Defiance in the face of adversity: a qualitative study of women’s attrition from and persistence in physics

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Women continue to be underrepresented in physics despite recent developments focusing on improving representation and equity within the discipline. Several recent papers have investigated the experiences of both white women and women of color within the discipline to understand the issues that most often affect them, and how those issues intersect. What has been less clear from previous research is how these factors contribute to women’s decision to stay in physics or leave for another discipline. Much of the literature on persistence has focused on leaving STEM majors for non-STEM majors, but this does not include the possibility of a woman leaving physics for another STEM discipline. In this study, we used a social constructivist lens to investigate the experiences of 5 women in physics at a large research university. We focused specifically on how the women’s experiences contributed to their decision to stay in physics (some even chose to pursue a Ph.D.) or leave physics for another STEM discipline. We find that lack of support, poor treatment by male peers and professors, and interest in physics are all major factors in these women’s decision-making process, but that lack of support was most prominent in the decision to leave physics. This provides interesting counter-narratives of women defying adversity in pursuit of their deep interests in physics but also highlights the need for structural changes and action by male physicists to better support women.
I. INTRODUCTION

In physics, women remain a minority of the student population, only making up about 20% of the population who graduate with a bachelor’s degree in physics [1–3]. Representation of women decreases as they move to higher levels within the academic system. Prior studies have shown the existence of sexism in the current physics culture [4], which contributes to the continued underrepresentation of women in the field. Other studies have shown that women are often perceived as less competent than men in many science fields [5–7], which may lead to overt mistreatment by peers and contribute to women leaving science.

The phenomena of student retention and attrition have been studied most thoroughly in the last 50 years [8], but there is still much room for the experiences of women in science, technology, engineering, and mathematics (STEM) fields to be studied. Talking about Leaving revolutionized the conversation surrounding the issue of women and students of color leaving STEM majors in 1997. This study was revisited in 2019 with quite similar findings, highlighting why underrepresentation and attrition continue to be issues nearly 30 years later. The authors found that although the rate of switching out of STEM majors had decreased since the publishing of the original 1997 study, the reasons for switching generally remained the same (poor learning environment, coursework overload, trouble finding auxiliary resources). They also found some new reasons contributing to attrition, such as lack of confidence, discomfort with a competitive environment, and having more career options [9]. Talking About Leaving is an ethnographic qualitative study (though it does have a large number of participants, \( \sim O(100) \)). Quantitative studies, such as that by Sonnert et al. [10], have added more understanding of which of the factors identified in Talking About Leaving might be most influential in students’ decision-making. Utilizing data from 499 institutions in the biology, engineering, and physical sciences, they found a disparity between women’s and men’s GPAs (grade point averages) that could possibly be contributing to higher attrition rates for women. This study highlighted the relevance of the institutional environment for the relative performance of male and female undergraduates and also suggested the possibility of multiple factors working together such as institutional location and Carnegie classification.

Though much research has been conducted pertaining to women’s experiences and persistence in STEM more broadly, there is less research on women’s experiences in physics. Recent studies by Santana and Singh suggest that students from underrepresented groups often experience a lack of sense of belonging within physics [11]. In a previous study, the authors suggested that due to the hostile environment created by male peers in physics, it is critical for women to create a community amongst themselves and have resources readily available to support this [12]. Though both studies underscore how underrepresented populations feel unwelcome in physics, they did not investigate how these experiences affected students’ decisions to stay in or leave physics. Therefore, in this study, we seek to bridge the gap by examining the relationship between women’s experiences in physics and understanding their decisions to leave or stay in the discipline. We note that prior studies on retention in STEM have mainly focused on why women leave STEM fields in general and have not investigated the factors that may cause women to leave one STEM field (e.g., physics) for another [9]. As a result, our investigations focused specifically on women who had started college as physics majors and explored what factors those women believed contributed to their decisions to remain in physics or leave for another STEM discipline.

The interpretive framework we chose for analyzing our data was social constructivism [13], which posits that multiple realities can exist. This is important when considering the different reasons why a woman may want to stay in physics, and also why she may leave: by understanding that each experience and perception is unique, we conclude that no singular reason can be attributed to why a woman would choose to stay or leave the field. The same logical steps can be taken to understand our use of social constructivism in framing our epistemological lens that knowledge and thus evidence is based on the subjectivity of the individual. By assuming reality is known through individual experiences, we are able to take the women’s reports of their experiences as truth. This framework is more broadly related to feminist standpoint theories, which hypothesize that knowledge is produced by one’s personal experiences and that researchers should highlight the experiences of the oppressed group [14], which includes women in physics. Standpoint theory calls upon the researchers to use the women’s experiences as a tool to dismantle the system of the oppressor. Thus, by taking the women’s experiences and statements as objective truths, we seek to undermine the patriarchal structure of physics.

II. METHODOLOGY

We conducted five interviews with women at a southeastern land-grant university. Four women were enrolled in the physics program at the time of the study, and one woman had left the program (pseudonym Claire). Two of the women who were currently enrolled were PhD students (Beatrice and Alyssa), and two were undergraduate students (Mary and Grace). The participants were recruited through a series of email advertisements sent via undergraduate advising. Each interview lasted 1 hour at the maximum, with each participant receiving a $25 Amazon gift card as compensation for her time. The participants were not required to use their real names or provide any contact information to sign-up for an interview. Additionally, they were given the option of speaking to a white woman or a man of color, depending on who they might be most comfortable with. Both interviewers were undergraduate students to ensure that there was no potential power imbalance between the interviewer and the participant. This was done in the interests of psychological safety [15].
as prior research shows that the environment might influence participants’ responses. The protocol was adapted from Talking About Leaving Revisited [9] (which is a semi-structured protocol) and modified to fit the nature of the interviews. This work was determined to be exempt from IRB review due to the absence of identifying information in the study recruitment and interview process.

All interviews were transcribed by the research team. For each interview, the first and second authors independently generated a narrative summary to understand different points of the woman’s educational journey within her field. These two narratives were then compared and discussed by the first and second authors to identify which themes arose in both narratives and which themes may have been noticed by only one of the interviewers. The first author then used an inductive coding scheme to generate themes that were present across all of the interviews and how each woman placed importance on these themes in her decision to leave or stay in physics. Four of the interview participants were White women and one was a woman of color. For this study, we will focus only on the experiences associated with gender and not on the intersectional nature of gender and race in physics. We made this decision because we only have the perspective of a woman of color who chose to stay in physics and not one who left the discipline. Thus we would not be able to draw the contrasts we would like in identifying factors that contribute to the persistence or attrition of women of color specifically.

The first author is a White woman majoring in engineering at the same university as the participants, and the second author is a Black man majoring in physics; both are undergraduate students. The third author is a White man and faculty in the Department of Physics at this university. All three authors are committed to improving the experiences of those underrepresented in physics and engineering at the university. The first and second authors are able to draw on their experiences as minoritized students in the physics classroom to better contextualize the experiences of the interview participants. The third author provided guidance on the qualitative analysis and protocol development and believes that his position of privilege requires him not only to educate himself about these women’s experiences but to then take action to improve the environment for women in his department.

III. RESULTS

We found four major themes that were present in all women’s interviews: (1) lack of support structures within physics, (2) negative treatment by male peers and professors, (3) acts of defiance against barriers to participation, and (4) suggested solutions to the problem of underrepresentation in physics. We did not originally intend to combine the experiences of graduate and undergraduate students but ended up finding that the themes were quite consistent across the two groups. We believe that the graduate students’ accounts of their experiences serve as an example of how the stigmatization of women extends from undergraduate school into graduate school. By allowing women to tell their stories of their experiences in physics and asking them why they stayed or left, we are drawing on Standpoint Theory and centering the experiences of the oppressed. In addition, we gave the women the opportunity to draw on their experiences and suggest challenges to the prevailing physics structure that could improve the experiences of future women.

A. Lack of Support

Almost all of the women interviewed mentioned a lack of support in the physics major. Claire described a time when she reached out to her advisor for a phone number of someone who could answer questions pertaining to the physics major, especially about being a female in STEM, and her academic advisor (who is a staff member, not a faculty member) said that she did not have one. She went on to say, “That was a really big part in my decision [to switch], is I felt like, there was no support system set up, so I couldn’t even, like, try to find help for myself.” Claire also mentioned that she felt that she would “not have been given the opportunity to thrive” in her intermediate mechanics course, as the class was graded on a curve, and she felt as though there were not enough resources available to help her do well. She went on to say “I think the expectations can be different at times...well kind of on both sides because then one if you’re a female in these male-dominated classes, the expectation is almost higher on you to like, do better and work harder, but at the same time, I felt like there was a lack of a support system.” Claire mentioned that had there been some sort of support for women in the major, she may have stayed: “When I was becoming unsure about my major, if I had been able to talk to someone, I may still be there today” It should also be mentioned that Claire’s switch to biology was due to her interest in medicine, and she found that biology both aligned with that interest and provided more support.

The theme of support also appeared in conversation with the women who stayed, with Mary noting that although she did not experience any barriers when seeking support, the number of sources of official support was small. She said her supplemental instruction classes “were fine, but they only lasted so long.” On the other hand, Beatrice, a current doctoral student who had previously graduated from a small liberal arts college in the Midwest, found that her graduate teachers were not an active source of support for her. This caused her to seek more outside support from women who were in the department but outside her immediate cohort.

B. Male Treatment

It is not a novel finding from these interviews that women experience negative treatment from their male peers and professors. However, our research aimed to understand why
women choose to stay in the face of negative male treatment, and when this treatment might compound with other factors to lead her to leave the discipline.

**Treatment by faculty:** Mary described what she felt was an “internal stigma,” describing how “sometimes, [she] felt like...[she] already walked in as if [she] didn’t belong, because [she] was outside the box for what somebody would consider a typical physics undergraduate, just because [she’s] a woman.” She also cites lab classes in which her opinions were ignored. When asked about how she dealt with these situations, she told us she befriended another woman in the cohort above her, “Just having somebody who could relate and make me not feel crazy, because, you know, sometimes I felt like I was overreacting about it.”

Claire said “It’s hard to describe, like, an environment, but, like, going to office hours and asking questions, and just kind of feeling like I was being looked down on as soon as I went through the door...It felt intimidating, at times.” Grace mentioned that her questions towards professors yielded different responses than if they had been asked by a man, and also said that oftentimes her answers on assignments such as homework were correct (while her male peers’ were not), but no one asked her for help. Alyssa (pseudonym) believes that there is a common societal misconception that women take longer to understand and grasp concepts than men. She provided a classic example of when one professor replied with “You don’t know?” when she approached him with a question.

**Treatment by peers:** Mary said “People would make unwanted approaches towards me, trying to like, almost harass me, a little bit,” when talking about the disadvantages of being a woman in physics. Interestingly, on another hand, Beatrice (graduate student), noted that a lot of things that she feels would be perceived as offensive were actually not to her. She referenced a time when a superior referred to her as “sweetheart”, and her peer was shocked that she was not offended. While Beatrice seemed relatively unbothered by microaggressions, she had experienced prior negative treatment by her male peers, describing a time when she was sexually assaulted at a study session as an undergraduate. While the same degree of sexual discrimination was not faced in her graduate years, she spoke of times when she was deliberately excluded by her male peers: “They would deliberately exclude me from things, and not tell me about things, and, like, tell me to go away if I came in and tried to work with them, and, like, very, very, very deliberate exclusion from what they were doing. And it’s really hard to learn physics when you cannot work with anybody.” Therefore, as mentioned beforehand, she was forced to seek help outside of her cohort with older women in the graduate program, which was made possible by a term where cohorts intermingled. Beatrice felt that this was a critical point in her physics career, saying that “[she] probably would not have been able to pass the qualifying exams had [she] not studied with the women in the year ahead of [her].”

**C. Acts of defiance**

As mentioned previously, a primary aim was to understand why women decided to stay in the face of this discrimination. We have chosen to call these themes “acts of defiance.” The women who had persisted in the face of discrimination all cited their passion for physics as the primary reason they chose to stay in the discipline. For example, Mary knew that she wanted to be involved in astrophysics, and explained that while her freshman year she considered switching out due to the difficulty of the courses, she “could not imagine studying anything else”. Along the same lines, Grace told us not only of the fascination she had with the subject but also that there was a side of her that wanted to prove people who told her to switch majors wrong, telling the interviewers "When people try to tell me what to do, it makes me wanna, you know, [be like] 'Let me prove you wrong.'" The same woman also went on to say that without physics, she felt she did not have a purpose. Beatrice also acknowledges this in her interview, answering the question about staying with the simple word “Stubbornness.” Beatrice also says that she has always found math to be beautiful and that in other subjects she was the smartest person in the room, while in the physics classroom, she wasn’t and she enjoyed the challenge.

D. Solution

The final question in the interview protocol pertained to the future of women in the physics department, asking the participants what they would change about the program and what advice they would give to the department about retaining and recruiting more women. A common response was simply more outreach, with many participants saying that the major continues to be smaller due to less outreach than other STEM majors. Claire mentioned that she believed weed-out classes should not be as difficult if the department wants to retain people in physics, and spoke of the difficulty of classes and how that can deter people by making them fear that higher-level classes will be similarly difficult and inaccessible. Claire mentioned that more resources and programs, such as a mentorship program, would be beneficial to the major to not only guide undergraduate students but to facilitate camaraderie among peers. A prior study [16] suggests that required courses covering implicit bias and discrimination in physics may be beneficial for creating a welcoming environment for women.

IV. DISCUSSION

We found that both women who left physics and stayed in physics commented about the lack of support they felt within physics and negative male treatment to varying degrees. The women who persisted in physics were to be doing so due to
a deeply-seated passion for physics [17] and to defy expectations, whether the expectations of their peers, professors, or even families. The women we interviewed suggested that providing more formal support within the major, improving outreach, and reducing barriers like weed-out classes could be potential ways to try and improve the representation of women in their department.

The theme of negative treatment by male peers and professors has been a recurring theme not just in the interviews conducted but for years in the literature in STEM fields. These male behaviors include a lack of support, disengagement by male professors, and implicit or explicit sexism by male peers and instructors. Prior literature suggests that these behaviors are common in physics and other STEM disciplines [6]. Dancy & Hodari [18] found that, while men might be aware of these issues in the abstract, they often use discourse that distances them from the issues. They might make claims such as “not in my classroom,” or argue that changing sexist attitudes and behaviors is beyond their control. For example, one professor in [18] stated that he speaks to his class at the beginning of each semester and emphasizes that he understands how this environment is for women, yet he forgoes the efforts of trying to make the environment better.

One of the ways that male faculty and peers often fail to provide support for women in physics is by not recognizing women as “physics people.” [5]. The importance of this recognition has been continually shown to be related to outcomes for women in physics, such as self-efficacy [19], sense of belonging, and persistence. The failure to recognize this often leads to discrediting women and is harmful to diversifying a homogeneous community—seeing that the perception of those in physics careers are usually white men. Recognition as a “physics person” by high school physics teachers seems to be most important for interest and retention in physics, as students and teachers are often able to forge closer relationships in smaller classrooms. By fostering a greater sense of support in the physics department, we have the opportunity to improve women’s sense of belonging, which Hazari et al. have empirically linked with identity development.

The women’s narratives highlighting a deep-seated interest in physics align with Hazari’s findings that interest is connected with career aspirations. Almost all women interviewed were motivated by a passion for physics and frequently mentioned that encouraging interest in physics would be important to recruiting more women physicists. Grace, one of the aforementioned women, explained to interviewers that she enjoyed watching movies that had to do with physics, but “didn’t see anyone in those movies that [made her think] this could be her in here”, which brings in another concern of underrepresentation of women who are in the physics community in pop culture and media. On the other hand, Mary, who said she could not see herself doing anything else, explained that it was her father who piqued her interest in physics, telling interviewers “My dad works on the arsenal [in Huntsville], and he’s really interested in space, so when I was a little kid he taught me a lot about it. I guess it just kind of stuck with me.”

Yet, we saw that the women often mentioned that they were not seen as physics people by their university peers and professors, relying only on recognition of their own academic strengths. Connecting these two lines of prior research suggests that one major step toward increasing the representation and improving the experiences of women in physics could be for men to more proactively recognize women as physics people—particularly physics instructors. We have some preliminary evidence that instructors might be able to foster this recognition simply by adopting more student-centered teaching methods. In addition to this, we also think a mentorship program would be pertinent, as well as having an alumni connection forum for new women in the program to connect with women who have graduated and are following through career paths. This would serve as not only a source of knowledge, but a source of encouragement to push through the major.

V. CONCLUSIONS AND FUTURE DIRECTIONS

In this qualitative study, we interviewed 5 women in a single physics department and found that they commented on a lack of support and negative treatment by male peers. When probed about why they stayed in the department, women reported acting in defiance of negative treatment or low expectations or being driven by a passion for physics that eclipsed these issues. The stories of women who persist in physics provide interesting counternarratives illustrating how women can persist in hostile environments. However, these acts of defiance should not be what is required simply to get a degree in a discipline you find interesting. Physics departments should do more to provide support for women, but as prior studies argue, should also interrogate their own cultures and power structures to see how men in their department perpetuate the marginalization of women through discrimination or simply through willful inaction.

There are some signs of change in the department studied. For example, there are three male faculty (of 20 total male faculty) who have volunteered to serve as mentors and advocates for female graduate students through the Society for Women in Physics chapter. This does not necessarily indicate cultural change, but could simply be the acknowledgment of some individuals that they need to actively work to change the environment for women in the department. We recommend that the department studied provides a structured support network for women in physics at all stages of their careers. In addition, previous efforts have highlighted the need for increased communication and transparency, which may improve the awareness for existing support structures. Efforts for coordinated, data-informed cultural change are currently underway and being studied thoroughly.