instances of mindset, with 24 reflecting a growth mindset. Notably, 17 of these indicated that outreach had contributed to its development. Through thematic analysis, we identified five significant themes: *more to learn, confidence in ability/knowledge, students' realization of understanding, development of understanding*, and *recognition of difficulty*. Four of these themes emerged from responses demonstrating a growth mindset, while the last was observed in fixed mindset responses. These findings, drawn on self-reported data, strongly suggest that participation in informal physics outreach programs can provide students with meaningful opportunities to develop a growth mindset, which may significantly benefit their academic performance and motivation to complete their degrees.

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I. INTRODUCTION

The practices, programs, and interventions that can improve student retention rates are of common interest to physics departments across the country. The bulk of the literature indicates that students with a well-developed disciplinary identity, a strong sense of belonging, and a growth mindset are more likely to remain in the major and graduate on time [1–4]. To date, most research has focused on helping students develop these characteristics through their coursework or labs. Prior literature has revealed a link between students' possession of a growth mindset and higher achievement and persistence, particularly in STEM courses [5, 6]. Research on students taking introductory physics courses has shown that mindset serves as a key marker of student success in a calculus-based physics sequence, making it a significant factor in determining their final grades [7].

Recent studies emphasize the importance of extracurricular programs, such as Learning Assistant programs and undergraduate research, in fostering students' physics identity and growth mindset [8, 9]. However, the impact of informal physics outreach programs on university student development remains a relatively understudied area. These programs, often referred to as outreach, public engagement, or informal physics experiences, encompass a broad set of activities that bring physics students out of the classroom to engage with the general public, both synchronously and asynchronously, to share their knowledge and passion for physics. Prior research shows that, through these interactions, students develop their disciplinary identity and enhance essential career skills (*e.g.*, communication, teamwork, and design) that are not commonly taught in a formal physics curricula [10–15].

Recent results from the first and largest nationwide study to date on the impacts of student facilitation of informal physics programs on physics identity, sense of belonging, and career skill development revealed another interesting connection with mindset [15]. Specifically, regression models showed that student engagement in outreach programs was significantly linked to indicators of a growth mindset. However, these models did not reveal essential details about student experiences, including whether outreach participation helps cultivate a growth mindset, or whether students who already exhibited a growth mindset were more likely to take part in outreach. This work seeks to explore that relationship using student responses to three open-ended questions. In this paper, we developed a code book to analyze the nature of the relationship between these two constructs. In the following sections we describe the code book and analysis, share and discuss significant results, identify our limitations, and highlight our conclusions. Our goal in analyzing responses coded as mindset was to gather evidence on whether facilitating outreach helped students develop a growth mindset, or whether students with a stronger growth mindset were more likely to facilitate outreach programs.

II. METHODOLOGY

To explore the relationship between mindset and outreach, we analyzed open-ended responses collected as part of a national survey distributed through the Society of Physics Students (SPS) network. Outreach was defined as informal physics programs that engage the public or peers through hands-on demonstrations, public presentations, science festivals, school visits, camps, and other interactive activities related to physics and astronomy. This definition was meant to be illustrative and not complete so students engaging in other, similar programs could respond. The survey was developed as a collaboration between researchers from three universities and the American Institute of Physics [15] and sent to 5,500 SPS students in spring 2023. The focus of the survey was to measure student perceptions of their physics identity, self-efficacy, mindset, confidence, belonging, and sense of ability to use non-disciplinary career skills. Of the 704 survey responses, 70% indicated they engaged in outreach, and approximately half of this subgroup answered the open-ended questions. Among those who responded to the open-ended items, 49% identified as men and 41% as women; 37% were from bachelor's-granting institutions, 4% from master's-granting institutions, and 46% from Ph.D.-granting institutions. Additionally, 62% identified as white and 27% as people of color. Respondents were also able to select options such as "I prefer not to reply".

Students who participated in physics outreach were asked to respond to three open-ended questions pertaining to outreach specifically: (1) What has been your most memorable experience from participating in physics/astronomy outreach? (2) How has participating in outreach provided you with opportunities to utilize your physics/astronomy knowledge in a real-world setting? (3) How has your perception of yourself as a physicist changed through your participation in physics/astronomy outreach? Respondents could choose to answer any or none of the questions.

The code book employed in this study contained six codes relating to mindset. The two main categories were *growth mindset* and *fixed mindset*. Following the research of Dweck [6], we defined growth mindset as students' perception of their intelligence and abilities as something that can grow or change in response to hard work, different learning strategies, and seeking help when needed. A fixed mindset, in contrast, was defined as the belief that intelligence of abilities are static and that hard work would have no impact in changing them. For this work we limited ourselves to examining students beliefs of mindset specifically about physics. Each of the mindset categories was further subdivided into three codes representing the directionality of mindset present within the responses: *outreach to discipline, discipline to outreach*, and *ambiguous/unclear*. Responses were coded as growth mindset if they exhibited signals related to malleability of intelligence related to physics or the ability to grow and change their views of their intelligence in physics as a result of effort. Fixed mindset was assigned to responses that demonstrated having beliefs that their intelligence and abilities are pre-determined and cannot be changed. In coding for directionality, discipline to outreach was assigned when students expressed this mindset changing through coursework or in classes. In contrast, outreach to discipline was assigned when students expressed this mindset changing through their facilitation of informal physics outreach programs. The ambiguous/unclear category was given to responses that did not have a clear origin for their growth or fixed mindset. Responses were only coded if the activities described were clearly due to facilitation of, or working with, informal physics outreach programs.

Of the 704 respondents, 239 survey takers answered at least one open-ended question, yielding 621 responses for analysis. Four researchers coded the responses working in three teams. Coding was completed separately, with researchers periodically meeting to discuss and compare codes, resolving differences when necessary. After the completed process, the inter-rater reliability was found to be $\kappa > 0.90$, well above conventional thresholds for acceptable agreement [16]. Codes were then combined to a single file for analysis.

Further analysis was limited only to responses which had evidence of mindset. A thematic analysis was then conducted to identify the common and significant themes present in the data. Following the process for a thematic analysis outlined by Odden *et al.* [17] and Hyater-Adams *et al.* [18], each response was read individually, making notes on major extractions or ideas. These were then reviewed by the research team to identify recurring themes shared by the individual responses, with similarities and differences being debated until there was consensus among the team that responses in each group represented connected ideas. Each theme was then assigned a name, described in the next section, representative of the common ideas across all responses.

III. RESULTS & DISCUSSION

Out of 239 surveys we observed a total of 26 mindset codes: 24 codes reflecting *growth mindset* and 2 codes reflecting *fixed mindset*, summarized in Table I. As the data show, growth mindset was more frequently observed as being *outreach to discipline*. That is, student experiences centered on their facilitation of informal physics outreach programs cultivating their growth mindset. The second most common observed code was *ambiguous/unclear*, where students showed evidence of a growth mindset while discussing their facilitation experiences but without indicating whether coursework or facilitation of informal physics outreach programs helped them develop that mindset.

After conducting the thematic analysis five central themes were evident from the data. These themes were: *realization of understanding, more to learn, confidence in ability/knowledge, development of understanding*, and *recognition of difficulty*. The first four of these themes were solely from growth mindset with the final theme evident solely from fixed mindset responses. It must be noted that some responses exhibited multiple themes and each of these themes were driven by internal reflections, motivated by themselves, or external reflections, motivated by others. The first three themes noted above were more common and will be discussed in detail, while the final two themes were observed less often and will be discussed more briefly in the remainder of this section. All quotes are shared verbatim from responses excepting minor edits noted in square brackets to enhance readability.

TABLE I. Code frequencies for all six growth and fixed mindset codes employed in this study. The specific code, number of surveys in which the code appeared, and the number of times the code was applied are presented. No responses received multiple codes.

	Growth	
Directionality		**Surveys**
Outreach to Discipline		17
Discipline to Outreach		1
Ambiguous/Unclear		6
	Fixed	
Directionality		**Surveys**
Outreach to Discipline		1
Discipline to Outreach		0
Ambiguous/Unclear		1

A. Theme: Realization of Understanding

The *realization of understanding* theme was assigned to 13 out of 24 students whose responses had evidence of growth mindset. Students who exhibited the theme of realization of understanding were individuals that showed evidence of growth mindset by being cognizant of their advancing abilities in physics and demonstrating an understanding of the discipline. This awareness typically came from individual's internal reflections, with a majority (7 responses) stemming from participation in outreach. Students who participated in outreach came to realize that they understood various topics in their discipline and were able to show that understanding while facilitating outreach programs.

Students with this theme recognized that physics as a discipline is "constantly advancing in difficulty," but "participating in outreach" allowed them to acknowledge that they "have actually been learning this whole time" despite the recognition of rigor. One student, when asked about how their self perception changed through outreach participation, conveyed this exact message, stating:

> "Even though my classes are difficult, which can be discouraging, I am reminded how far I have come in my understanding of physics/astronomy when I am teaching others about [it]".

This theme originated from students sharing that outreach allowed them to recognize they are "absorbing the knowledge and information" that they have been taught through their various "classes and studies," elaborating on this connection.

B. Theme: More to Learn

There were 8 out of 24 students who exhibited a growth mindset theme of recognizing there was *more to learn* in physics. This theme was assigned to students whose responses demonstrated the individual not only having a desire to learn more about physics but also recognizing they had the ability to do so.

These students showed evidence of growth mindset through this recognition of their capabilities from internally reflecting on themselves, typically after participation in physics outreach (7 responses). From one student's experience, they recognized they "have learned the importance of being teachable, and that a physicist isn't someone who has all the answers but someone who actively searches for them". Another student began by discussing how they grew more passionate about their major from participation in outreach, but noting that they "still have a ways to go" in their own learning. This theme was also demonstrated by a student who said, "I realize how little I actually know and wish to expand that knowledge".

C. Theme: Confident in Ability/Knowledge

The last of the more common themes was assigned to 5 out of the 24 individuals exemplifying growth mindset. These responses demonstrated an increase in their confidence, either in their knowledge or abilities in physics. Student responses exhibiting this theme noted that they had the knowledge, but did not initially feel confident in this knowledge until they began facilitating outreach programs. These respondents recognized their own growth through internal reflection and did so after their participation in physics outreach (3 responses), bringing their growth mindset with them back to their physics coursework.

One student response noted that after participating in physics outreach, they were "more confident" in their "grasp of the knowledge", demonstrating a recognition of their growth in confidence. Another student wrote that after participating in outreach, their self perception changed, as they "gain[ed] confidence as a physicist" and felt reassured that they were "capable of becoming a great physicist".

D. Other Themes

The last theme assigned to growth mindset responses was the *development of understanding* theme. This theme was observed in 3 of 24 students and was applied to students who discussed how outreach helped them understand concepts in courses they did not have a good grasp on, demonstrating cues of growth mindset. The responses exhibiting this theme were focused more around external reflection, in contrast to the prior themes, and showed evidence of development of a growth mindset after participation in outreach. One student's response embodied this theme, sharing:

> "I feel that engaging with the general public forces you to reevaluate your understanding of physics and astronomy so you can explain topics in ways that make sense to laymen. That process has definitely improved my own knowledge of the fields."

Analyzing the two fixed mindset codes revealed a commonality between them: *recognition of difficulty*. This theme was focused on students recognizing the difficulty in physics, and felt they did not have the ability to overcome this difficulty. This can be summarized by one student response where they expressed that they "learned how difficult it actually is to understand physics at a higher level" after participating in outreach. This student did not recognize this mindset as something that could change or this difficulty as a challenge that could be overcome, but as an obstacle preventing them from success, making it fixed mindset. The second response reported how they compared their abilities to their peers and felt less intelligent.

IV. DISCUSSION

For many students physics as a discipline is a challenging endeavor. Prior studies have shown that those who possess or develop more of a growth mindset about physics are more likely to persist in the field. In a recent national survey [15] it was observed that participation in outreach and growth mindset were significantly linked. The goal of this work was then to explore this relationship by examining the important themes of mindset from student responses. The data indicate a clear discrepancy, with codes related to growth mindset being far more common than codes related to fixed mindset (24 vs. 2) in the open-ended responses. Mindset codes appeared in a relatively small number of survey responses ($\approx$10%), which is unsurprising given that mindset was not explicitly elicited through the wording of the open-ended questions.

Our analysis of students' self-reported experiences in facilitating outreach showed that they felt more confident in their physics abilities, were more aware of their progression of learning physics content, and were motivated to explore the breadth of physics knowledge. These more common themes were all focused on growth mindset experiences from students. This is an important impact to note from outreach, as recent research has shown how students with a growth mindset are more likely to succeed in their coursework [7, 19]. This is particularly important, as the majority of the codes supporting these themes indicated that students' growth mindset was cultivated not in the classroom but through their engagement with the general public sharing their knowledge and passion for physics. Participation in outreach can allow students to recognize their growth and abilities, and be more able to overcome challenges presented through courses, impacting overall academic success.

These results parallel those from prior work examining the experiences of women in physics [14] which showed that all 11 women in the single institution sample exhibited a growth mindset theme during in depth interviews. From this study, growth mindset was observed to be significantly linked to persistence, performance and competence beliefs, as well as confidence and self-efficacy. The benefits of fostering growth mindset among students has been noted to enhance academic performance and persistence in STEM courses in both K-12 and higher education environments [5, 20]. According to work from Han *et al.* [21] this impact on academic success may also have an indirect, but important, impact on student retention. As outreach provides a flexible and potentially low-cost space for student experiences, offering these opportunities seems like a simple and effective way to help students foster a growth mindset, ultimately benefiting their academic trajectories.

V. LIMITATIONS

The data within this work have allowed us to explore a significant relationship between mindset and outreach, however we must note some limitations. The data collected were self-reported by undergraduate students. Further, this was an optional survey with a potential selection bias from those willing to complete it. Lastly, the questions did not specifically target mindset and, given the nature of the written responses, researchers were not able to elicit further details.

VI. CONCLUSIONS

We have explored the connection between student mindset and their facilitation of informal physics outreach programs, drawing on a database of 239 responses to three open-ended questions collected as part of a national survey. This survey, distributed through the Society of Physics Students, aimed to examine the impact on students' physics identity, sense of belonging, mindset, and career skill development through their facilitation of informal physics outreach programs [15]. Prior analysis, using regression models of closed-ended responses, showed a strong link between students' facilitation of physics outreach programs and their possessing of a growth mindset [15].

In this work, we focused on analysis of mindset themes, specifically the directionality of the relationship between student mindset and their engagement in informal physics outreach programs. Our analysis identified 26 responses demonstrating evidence of mindset, with 24 indicating a growth mindset and 2 indicating a fixed mindset. Survey responses overwhelmingly exhibited a directionality from outreach to discipline, providing evidence that students' mindsets can become more growth-oriented through their facilitation of informal physics outreach programs.

By employing a thematic analysis, we identified five themes in student responses: *realization of understanding, more to learn, confidence in ability/knowledge, development of understanding*, and *recognition of difficulty*. The first four themes were found from responses exhibiting evidence of growth mindset, while the last theme was attributed to student responses assigned to a fixed mindset code. Most of the students' responses belonged to three themes: *realization of understanding, more to learn, confidence in ability/knowledge*. These themes were centered around students' recognition of their own growth in physics, with the majority of respondents focusing on their mindset development through participation in physics outreach which impacted their learning and self-perception. Together, these three themes are encapsulated by one student's response, who shared that:

> "[Participation in outreach] made me realize I am smarter than I think and I am capable to of doing whatever I set my mind to."

In addressing the question of directionality, the thematic analysis supports an interpretation that student facilitation of informal physics programs can promote the development of a growth mindset. This is an important result as, according to prior studies [3, 7, 19], a growth mindset enhances student success in their coursework and can increase their likelihood to persist in the discipline and complete their degrees. These results were primarily driven by students' internal reflections through their authentic interactions with the general public and may therefore be an inherent feature of their experiences in facilitating outreach programs.

Such outcomes, driven by the first nationwide survey on the impacts of student facilitation of outreach, provide exciting data that could potentially be used by departments everywhere to improve the resilience of their physics majors. To help articulate specific actions that departments could take, a more in-depth analysis is needed. We plan to explore the connection between growth mindset and student facilitation of informal physics outreach programs using a larger dataset, potentially with longitudinal data, and more extensive interview data in the future.

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[1] K. L. Lewis, J. G. Stout, S. J. Pollock, N. D. Finkelstein, and T. A. Ito, Phys. Rev. Phys. Educ. Res. **12**, 020110 (2016), URL https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.12.020110.

[2] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, Journal of Research in Science Teaching **47**, 978 (2010), https://onlinelibrary.wiley.com/doi/pdf/10.1002/tea.20363, URL https://onlinelibrary.wiley.com/doi/abs/10.1002/tea.20363.

[3] D. S. Yeager, C. J. Bryan, J. J. Gross, J. S. Murray, D. Krettek Cobb, P. HF Santos, H. Gravelding, M. Johnson, and J. P. Jamieson, Nature **607**, 512 (2022).

[4] C. L. Williams, Q. Hirschi, C. S. Hulleman, and J. Roksa, International Journal of Community Well-Being pp. 1–37 (2021).

[5] D. S. Yeager, G. M. Walton, S. T. Brady, E. N. Akcinar, D. Paunesku, L. Keane, D. Kamentz, G. Ritter, A. L. Duckworth, R. Urstein, et al., Proceedings of the National Academy of Sciences **113**, E3341 (2016).

[6] C. S. Dweck (2014), URL https://www.growthmindsetmaths.com/.

[7] Z. Y. Kalender, E. Marshman, C. D. Schunn, T. J. Nokes-Malach, and C. Singh, Physical Review Physics Education Research **18**, 010116 (2022).

[8] E. W. Close, J. Conn, and H. G. Close, Phys. Rev. Phys. Educ. Res. **12**, 010109 (2016), URL https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.12.010109.

[9] P. W. Irving and E. C. Sayre, Phys. Rev. ST Phys. Educ. Res. **11**, 020120 (2015), URL https://link.aps.org/doi/10.1103/PhysRevSTPER.11.020120.

[10] K. A. Hinko, P. Madigan, E. Miller, and N. D. Finkelstein, Phys. Rev. Phys. Educ. Res. **12**, 010111 (2016), URL https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.12.010111.

[11] C. Rethman, J. Perry, J. Donaldson, D. Choi, and T. Erukhimova, accepted to Phys. Rev. Phys. Educ. Res. (2021).

[12] J. Perry, J. P. Donaldson, and T. Erukhimova, in *Proceedings of PER Conf. 2021, virtual conference* (2021), vol. 10.

[13] B. Prefontaine, C. Mullen, J. J. Güven, C. Rispler, C. Rethman, S. D. Bergin, K. Hinko, and C. Fracchiolla, Physical Review Physics Education Research **17**, 020134 (2021).

[14] J. Randolph, J. Perry, J. P. Donaldson, C. Rethman, and T. Erukhimova, Physical Review Physics Education Research **18**, 020123 (2022).

[15] J. D. Perry, T. L. Erukhimova, C. Garrett, T. Sauncy, J. P. Donaldson, S. White, J. Tyler, and R. L. Ivie, in *Physics Education Research Conference 2024* (Boston, MA, 2024), PER Conference, pp. 318–323.

[16] K. L. Gwet, *Handbook of inter-rater reliability: The definitive guide to measuring the extent of agreement among raters* (Advanced Analytics, LLC, 2014).

[17] T. O. B. Odden, A. Marin, and M. D. Caballero, Physical Review Physics Education Research **16**, 010142 (2020).

[18] S. Hyater-Adams, C. Fracchiolla, N. Finkelstein, and K. Hinko, Physical Review Physics Education Research **14**, 010132 (2018).

[19] A. Malespina, C. D. Schunn, and C. Singh, International Journal of STEM Education **9**, 28 (2022).

[20] M. Smith, C. Fracchiolla, S. Fleming, A. Dominguez, A. Lau, S. Greco, D. Lincoln, E. Katifori, W. Ratcliff, M. Longobardi, et al., arXiv preprint arXiv:2112.10623 (2021).

[21] C.-w. Han, S. P. Farruggia, and T. P. Moss, Journal of College Student Development **58**, 1119 (2017).