Investigating underrepresented students' choice of a physics major

Dr. Katrina Piatek-Jimenez
Department of Mathematics, Central Michigan University, 214 Pearce Hall, Mount Pleasant MI, 48859

Dakota Keblbeck and Cielo Medina Medina
Department of Physics, Central Michigan University, 203 Dow Science Complex, Mount Pleasant MI, 48859

It is well documented that there is little diversity within physics at the undergraduate level in the United States, and this problem is amplified in graduate school and the workforce. The cause of this underrepresentation of women and people of color in physics is reported to be partially due to a "cold" and unwelcoming climate within physics departments and differential pre-college experiences. Our larger research project aims to investigate undergraduate physics students' experiences, to better understand the factors leading to the selection and retention of a physics major, and how these experiences may differ by the intersectionality of one's social identities. To achieve this goal, we conducted a series of in-depth interviews with physics majors at one university to learn more about their pre-college and college experiences regarding physics and astronomy. In this paper, we report a subset of our findings. In particular, we share our preliminary results on the data collected from our nine participants with identities underrepresented in the discipline of physics with regards to their selection of a physics major. Our findings reveal both internal and external motivators for selecting a major in physics and suggest that many of the pre-college obstacles they faced relate to their underrepresented identities.

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I. INTRODUCTION

Broadly speaking, women and people of color have been historically underrepresented in the fields of Science, Technology, Engineering, and Mathematics (STEM) [1-2]. For the subfield of physics, this underrepresentation tends to be just as notable. According to the American Institute of Physics (AIP), in 2018, of those that received a physics bachelor's degree, only 22% were women and 21% were students of color [3]. While the number of women receiving undergraduate degrees in physics have made small increases over time, the number of degrees awarded to students of color have been virtually stagnant for the past 30 years [4].

Part of this disproportionately low representation is attributed to a "cold" and unwelcoming climate within physics departments towards women and students of color [5-7]. Prior research indicates this is partly due to their white male peers' and instructors' attitudes, as well as an unawareness within the culture of physics toward the differential experiences that marginalized groups face [8-9]. Additional contributions to the lack of women and students of color in physics come from dissimilar pre-college experiences. Previous research has shown that students' success in introductory physics courses can be predicted by certain factors during their high school experiences [10-11]; however, research also indicates that these experiences are not the same for women and students of color as they are for white men and may negatively impact their success in and selection of a physics major post high school [12-14].

One might consider that the gender gap in physics, post high school, is due to a performance difference between males and females, in the courses that develop the skills necessary to succeed in physics, such as mathematics. There is ample research to suggest that this is not the case, and that there is little to no gender performance differences within mathematics and science courses [15,16]. One study suggests the difference in participation is due to students' development of their 'physics identity' during high school, which is partially influenced by their gender [17]. The findings of this study also indicate that a female's physics identity is greatly improved during high school when there is discussion of the under-representation of women in science, while their male counterpart's physics identity remains unchanged by these discussions.

When examining the low rates of people of color in physics, there are other factors that may play a role; there is evidence to suggest that students of color lack adequate access to high school science and mathematics classes. The Civil Rights Data Collection for the 2015 – 2016 school year surveyed 26,300 U.S. public high schools of the mathematics and sciences courses offered [18]. This survey found that high schools with high levels of African American and Latino students were much less likely to offer advanced mathematics and science courses, such as calculus and physics. The 2012-13 Nationwide Survey of High School Physics Teachers suggests that even when these courses are offered, the rate at which students of color take them is partially dictated by their socioeconomic status [19].

More recently, a team of scholars have begun conducting much needed work on the intersectionality of social identities within the field of physics by investigating the experiences of women of color and LGBTQ+ women at the collegiate level [20-22]. However, virtually no work that we could find also included other social identities such as disability, socio-economic status, and first-generation college student status into their analysis of physics students' experiences. In our work, we aim to fill this gap. In this paper we discuss a portion of our research, through which we aim to address the following research questions: What factors influence students with multiple underrepresented identities to choose a major in physics? What pre-college obstacles do they face?

II. METHOD

The participants in this study were a subset of physics students enrolled at a large R2 institution within the U.S. To recruit participants for this study, the researchers obtained a list from the university of all 30 students who were declared physics majors at the institution. The researchers then sent an email invitation to all physics majors labeled in the university's system as either female or a racial minority. Of the 12 students who fit this criterion, nine of them chose to participate in this study.

The data for this part of the study were collected through a demographic survey and an in-depth individual interview with each of the participants that focused on their pre-college science experiences. The length of the interviews ranged from between 26 minutes to 70 minutes, with the typical interview lasting approximately 50 minutes. The demographic survey provided us with information regarding multiple social identities of our participants.

The interviews were conducted jointly by the second and third authors of this manuscript, both of whom are undergraduate students studying physics. The second author identifies as a white, heterosexual, cisgender male who is a first-generation college student and considers himself an ally to all underrepresented groups. The third author identifies as a Latina, cisgender female who is an international student. Each interview was audio recorded and transcribed. The researchers familiarized themselves with the transcripts and developed initial codes inductively from the data. Each interview was then individually coded by at least two of the three researchers on the project. Throughout the process, all three researchers would meet regularly to discuss the coding together and reconcile any disagreements within the coding process, following recommendations from [23]. During these meetings, new codes were introduced to the codebook as necessary. Once all transcripts were coded, two of the researchers recoded all of the interview transcripts with the

additional codes and reconciled any differences. Finally, once the coding process was complete, the researchers examined all data instances for each code, identifying themes that address our research questions.

III. RESULTS

In this section, we first provide some background information about our participants. We then discuss internal and external motivators that influenced our participants' decision to major in physics. Finally, we discuss some of the pre-college obstacles that our participants faced.

A. Background information about our participants

All nine of the participants in this study are members of social identity groups that are underrepresented in the field of physics. Four self-identify as women, three as men, and two self-identify as non-binary. Four of our participants identify as students of color, one of whom is an international student. Four participants identify as a member of the LGBTQ+ community. Five of the participants are first-generation college students and three participants consider themselves to be from a relatively low socio-economic background. Two of our participants stated that they have a disability. When taking into account all of these social identity groups, our participants ranged from identifying with between one and four identities underrepresented in the field of physics, with the average being 2.55.

At this particular university, students can choose a traditional physics major or may choose to major in physics with an emphasis in astronomy and astrophysics. Approximately 80% of the total physics majors at this institution choose the physics major with the emphasis in astronomy and astrophysics. Of our nine participants, eight have chosen to earn the degree with this emphasis.

B. Internal motivators for selecting a physics major

When considering internal motivators for choosing to major in physics, there were three major themes that arose. We expand on each of these below.

1. Personal interest

Nearly all of our participants expressed an early interest in physics or astronomy. When discussing why they enjoy physics, some participants expressed their fascination for the unknown, others noted an interest in how physics explains the world, while others claimed that the complexity and abstraction of physics drives their curiosity about the subject. One participant explained that astronomy is fascinating to them because it is something you cannot see or do on earth, unlike other sciences:

> *I think the thing that interests me the most about space in astronomy is just the fact of how little we know. And, like, you know, they say that astronomy is one branch of science that is basically all theoretical because we can't test any of it physically. You know, like biology and stuff like that, you can test it physically; astronomy you can't do that.*

Because of their early fascination with either physics or astronomy, many of our participants talked about checking out books from the library or getting telescopes when they were young, so they could further their early interest in the subject.

2. Good at math and science

Another clear trend amongst our participants was being good at math or science from at a young age. In particular, most of our participants described math as "easy" and noted that they participated in advanced math courses during middle and high school. Three of our participants explicitly stated that their choice to major in physics was connected to enjoying mathematics and the heavy mathematics load in physics. For example, one participant expressed:

> *I enjoyed physics, but it was more of like, okay, I'm good at math, so I'm gonna choose to do physics, because of it.*

Because of their strong connection to mathematics, most participants in our study explained they knew early that they would pursue a math or science-related career. Furthermore, many participants noted that exceling in math and science boosted their confidence in school, which increased their interest in science. For instance, one participant noted that her achievements in Science Olympiad raised her interest in science:

> *I competed in five different subjects and I medaled in all five during competition, so that was a big influence on my life… I think it made me feel like I'm actually good at something.*

3. Likes a challenge

Our participants also really seem to enjoy participating in science competitions, learning hard subjects, or being challenged to excel by their peers. Three of our participants competed in Science Olympiad or other science competitions during middle school. These experiences seemed to boost their confidence in their ability to pursue a science-related career. Furthermore, two participants expressed enjoying being challenged by their peers:

> *I think it was fun being challenged by my peers a little bit. It was never anything like super crazy, but we'd always be like... What'd you get on the exam? Well, I got a 92. Well, I got a 94.*

Specifically for physics, three participants mentioned that the difficulty of physics as a subject is part of what drove them to pursue a physics undergraduate degree. For instance, one participant compared geology with astronomy and noted how they differ in complexity:

> *I don't know, in my mind, geology is more of an easy to prove science than astronomy is. And it was that*

challenge of proving whatever I found, I think was what kind of drove me towards astronomy.

C. External motivators for selecting a physics major

While there were many internal factors that influenced our participants to pursue a physics major, we were able to categorize eight external factors as well. Of these eight, there were four that our participants discussed most frequently or seemed most influential. Below, we discuss how these four factors motivated our participants to pursue a physics major.

1. Family

All nine of our participants discussed how their family influenced their interest in science, and ultimately physics. A common theme was strong support from family members who fostered their interest in science. While some participants talked about a specific family member with an attraction to science who inspired their interest, others talked about their parents simply supporting them in any interest that they had. One participant, in particular, noted that even though his parents did not have an interest in science, they provided him extra support in that area:

> *[My parents] were always supportive in anything I wanted to do because I was also interested in sports and everything… They were supportive in every aspect, but I think science was another thing that really, they supported me with extra effort. Like, if I wanted to buy any [science] equipment or something, they would be willing to buy it rather than if I say that, 'Hey Dad, I need a bat' and he'd be like 'Save your money and buy it yourself.'*

The general trend our participants expressed was that regardless of their family's connection to science, the support and encouragement they received from their families was a major motivator to pursue their interests in both science and physics.

2. Science teachers

Another frequent external motivator that we identified was the support, encouragement, and enthusiasm of science teachers. All nine of our participants discussed how a science teacher, at some point, motivated them to pursue their interests. Many participants talked about science teachers that made their classes fun and interesting. Specifically, many students discussed physic-based labs they did for class, such as building bridges, amusement park rides, or bottle rockets. In addition to good science teaching, some participants talked about a special teacher who took an interest in them, by providing extra words of encouragement or supplying them with extra resources to feed their interest. For example, one participant talked about his high school physics teacher helping to develop his interest in astronomy:

> *I think it was at the end of 11th grade or maybe in the beginning of senior year, [my physics teacher] gave me this really old astronomy book and it even had like a DVD in the back too... Yeah, that also was another thing, he helped me dig a little deeper into astronomy and astrophysics.*

It is clear from the many experiences of our participants, that a good, supportive, and enthusiastic educator was important in helping develop their scientific interests.

3. Extra-curricular school activities

Involvement in extra-curricular school activities, particularly those that were science related, also played a role in motivating the participants to pursue physics. All but one participant discussed involvement in some type of extra-curricular science activity through their school. Some of these activities were involvement in Science Olympiad, while others were trips to national laboratories or other science related facilities. One participant who was initially planning to major in electrical engineering, talked about how a trip to a national lab helped remind her of her passion for astronomy:

> *That summer [before college], I did the PAN at [university], which is Physics of Atomic Nuclei. Um, we got to go to, like, the FRIB, and we got to talk to a bunch of people…who worked on it and stuff so that also helped, I think to bring it back to where I was when I was a kid, like I really like astronomy, I really like space.*

Based on how our participants spoke about their experiences in science-based extra-curricular school activities, it was clear that the level of influence these experiences and resources had were influential in aiding and encouraging their interests in physics.

4. Public science communicators

A somewhat surprising finding from our data was the influence that public science communicators, such as Neil deGrasse Tyson, Carl Sagan, and Bill Nye, played in our participants' interest in physics. Five of our participants referenced at least one public science communicator that had a powerful influence on their interest in science. Many of our participants talked about following these famous figures on social media, or reading books they had written, so that they could learn more. Not all of the public science communicators mentioned were famous figures though. For example, one participant talked about a science-based podcast that they listened to while another participant credited "a random streamer" she found online for her decision to major in physics.

D. Pre-College Obstacles

Despite their strong interest in science, our participants encountered many obstacles to pursuing a degree in physics even prior to arriving to college. All participants discussed at least one pre-college obstacle and most participants talked

about multiple obstacles to their path of becoming a physics major. We classified these obstacles into eight categories. Here, we discuss three of the most prominent categories.

1. Lack of school resources

Six of our participants discussed a disappointment with the academic resources offered by their high schools. Some of the participants credited the absence of such opportunities to being from a poor school district while others felt that the lack of opportunities was related to attending a small school. The most frequently mentioned concern was a lack of course offerings available to them in the sciences. For example, one participant stated:

> *I didn't really go to like a really good high school, so we didn't really have a lot of higher up level math classes or science courses. I think the highest we had was like AP Biology and they stopped teaching that the year I was gonna try and take it.*

Other resources participants wish they had during their high school careers included science clubs and more experienced teachers.

2. Lack of exposure/information

Another obstacle mentioned by six of our participants was not having had much exposure or information regarding science, while growing up. For example, as one participant who did not have family members interested in the STEM fields noted:

> *I think if I went to a physics museum or those things. Or, like the science museum, I think my interest would have been way more than what I had, but I never went… Other ways are like, being a first-generation college student, or, like, the parents who are not from science background.*

Other participants expressed not having enough information specifically about physics or astronomy:

> *I didn't really understand until high school that like astronomy was an option. I thought it was just like astronaut or nothing. And then I realized in high school that that's wrong because, like, mission control exists. But… it almost was like a side interest and then I realized this. I found that I really enjoy studying and learning about [astronomy].*

3. Negative stereotypes

Another obstacle, mentioned by four participants, is the negative societal stereotypes surrounding science and mathematics. Multiple participants talked about the reactions they would get when they shared with family or friends their intended major. Often, they would be met with distaste, and comments about how difficult those fields are, suggesting they had chosen an unappealing major. One participant, in particular, was really pressed by adults in her life to reconsider whether a science field was the right field for her:

> *I did have a lot of adults telling me to be careful with what field I went into, because any science that I went into was gonna be like dominated by men, and I might have a hard time actually going through with the whole program because of it… It kind of scared me for a little bit, and it made me really think, like, do I actually want to go into this field? But the more I thought about it, the more I was like, I'm not going to let a man tell me what to do with my life. Like that's true. So, I kind of just chose to stick with it and I would just keep an eye out for anyone that had those beliefs and I would stay away from them.*

While these stereotypes about the STEM fields did not end up persuading our participants to leave the field of physics, they were, however, obstacles our participants had to navigate along the way.

IV. DISCUSSION

Through the preliminary analysis of our data, we have been able to uncover both internal and external factors that motivated our participants to choose a physics major. We have found that while an inherent interest in the field from a young age is common, having that interest supported by critical people in their lives and through life experiences provided our participants with enough support to continue pursuing the degree. These are similar results found by other scholars who have explored the choice of the physics major in general, and not specifically by those with underrepresented identities [24]. We also found it interesting that the vast majority of our participants were drawn to the field of physics through astronomy. This path may be a useful one in recruiting more undergraduate students into studying physics.

Despite their many supports, our participants also experienced many obstacles to pursuing physics, even prior to arriving to college. Some of these obstacles were clearly related to one of their underrepresented social identities (such as being a woman or being from a low socio-economic background). In fact, when we conducted a rough analysis of the demographic data of our participants and the number of different pre-college obstacles they faced, we noticed that the more underrepresented characteristics they identified with, the more pre-college obstacles they encountered. This finding is supported by other scholars' work on intersectionality (for example, see [20,25]). Our findings suggest that more work should be conducted in this area to explore how intersectional identities (including low socioeconomic status, first-generation college student, and having a disability) affect one's experiences in physics.

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[1] APS and IPEDS, Bachelor's degrees in physics and STEM earned by women.
[2] National Science Foundation, National Center for Science and Engineering Statistics, Science and engineering degrees earned by underrepresented minorities, as a percentage of degree type: 1996–2016.
[3] P. J. Mulvey and S. Nicholson, Physics bachelor's degrees: 2018, retrieved from: https://www.aip.org/statistics/reports/physics-bachelors-degrees-2018 (2020).
[4] S. Malcom, Diversity in physics, Physics Today, 59, 44 (2016).
[5] R. S. Barthelemy, M. McCormick, and C. Henderson, Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions, Phys. Rev. Phys. Educ. Res., 12, (2016).
[6] D. Doucette and C. Singh, Why are there so few women in physics? Reflections on the experiences of two women, Phys. Teach. 58, 297 (2020).
[7] F. Abdurrahman and A. Olmstead, Objectivity, culturelessness, and apoliticism: How cultural beliefs prevent the advancement of equity in astronomy graduate programs, in *Proceedings of the 2021 Physics Education Research Conference*, edited by M. B. Bennett, B. W. Frank, and R. E. Vieyra, pp. 15-20.
[8] L. M. Santana and C. Singh, Negative impacts of an unwelcoming physics environment on undergraduate women, in *Proceedings of the 2021 Physics Education Research Conference*, edited by M. B. Bennett, B. W. Frank, and R. E. Vieyra, pp. 377-383.
[9] J. M. Nissen and B. Van Dusen, Educational debts incurred by racism and sexism in students' beliefs about physics, in *Proceedings of the 2019 Physics Education Research Conference*, edited by Y. Cao, S. Wolf, and M. B. Bennett, pp. 408-414.
[10] P. M. Sadler and R. H. Tai, Success in introductory college physics: The role of high preparation, Science Education, 85, 111 (2001).
[11] E. Burkholder, L. Blackmon, and C. Wieman, What factors impact student performance in introductory physics?, Public Library of Science One, 15, 12 (2020).
[12] Z. Hazari, P. M. Sadler, and R. Tai, Gender differences in the high school and affective experiences of introductory college physics students, The Physics Teacher, 46, 423 (2008).
[13] Z. Kalender, E. Marshman, C. Schunn, T. Nokes-Malach, and C. Singh, Investigating the role of prior preparation and self-efficacy on female and male students' introductory physics course achievements, in *Proceedings of the 2019 Physics Education Research Conference*, edited by Y. Cao, S. Wolf, and M. B. Bennett, pp. 275-281.
[14] R. Krakehl and A. M. Kelly, Intersectional analysis of advanced placement physics participation and performance by gender and ethnicity, Phys. Rev. Phys. Educ. Res., 17, (2021).
[15] J. S. Hyde, and M. C. Linn, Gender similarities in mathematics and science, Science, 314, 599–600 (2006).
[16] Z. Hazari, R. Tai, and P. Sadler, Gender differences in introductory university physics performance, Science Education, 91(6), 847–876 (2007).
[17] Z. Hazari, G. Sonnert, P. M. Sadler, M. Shanahan, Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study, Journal of Research in Science Teaching, 47, 978–1003 (2010).
[18] U.S. Department of Education: Office of Civil Rights, 2015 – 16 Civil Rights Data Collection: STEM course taking, (2018).
[19] S. White and J. Tyler, Underrepresented minorities in high school physics, The Physics Teacher, 53, 376 (2015).
[20] X. R. Quichocho, E. M. Schipull, and E. W. Close, Understanding physics identity development through the identity performances of Black, Indigenous, and women of color and LGBTQ+ women in physics, in *Proceedings of the 2020 Physics Education Research Conference*, edited by S. Wolf, M. B. Bennett, and B. W. Frank, pp. 412-417.
[21] X. R. Quichocho, J. Conn, E. M. Schipull, and E. W. Close, Who does physics? Understanding the composition of physicists through the lens of women of color and LGBTQ+ women physicists, in *Proceedings of the 2019 Physics Education Research Conference*, edited by Y. Cao, S. Wolf, and M. B. Bennett, pp. 488-493.
[22] E. M. Schipull, X. R. Quichocho, and E. W. Close, "Success together": Physics departmental practices supporting LGBTQ+ women and women of color, in *Proceedings of the 2019 Physics Education Research Conference*, edited by Y. Cao, S. Wolf, and M. B. Bennett, pp. 535-540.
[23] J. L. Campbell, C. Quincy, J. Osserman, and O. K. Pedersen, Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement, Sociological Methods & Research, 42, 294-320 (2013).
[24] L. Stiles-Clarke and K. MacLeod, Choosing to major in physics, or not: Factors affecting undergraduate decision making, European Journal of Physics Education, 7, 1 (2016).
[25] K. Crenshaw, Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics, University of Chicago Legal Forum, 1, 139 (1989).